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(54) NUCLEIC ACID CLEAVAGE ASSAYS

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Related U.S. Application Data

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Said application No. 09/308,825 is a continuation-in-part of application No. 08/758,314, filed on Dec. 2, 1996, now Pat. No. 6,090,606, which is a continuation-in-part of application No. 08/756,386, filed on Nov. 26, 1996, now Pat. No. 5,985,557, which is a continuation-in-part of application No. 08/682,853, filed on Jul. 12, 1996, now Pat. No. 6,001,567, which is a continuation-in-part of application No. 08/599,491, filed on Jan. 24, 1996, now Pat. No. 5,846,717.

Said application No. 09/714,935 is a continuation-in-part of application No. 09/350,309, filed on Jul. 9, 1999, now Pat. No. 6,348,314, which is a division of application No. 08/756,386, filed on Nov. 26, 1996, now Pat. No. 5,985,557.

Said application No. 09/714,935 is a continuation-in-part of application No. 09/381,212, filed on Feb. 8, 2000, now Pat. No. 6,872,816, filed as 371 of international application No. PCT/US98/05809, filed on Mar. 24, 1998, and which is a continuation-in-part of application No. 08/823,516, filed on Mar. 24, 1997, now Pat. No. 5,994,069, which is a continuation-in-part of application No. PCT/US97/01072, filed on Jan. 22, 1997, and which is a continuation-in-part of application No. 08/759,038, filed on Dec. 2, 1996, now Pat. No. 6,090,543, which is a continuation-in-part of application No. 08/756,386, filed on Nov. 26, 1996, now Pat. No. 5,985,557.

Publication Classification

(51) **Int. Cl.**
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(52) **U.S. Cl.** **435/6**

(57) ABSTRACT

The present invention provides novel cleavage agents and polymerases for the cleavage and modification of nucleic acid. The cleavage agents and polymerases find use, for example, for the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. In some embodiments, the 5' nuclease activity of a variety of enzymes is used to cleave a target-dependent cleavage structure, thereby indicating the presence of specific nucleic acid sequences or specific variations thereof.

```
MAJORITY ATGXXGGCGATGCTTCCCCTCTTTGAGCCCAAAGGCCGGGTCCTCCTGGTGGACGGGCACCACCTGGCCT

DNAPTAQ  ...AG..G.....G.....................G.....................................  70
DNAPTFL  ..............................................C..G.....................  67
DNAPTTH  ...GA...........G.......A.....................................................  70

MAJORITY ACCGCACCTTCTTCGCCCTGAAGGGCCTCACCACCACCOGGGGGGAACCGGTGCAGGCGGTCTACGGCTT

DNAPTAQ  ...........CA.....................................G..G.....................  140
DNAPTFL  ............T.....C.....................C.........C..T.....................  137
DNAPTTH  ..................................G.....................................  140

MAJORITY CGCCAAGAGCCTCCTCAAGGCCCTGAAGGAGGACGGGGACXXGCCGGTGXTCGTGGTCTTTGACGCCAAG

DNAPTAQ  ..........................C.....................A.....................  207
DNAPTFL  ......A.....................................GT..T.....................  204
DNAPTTH  ..................................T..AA...C..CT.....................  280

MAJORITY GCCCCCTCCTTCCGCCACGAGGCCTACGAGGCCTACAAGGCGGGCCGGGCCCCCACCCCGGAGGACTTTC

DNAPTAQ  ..........................G..GG.....................G.....................  277
DNAPTFL  ..............................................................................  274
DNAPTTH  ..................................GA.......G.....C.........C.  280

MAJORITY CCCGGCAGCTCGCCCTCATCAAGGAGCTGGTGGACCTCCTGGGGCTTGCGCGCCTCGAGGTCCCCGGCTA

DNAPTAQ  .......A.....................................G.....................G.....  347
DNAPTFL  .........G.....................T.............A..C....T...G..G.....T.......T  344
DNAPTTH  ..................................T..A.C.....................  350
```

```
MAJORITY ATGXXGGCGATGCTTCCCCTCTTTGAGCCCAAAGGCCGGGTCCTCCTGGTGGACGGGCACCACCTGGCCT

DNAPTAQ  ...AG..G......G.................G.....................................  70
DNAPTFL  ..........................................C..G.........................  67
DNAPTTH  ...GA............G........A.....................................  70

MAJORITY ACCGCACCTTCTTCGCCCTGAAGGGCCTCACCACCACCOGGGGGGAACCGGTGCAGGCGGTCTACGGCTT

DNAPTAQ  ............CA.....................................G..G.....  140
DNAPTFL  ..............T.....C.....................C........C..T.....  137
DNAPTTH  ..................................G.....  140

MAJORITY CGCCAAGAGCCTCCTCAAGGCCCTGAAGGAGGACGGGGACXXGCCGGTGXTCGTGGTCTTTGACGCCAAG

DNAPTAQ  ........................C.....................A.....  207
DNAPTFL  ......A.....................................GT..T.....  204
DNAPTTH  ..........................................T..AA...C..CT.....  280

MAJORITY GCCCCCTCCTTCCGCCACGAGGCCTACGAGGCCTACAAGGCGGGCCGGGCCCCCACCCCGGAGGACTTTC

DNAPTAQ  ..............................G..GG.....................G.....  277
DNAPTFL  ..............................................................  274
DNAPTTH  ..............................................GA.....G.....C.....C.  280

MAJORITY CCCGGCAGCTCGCCCTCATCAAGGAGCTGGTGGACCTCCTGGGGCTTGCGCGCCTCGAGGTCCCCGGCTA

DNAPTAQ  .......A.....................................G.....................G.....  347
DNAPTFL  ..........G..............T.............A..C....T...G..G.....T.......T  344
DNAPTTH  ..................................................T..A.C.....  350
```

FIG. 1A

```
MAJORITY CGAGGCGGACGACGTXCTGGCCACCCTGGCCAAGAAGGCGGAAAAGGAGGGGTACGAGGTGCGCATCCTC

DNAPTAQ  ..............C.......G.............................C........C.........  417
DNAPTFL  T.............G.................CG.....................................  414
DNAPTTH  ..............T..C.....................................................  420

MAJORITY ACCGCCGACCGCGACCTCTACCAGCTCCTTTCCGACCGCATCGCCGTCCTCCACCCCGAGGGGTACCTCA

DNAPTAQ  .........AAA....T.........................CA............................  487
DNAPTFL  ..T.............................G..G.........A.........T...........G.  484
DNAPTTH  .......................A...G.C.........G.....................CC......  490

MAJORITY TCACCCCGGCGTGGCTTTGGGAGAAGTACGGCCTGAGGCCGGAGCAGTGGGTGGACTACCGGGCCCTGGC

DNAPTAQ  .........C...........A................C..C......CC..............A.  557
DNAPTFL  .................AC..............C.C.................................  554
DNAPTTH  .........A.........................C.....................T...C.....C.T 560

MAJORITY GGGGGACCCCTCCGACAACCTCCCCGGGGTCAAGGGCATCGGGGAGAAGACCGCCCXGAAGCTCCTCXAG

DNAPTAQ  C......GAG...........T.............................G..GAG......T..GG..  627
DNAPTFL  ...........G..T...A.........G.........................A..G....A..CGC  624
DNAPTTH  ..................................................TC.........A..  630

MAJORITY GAGTGGGGGAGCCTGGAAAACCTCCTCAAGAACCTGGACCGGGTGAAGCCCGC···CXTCCGGGAGAAGA

DNAPTAQ  .................GC.....................C.............A.............  694
DNAPTFL  .......................T..C..C.........A.........T.....T.G.........C  691
DNAPTTH  ........A.....................................A.....A.AAAA.G.............  700
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FIG. 1B

```
MAJORITY TCCAGGCCCACATGGAXGACCTGAXGCTCTCCTGGGAGCTXTCCCAGGTGCGCACCGACCTGCCCCTGGA

DNAPTAQ  ...T.....C..T....A.....C..GG..A..... 764
DNAPTFL  .......GGG......G.C....GCC..T...C..A....T.....A...T..... 761
DNAPTTH  ..A.....C....A.....C.G.....T.....C....G.....C..... 770

MAJORITY GGTGGACTTCGCCAAGXGGCGGGAGCCCGACCGGGAGGGGCTTAGGGCCTTTCTGGAGAGGCTGGAGTTT

DNAPTAQ  .....AA.....A.....T..... 834
DNAPTFL  .....GG.G.C.C..CACA...A...T.....T..GC....T...T.....C..T..... 831
DNAPTTH  .....C.....C..G.....C.....C 840

MAJORITY GGCAGCCTCCTCCACGAGTTCGGCCTCCTGGAGGGCCCCAAGGCCCTGGAGGAGGCCCCCTGGCCCCCGC

DNAPTAQ  .....T.....AA..... 904
DNAPTFL  ..A.....G..G.....GGCA.....T. 901
DNAPTTH  .....C....GCCC..... 910

MAJORITY CGGAAGGGGCCTTCGTGGGCTTTGTCCTTTCCCGCCCCGAGCCCATGTGGGCCGAGCTTCTGGCCCTGGC

DNAPTAQ  .....G.....AAG.....T..... 974
DNAPTFL  .....T..TT.....TC.T.....T..... 971
DNAPTTH  .....C.....C.....G.....AAA..... 980

MAJORITY CGCCGCCAGGGAGGGCCGGGTCCACCGGGCACCAGACCCCTTTAXGGGCCTXAGGGACCTXAAGGAGGTG

DNAPTAQ  .....G.....C..C..G..T.A..AA.C...C.....G.....C. 1044
DNAPTFL  T.GG..GT.....G..CC....T.....A.....C...G.....G.....T....G.... 1041
DNAPTTH  ....TG.....C.....G.....G.....GGC...G..A.A.....C.....C 1050
```

FIG. 1C

```
MAJORITY CGGGGXCTCCTCGCCAAGGACCTGGCCGTTTTGGCCCTGAGGGAGGGCCTXGACCTCXTGCCCGGGGACG

DNAPTAQ  .....G..T........A......AG....C.............A.....T.G....CC......C.... 1114
DNAPTFL  .....AA....G.............G.............C..........G......T.C..A.A..... 1111
DNAPTTH  .....C.................C.....C......TC.........G..A......G............ 1120

MAJORITY ACCCCATGCTCCTCGCCTACCTCCTGGACCCCTCCAACACCACCCCCGAGGGGGTGGCCCGGCGCTACGG

DNAPTAQ  ................................T..................................... 1184
DNAPTFL  ...........G.........T.......................T.................T..... 1181
DNAPTTH  ..................................................G............ 1190

MAJORITY GGGGGAGTGGACGGAGGAXGCGGGGGAGCGGGCCCTCCTXTCCGAGAGGCTCTTCCXGAACCTXXXGGAG

DNAPTAQ  C.................G..............GC...T..............GCC.....GTG..G. 1254
DNAPTFL  .................T.........A..........GG.....C.C.......A..C...AAA.... 1260
DNAPTTH  .................C..C.CCC.C...........C..G.........CAT.G......CCTTA.. 1260

MAJORITY CGCCTTGAGGGGGAGGAGAGGCTCCTTTGGCTTTACCAGGAGGTGGAGAAGCCCCTTTCCCGGGTCCIGG

DNAPTAQ  A.G.....................................G..........G..........GCT....... 1324
DNAPTFL  ......A....A..A..AC.C..G............G..............G...........GT... 1321
DNAPTTH  .....C.............A............C.....C........A........C............. 1330

MAJORITY CCCACATGGAGGCCACGGGGGTXCGGCTGGACGTGGCCTACCTCCAGGCCCTXTCCCTGGAGGTGGCGGA

DNAPTAQ  .....................G..C.............T...AG....T.G.............C.. 1394
DNAPTFL  ...GG.................C.............................C.............A..C 1391
DNAPTTH  ...............C.....A.....................T........T.........C.T..... 1400
```

FIG. 1D

```
MAJORITY GGAGATCCGCCGCCTCGAGGAGGAGGTCTTCCGCCTGGCCGGCCACCCCTTCAACCTCAACTCCCGGGAC

DNAPTAQ  .......GC...........CC.....................................................  1464
DNAPTFL  ....G.G....AG..G.....................................................C...  1461
DNAPTTH  ..................................T....G.....................................  1470

MAJORITY CAGCTGGAAAGGGTGCTCTTTGACGAGCTXGGGCTTCCCGCCATCGGCAAGACGGAGAAGACXGGCAAGC

DNAPTAQ  .............C.............A.....................................C.......  1534
DNAPTFL  ........GC..................G..C..G..T.....................G..G..A.  1531
DNAPTTH  ..........................TA..........T.G..G......C.A.....A.......  1540

MAJORITY GCTCCACCAGCGCCGCCGTGCTGGAGGCCCTXCGXGAGGCCCACCCCATCGTGGAGAAGATCCTGCAGTA

DNAPTAQ  ..................C...........C..C.....................................  1604
DNAPTFL  ............T.................G..A.................CCGC.....  1601
DNAPTTH  ...............G.............A..G.....................C...C.  1610

MAJORITY CCGGGAGCTCACCAAGCTCAAGAACACCTACATXGACCCCCTGCCXGXCCTCGTCCACCCCAGGACGGGC

DNAPTAQ  ..................G....G.........T.....T....G.A....A.....................  1674
DNAPTFL  ..............................A.............C.C...G..........A...C...  1671
DNAPTTH  ..............................G.G.............AAG............G..........  1680

MAJORITY CGCCTCCACACCCGCTTCAACCAGACGGCCACGGCCACGGGCAGGCTTAGTAGCTCCGACCCCAACCTGC

DNAPTAQ  ..............................................A...........T........C.  1744
DNAPTFL  ..G..............................C...............TCC.....................  1741
DNAPTTH  ..........................................G.............................  1750
```

FIG. 1E

```
MAJORITY AGAACATCCCCGTCCGCACCCCXCTGGGCCAGAGGATCCGCCGGGCCTTCGTGGCCGAGGAGGGXTGGGT

DNAPTAQ  .....................G..T..G.....................A.C...........G...C. 1814
DNAPTFL  .............G........T.........C.C.........A.....................C..... 1811
DNAPTTH  .....................CT.....................................C...T....C 1820

MAJORITY GTTGGTGGCCCTGGACTATAGCCAGATAGAGCTCCGGGTCCTGGCCCACCTCTCCGGGGACGAGAACCTG

DNAPTAQ  A.....................................A....G.................C.......... 1884
DNAPTFL  .C......T.T.......C........T.....T..................................... 1881
DNAPTTH  .....................................C.....C.....................A...... 1890

MAJORITY ATCCGGGTCTTCCAGGAGGGGAGGGACATCCACACCCAGACCGCCAGCTGGATGTTCGGCGTCCCCCCGG

DNAPTAQ  .....................C.............GG.....................................G.. 1954
DNAPTFL  ...........T.....................................................TT....C. 1951
DNAPTTH  ...A..................A.....................A..... 1960

MAJORITY AGGCCGTGGACCCCCTGATGCGCCGGGCGGCCAAGACCATCAACTTCGGGGTCCTCTACGGCATGTCGGC

DNAPTAQ  .....................................................................G.. 2024
DNAPTFL  .A.GG..A.....T.....................................G.................. 2021
DNAPTTH  .....................................GG.G........C..... 2030

MAJORITY CCACCGCCTCTCCCAGGAGCTTGCCATCCCCTACGAGGAGGCGGTGGCCTTCATTGAGCGCTACTTCCAG

DNAPTAQ  .....................A........T.........CCA.....................T... 2094
DNAPTFL  .............GG.......T..................................... 2091
DNAPTTH  ...TA.G.....................................T..A.............A 2100
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FIG. 1F

```
MAJORITY AGCTTCCCCAAGGTGCGGGCCTGGATTGAGAAGACCCTGGAGGAGGGCAGGAGGCGGGGGTACGTGGAGA

DNAPTAQ  ..................................................................... 2164
DNAPTFL  ....A.....................GG......C.........C.CC..........T....... 2161
DNAPTTH  .....................A..A.................G....A......C........A. 2170

MAJORITY CCCTCTTCGGCCGCCGGCGCTACGTGCCCGACCTCAACGCCCGGGTGAAGAGCGTGCGGGAGGCGGCGGA

DNAPTAQ  ..............C...........A.....AG.G.........................C.. 2234
DNAPTFL  ....................T.....................................C..... 2231
DNAPTTH  ..........AA.AA.....................................CA.......C..... 2240

MAJORITY GCGCATGGCCTTCAACATGCCCGTCCAGGGCACCGCCGCCGACCTCATGAAGCTGGCCATGGTGAAGCTC

DNAPTAQ  .....................................................T..... 2304
DNAPTFL  ....................G.....................................CG...T 2301
DNAPTTH  ..................................................C.............. 2310

MAJORITY TTCCCCCGGCTXCAGGAAATGGGGGCCAGGATGCTCCTXCAGGTCCACGACGAGCTGGTCCTCGAGGCCC

DNAPTAQ  ......A....GG.....................T.............................. 2374
DNAPTFL  ..........T......C.......G........TT.G....G..................... 2371
DNAPTTH  ........C..C.G...G.........C.C........C.................CC....G..... 2380

MAJORITY CCAAAGAGCGGGCGGAGGXGGTGGCCGCTTTGGCCAAGGAGGTCATGGAGGGGGTCTATCCCCTGGCCGT

DNAPTAQ  .A......A.........CC......CGGC.........................G..... 2444
DNAPTFL  ....G..C.........AG...A.................................GG......CAG.. 2441
DNAPTTH  ..C...C......C....A......G..............C.......AA..C.........C..... 2450
```

FIG. 1G

```
MAJORITY GCCCCTGGAGGTGGAGGTGGGGATGGGGGAGGACTGGCTCTCCGCCAAGGAGTAG

DNAPTAQ  .....A.....GA.  2499
DNAPTFL  .....CC.....    2496
DNAPTTH  .....T.....GT...  2505
```

FIG. 1H

```
MAJORITY MXAMLPLFEPKGRVLLVDGHHLAYRTFFALKGLTTSRGEPVQAVYGFAKSLLKALKEDG·DAVXVVFDAK

TAQ PRO  .RG.....H.....·...I.....  69
TFL PRO  .·.....·.V.V.....  68
TTH PRO  .E.....YK..F.....  70

MAJORITY APSFRHEAYEAYKAGRAPTPEDFPROLALIKELVDLLGLXRLEVPGYEADDVLATLAKKAEKEGYEVRIL

TAQ PRO  .....GG.....A.....S.....  139
TFL PRO  .....V.....F.....R.....  138
TTH PRO  .....FT.....  140

MAJORITY TADRDLYQLLSDRIAVLHPEGYLITPAWLWEKYGLRPEQWVDYRALXGDPSDNLPGVKGIGEKTAXKLLX

TAQ PRO  ...K.....H.....D..A.....T..E.....R...E  209
TFL PRO  .....E...I.....Y.....A.....I.....QR.IR  208
TTH PRO  .....V...V.....H....E.....F...V.....L...K  210

MAJORITY EWGSLENLLKNLDRVKP·XXREKIXAHMEDLXLSXXLSXVRTDLPLEVDFAXRREPDREGLRAFLERLEF

TAQ PRO  .....A.....L..·AI....L...D..K..WD.AK.....K.....R.....  278
TFL PRO  .....FQH..Q...·SL...LQ.G..A.A..RK..Q.H.....GR..T.NL.....  277
TTH PRO  .....ENV....K..L...R..LE..R.....L.QG.....  280

MAJORITY GSLLHEFGLLEXPKALEEAPWPPPEGAFVGFVLSRPEPMWAELLALAAARXGRVHRAXDPLXGLRDLKEV

TAQ PRO  .....S.....K....D.....PE.YKA.....A  348
TFL PRO  .....G...A.....L..SF.....G.WE..L...Q...R.....G.  347
TTH PRO  .....A.AP.....K....C.D.....A...A..K.....  350
```

FIG. 2A

```
MAJORITY RGLLAKDLAVLALREGLDLXPGDDPMLLAYLLDPSNTTPEGVARRYGGEWTEDAGERALLSERLFXNLXX

TAQ PRO  ........S........G.P.....................................E.....A......A..WG  418
TFL PRO  ..I.................F.E.....................................A....QT.KE  417
TTH PRO  ............S......V.....................................AH........HR..LK  420

MAJORITY RLEGEERLLWLYXEVEKPLSRVLAHMEATGVRLDVAYLQALSLEVAEEIRRLEEEVFRLAGHPFNLNSRD

TAQ PRO  ............R...R...A.................R..........A...A.................  488
TFL PRO  ..K.........E...........R.....................EA.V.Q.....................  487
TTH PRO  ......K.....H.....................................L.....................  490

MAJORITY QLERVLFDELGLPAIGKTEKTGKRSTSAAVLEALREAHPIVEKILQYRELTKLKNTYIDPLPXLVHPRTG

TAQ PRO  ..........................................................S.......D.I.....  558
TFL PRO  ..........................................DR..................A....K..  557
TTH PRO  ..........R...L...Q.....................................H..........V....S.......  560

MAJORITY RLHTRFNQTATATGRLSSSDPNLQNIPVRTPLGQRIRRAFVAEEGWXLVALDYSQIELRVLAHLSGDENL

TAQ PRO  ..........................................I.....L.....................  628
TFL PRO  ..........................................V..V.....................  627
TTH PRO  ..........................................A..A.....................  630

MAJORITY IRVFQEGRDIHTQTASWMFGVPPEAVDPLMRRAAKTINFGVLYGMSAHRLSQELAIPYEEAVAFIERYFQ

TAQ PRO  ............E.........R.....................................Q........  698
TFL PRO  ....................S..G.....................G..S..............  697
TTH PRO  .......K.............................V.....................  700
```

FIG. 2B

```
MAJORITY SFPKVRAWIEKTLEEGRRRGYVETLFGRRRYVPDLNARVKSVREAAERMAFNMPVQGTAADLMKLAMVKL

TAQ PRO  ....................................E.....................................  768
TFL PRO  .Y........G.....................................................R.  767
TTH PRO  ................K.....................................................  770

MAJORITY FPRLXEMGARMLLQVHDELVLEAPKXRAEXVAALAKEVMEGVYPLAVPLEVEVGXGEDWLSAKEX

TAQ PRO  ....E.....................E...A..R.....................I.........  833
TFL PRO  ....Q.L.................D...R...........W..Q........L.........  831
TTH PRO  ....R.............L....QA...E.......A..KA...........M........G  835
```

FIG. 2C

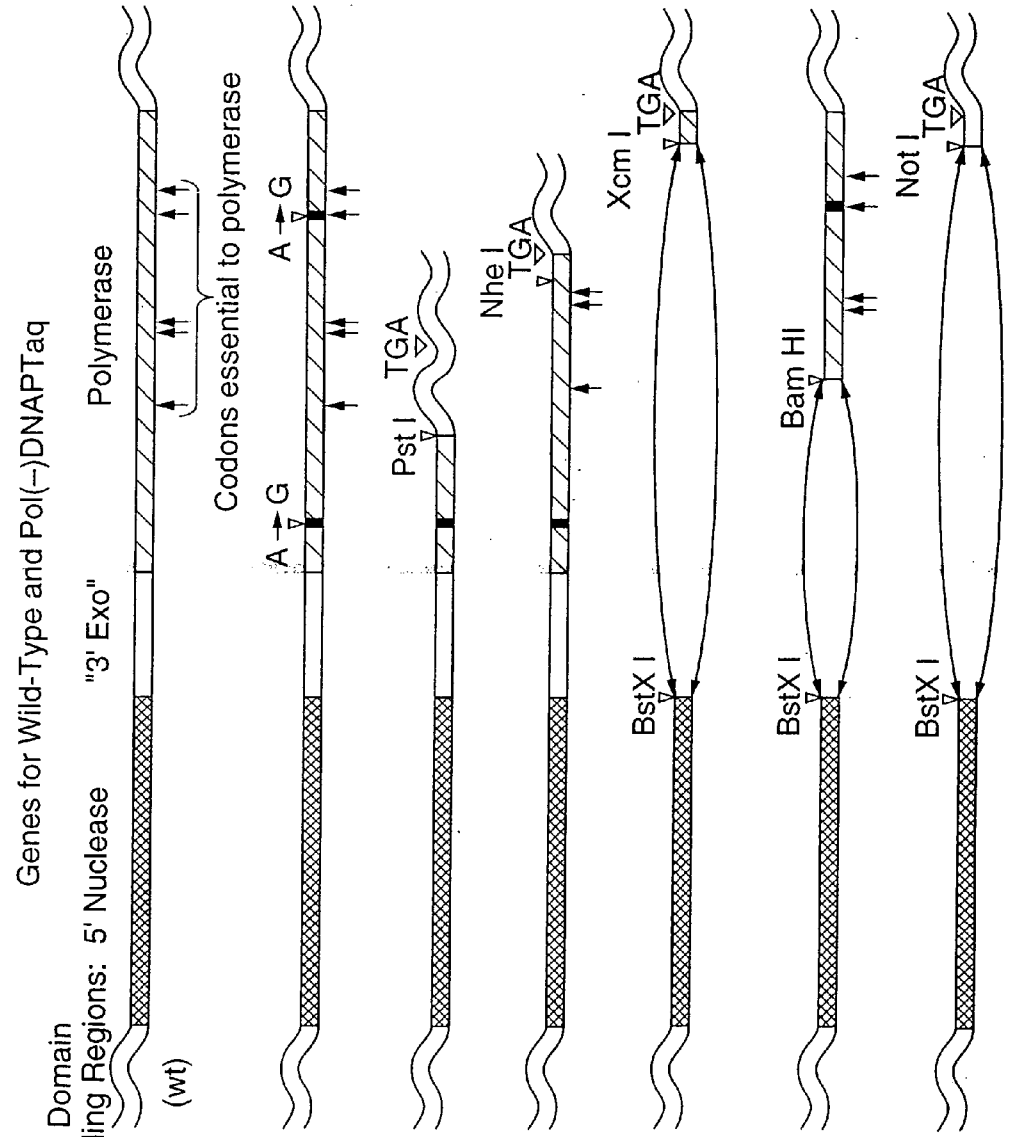


FIG. 3A

FIG. 3B

FIG. 3C

FIG. 3D

FIG. 3E

FIG. 3F

FIG. 3G

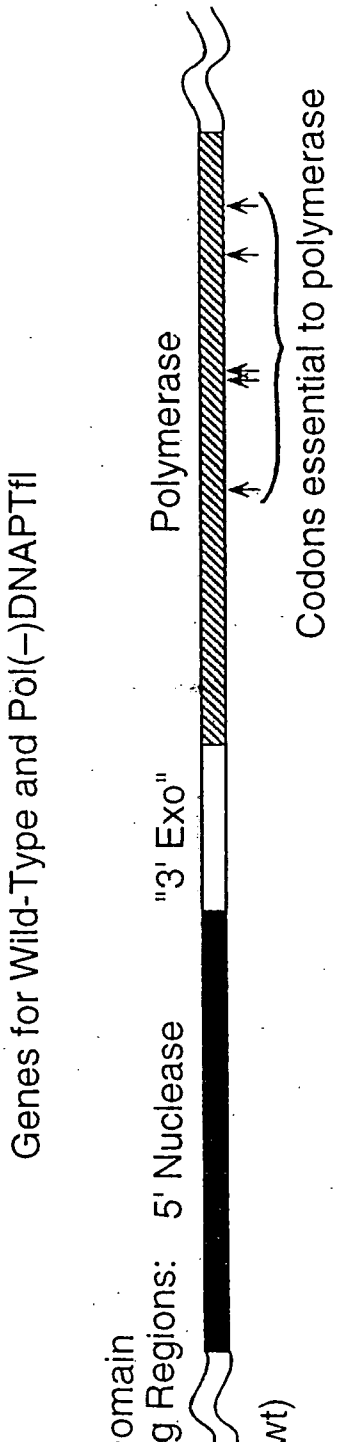

Genes for Wild-Type and Pol(−)DNAPTfl
Domain
Coding Regions:
5' Nuclease
"3' Exo"
Polymerase
Codons essential to polymerase
(wt)

FIG. 4A


Bam HI

FIG. 4B

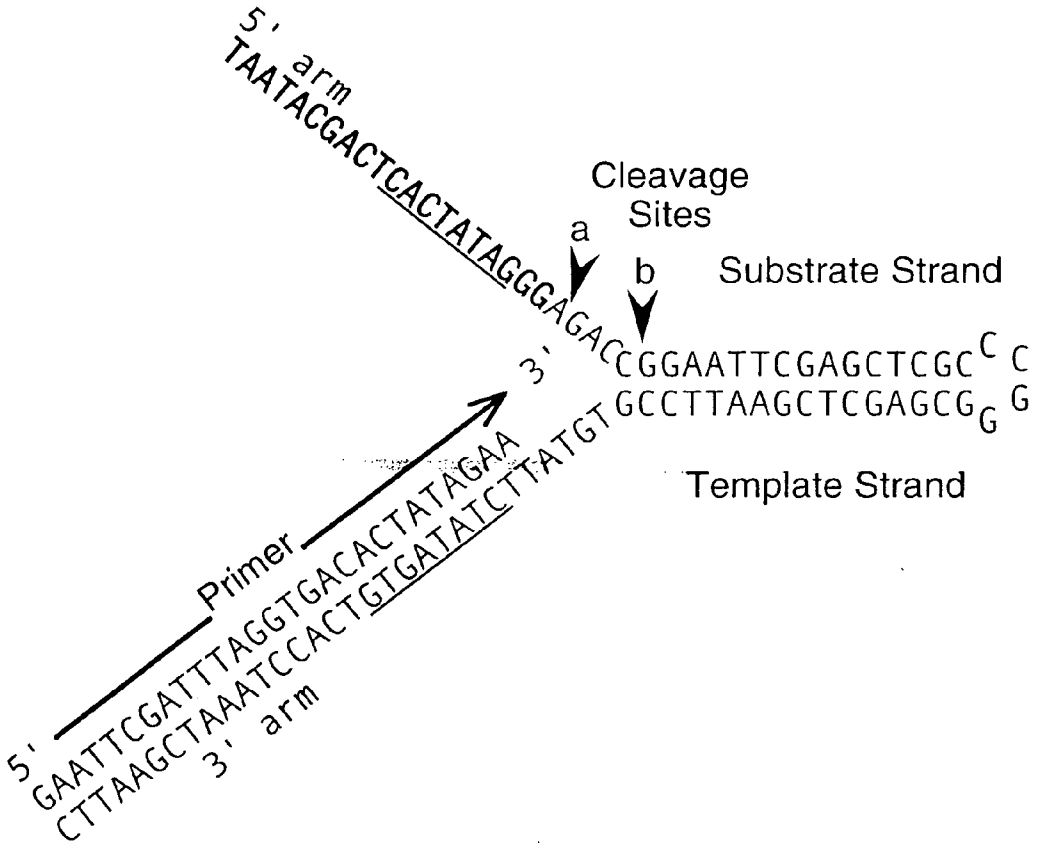

5' arm
TAATACGACTCACTATAGGGAGAC
Cleavage
Sites
a
b
Substrate Strand
3'
CGGAATTCGAGCTCGC C C
GCCTTAAGCTCGAGCG G G
Template Strand
Primer
5'
GAATTCGATTTAGGTGACACTATAGAA
CTTAAGCTAAATCCACTGTGATATCTTATGT
3' arm

FIG. 5

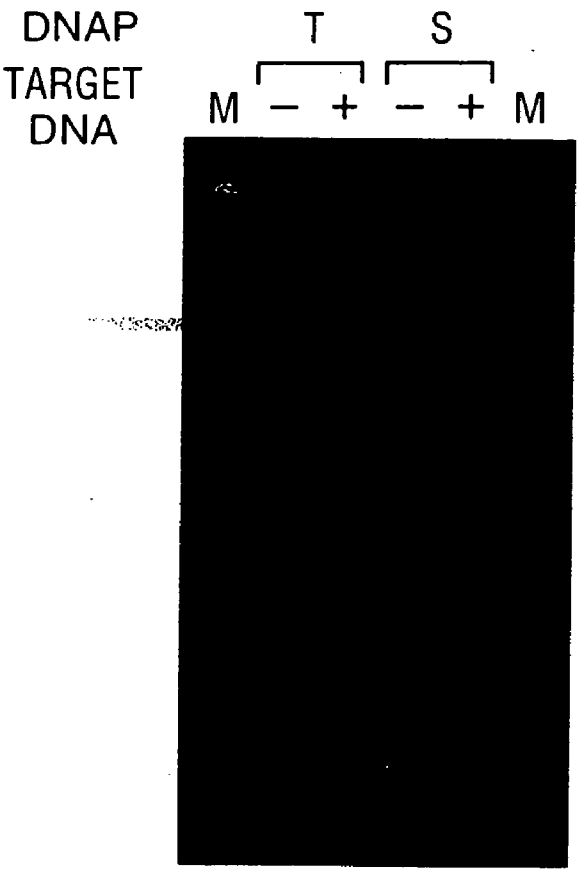


FIG. 6

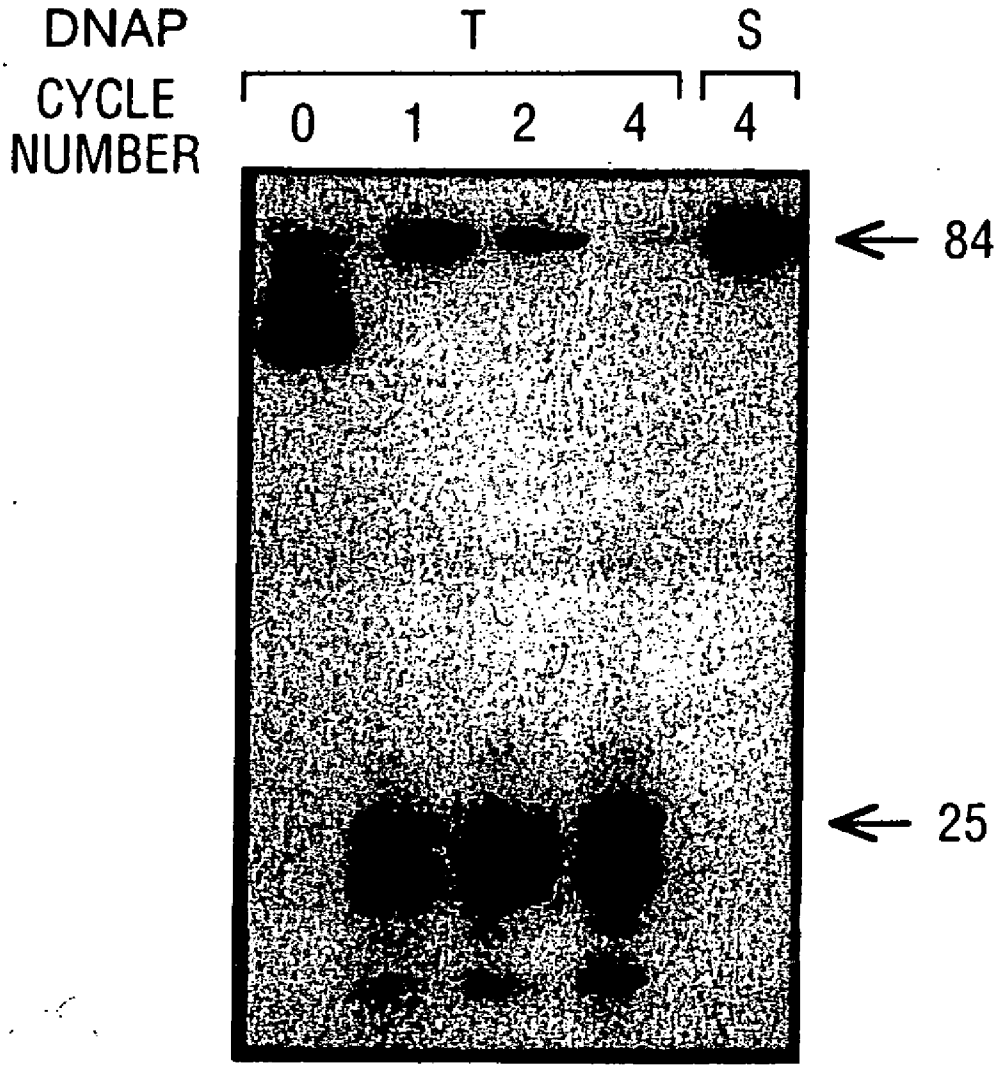


FIG. 7

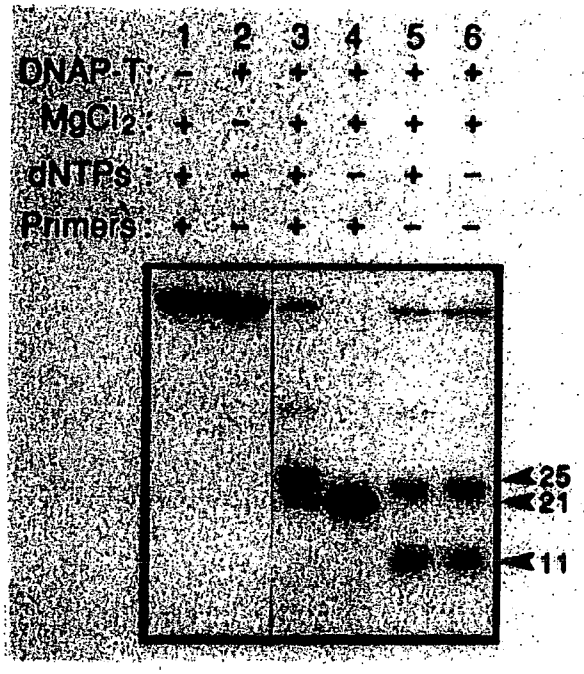


FIG. 8A

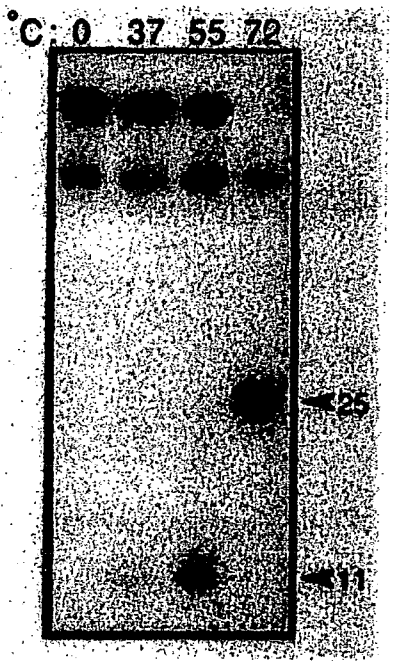


FIG. 8B

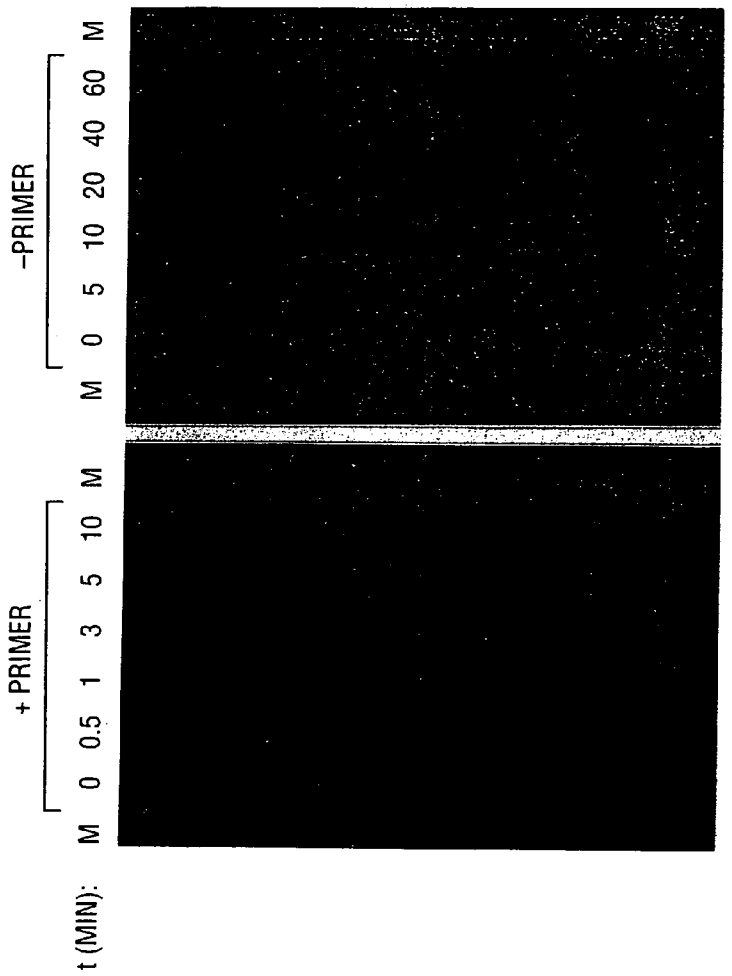


FIG. 9A

FIG. 9B

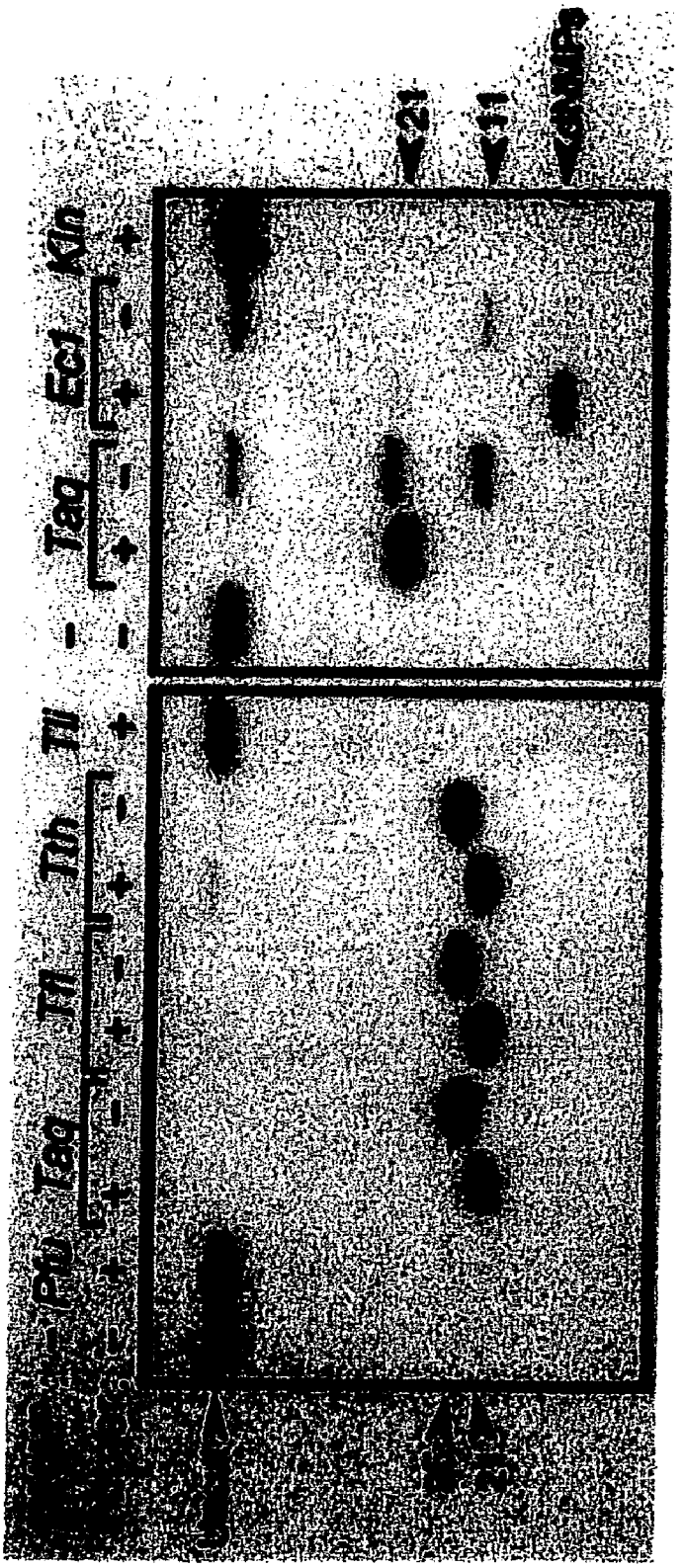


FIG. 10A

FIG. 10B

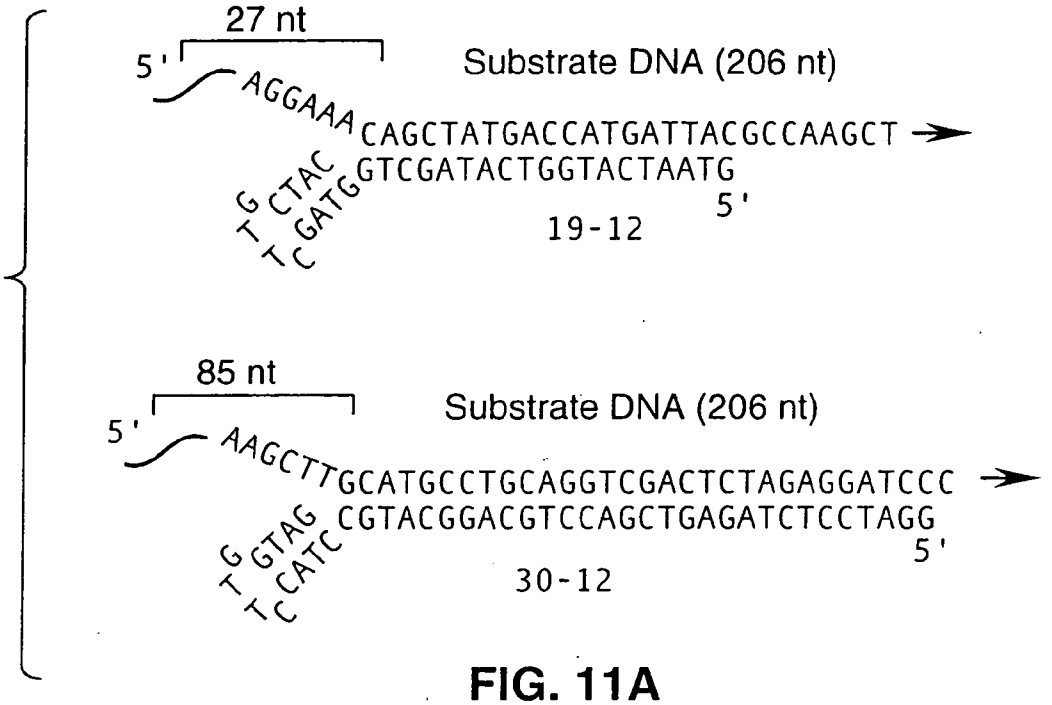


FIG. 11A

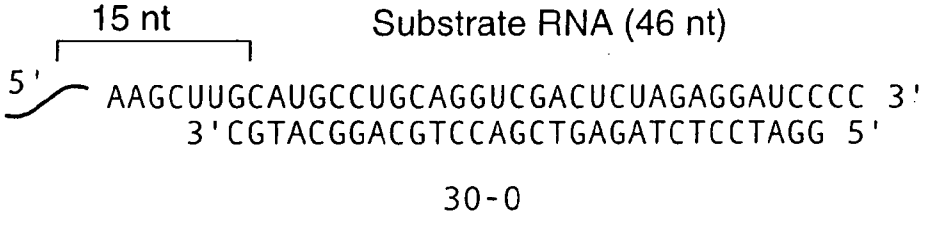


FIG. 12A

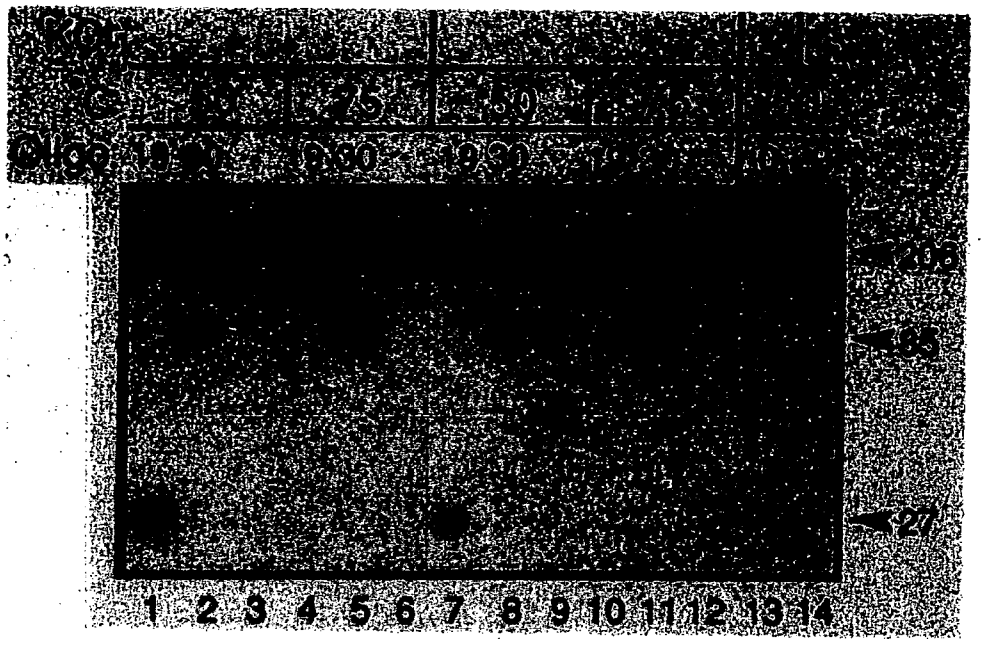


FIG. 11B

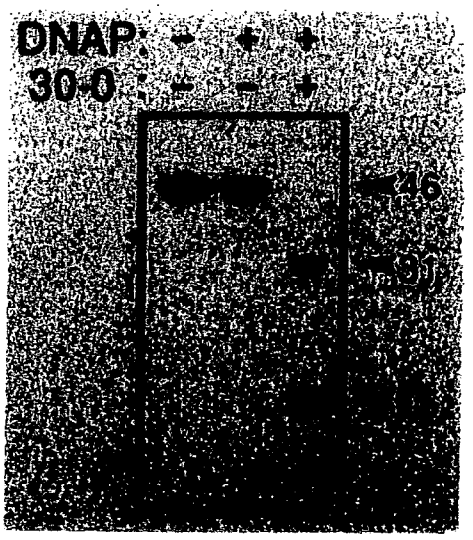


FIG. 12B

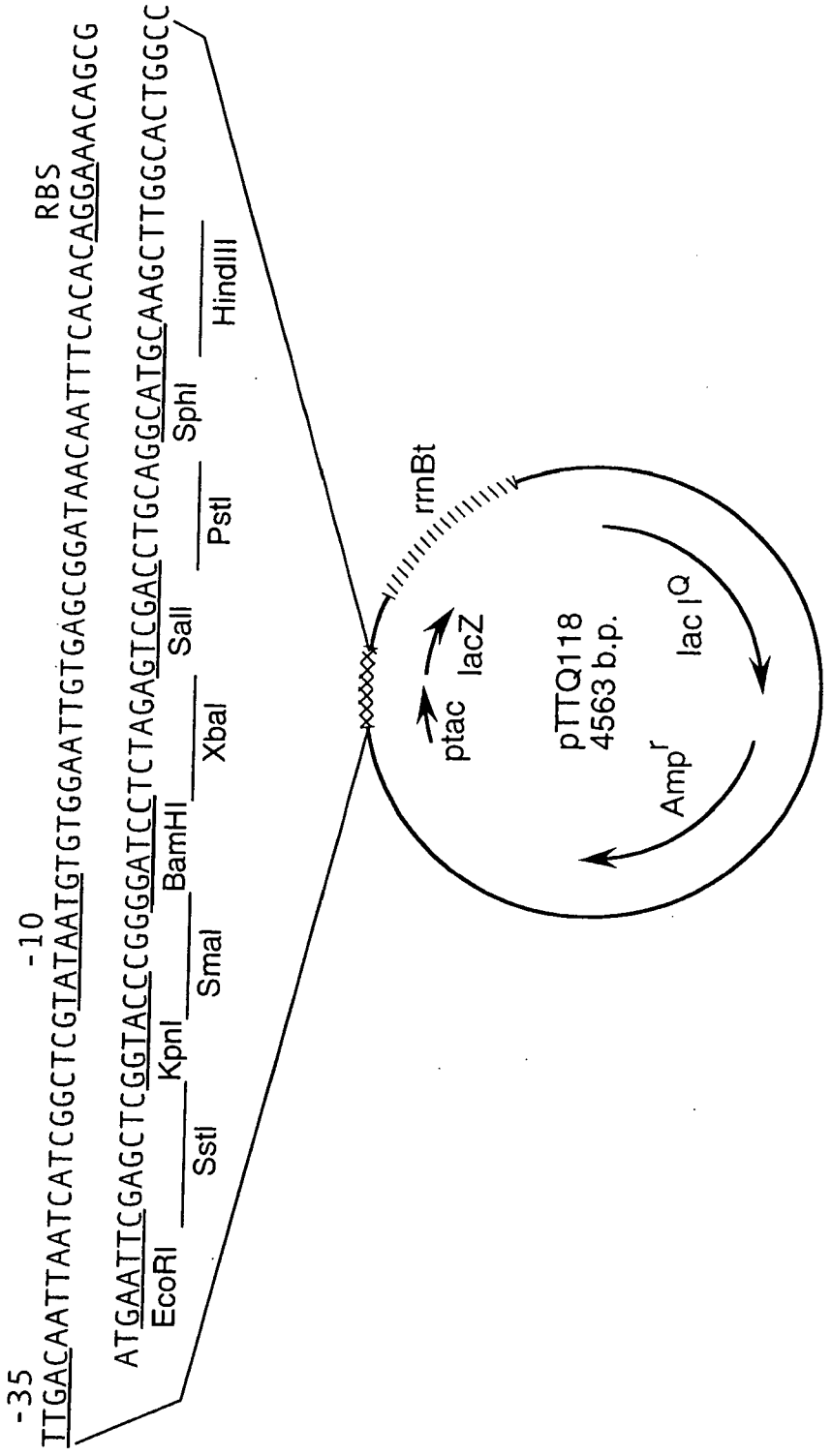
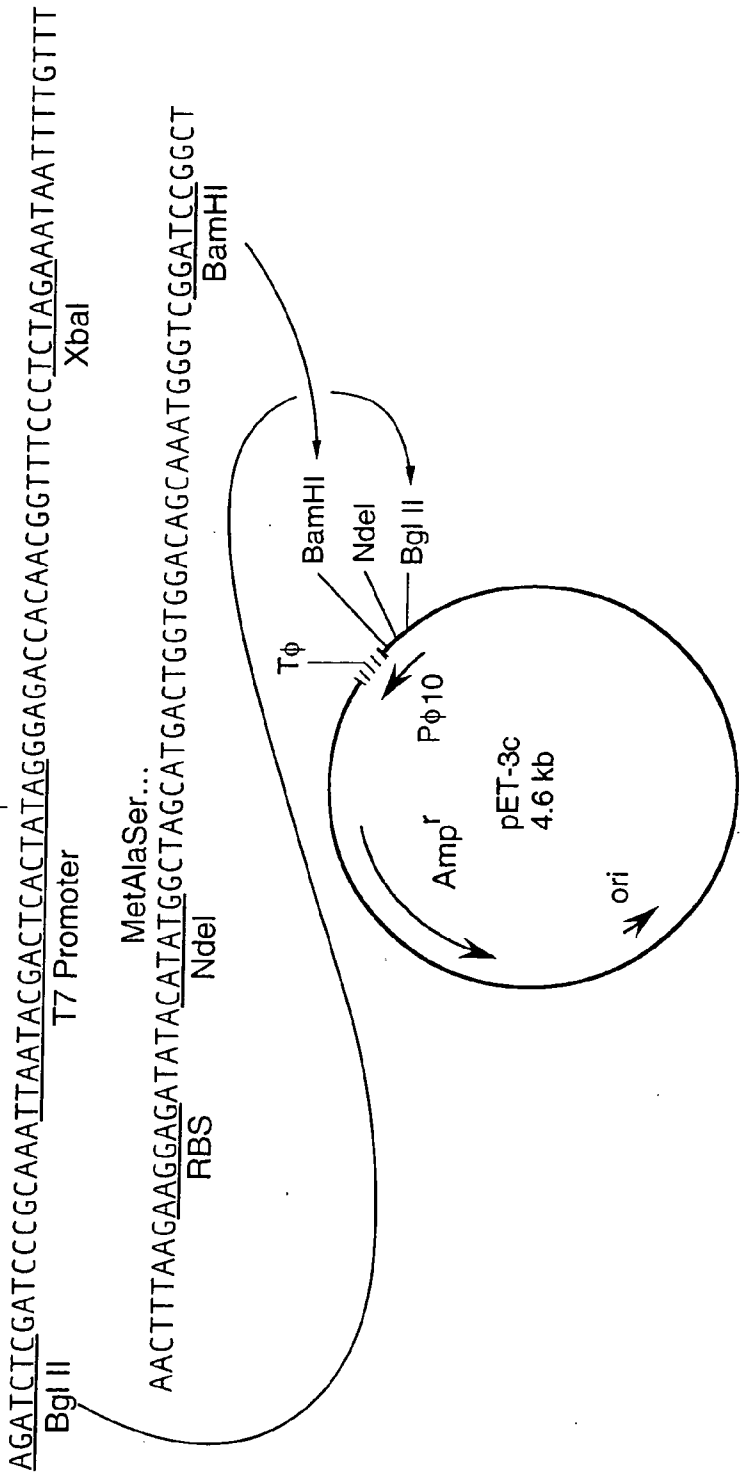

-35
TTGACAATTAATCATCGGCTCGTATAATGTGTGGAATTGTGAGCGGATAACAATTTCACACAGGAAACAGCG
-10
RBS
ATGAATTCGAGCTCGGTACCCGGGGATCCTCTAGAGTCGACCTGCAGGCATGCAAGCTTGGCACTGGCC
EcoRI
SstI
KpnI
SmaI
BamHI
XbaI
SalI
PstI
SphI
HindIII
rrnBt
ptac
lacZ
pTTQ118
4563 b.p.
Amp^r
lac I^Q
RBS: Ribosome binding site
ptac: Synthetic tac promoter
lac I^Q: Lac repressor gene
lacZ: Beta-galactosidase alpha fragment
rrnBt: E. coli rrnB transcription terminator

FIG. 13



$P_{\phi 10}$: Bacteriophage T7 φ10 promoter RBS: Ribosome binding site
Tφ: T7 φ Terminator

FIG. 14

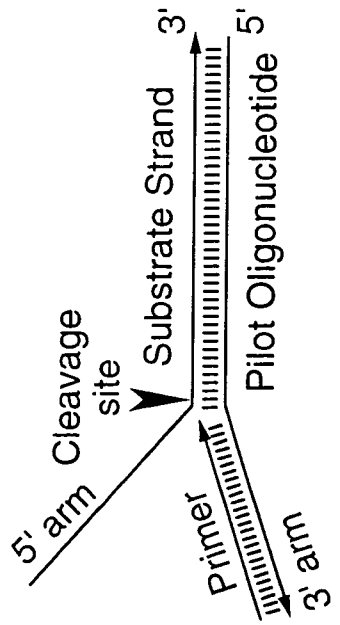


FIG. 15B

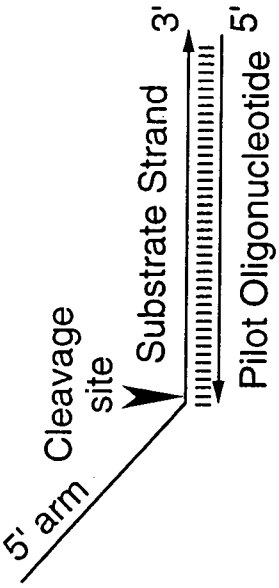


FIG. 15D

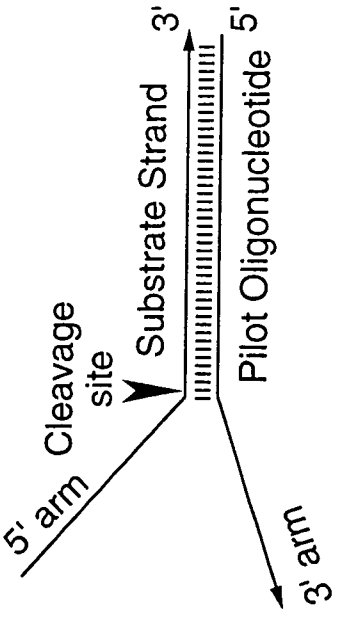


FIG. 15A

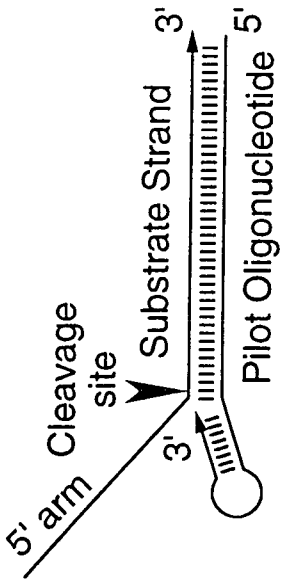


FIG. 15C

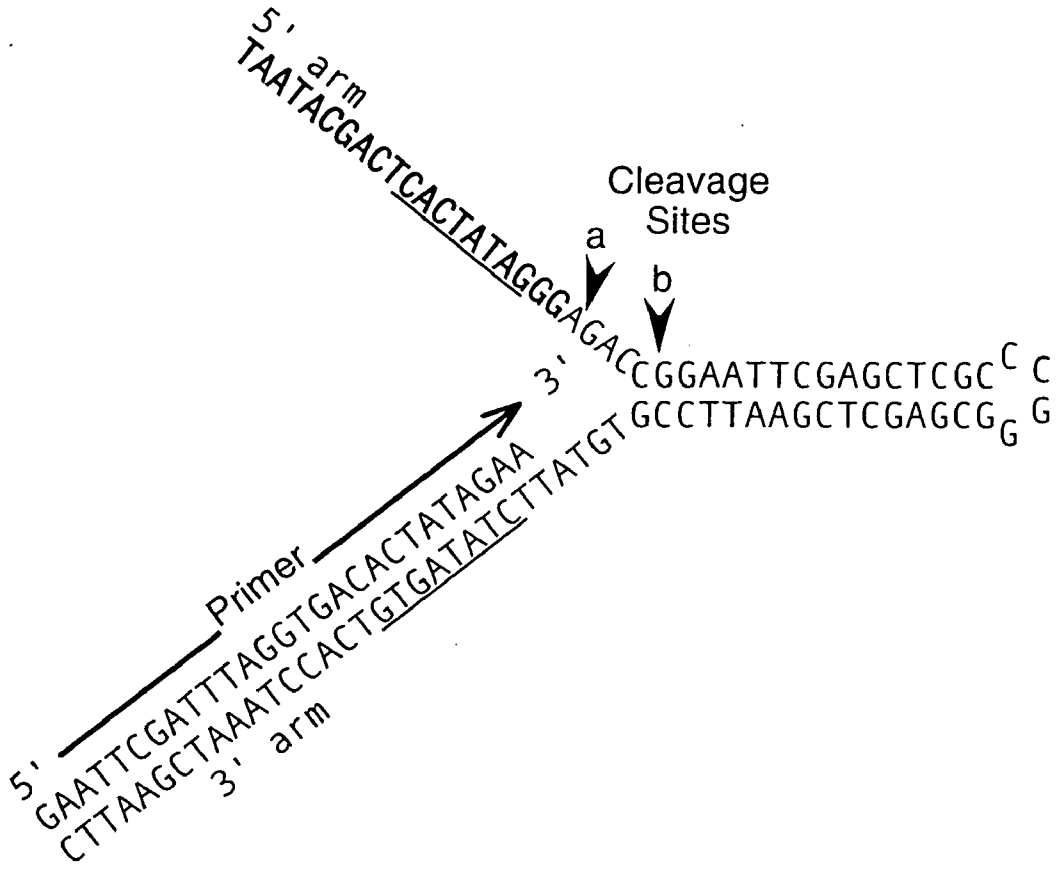

5' arm
TAATACGACTCACTATAGGGAGAC
Cleavage
Sites
a
b
3'
CGGAATTCGAGCTCGC C C
GCCTTAAGCTCGAGCG G G
Primer
GAATTCGATTTAGGTGACACTATAGAA
CTTAAGCTAAATCCACTGTGATATCTTATGT
5'
3' arm

FIG. 15E

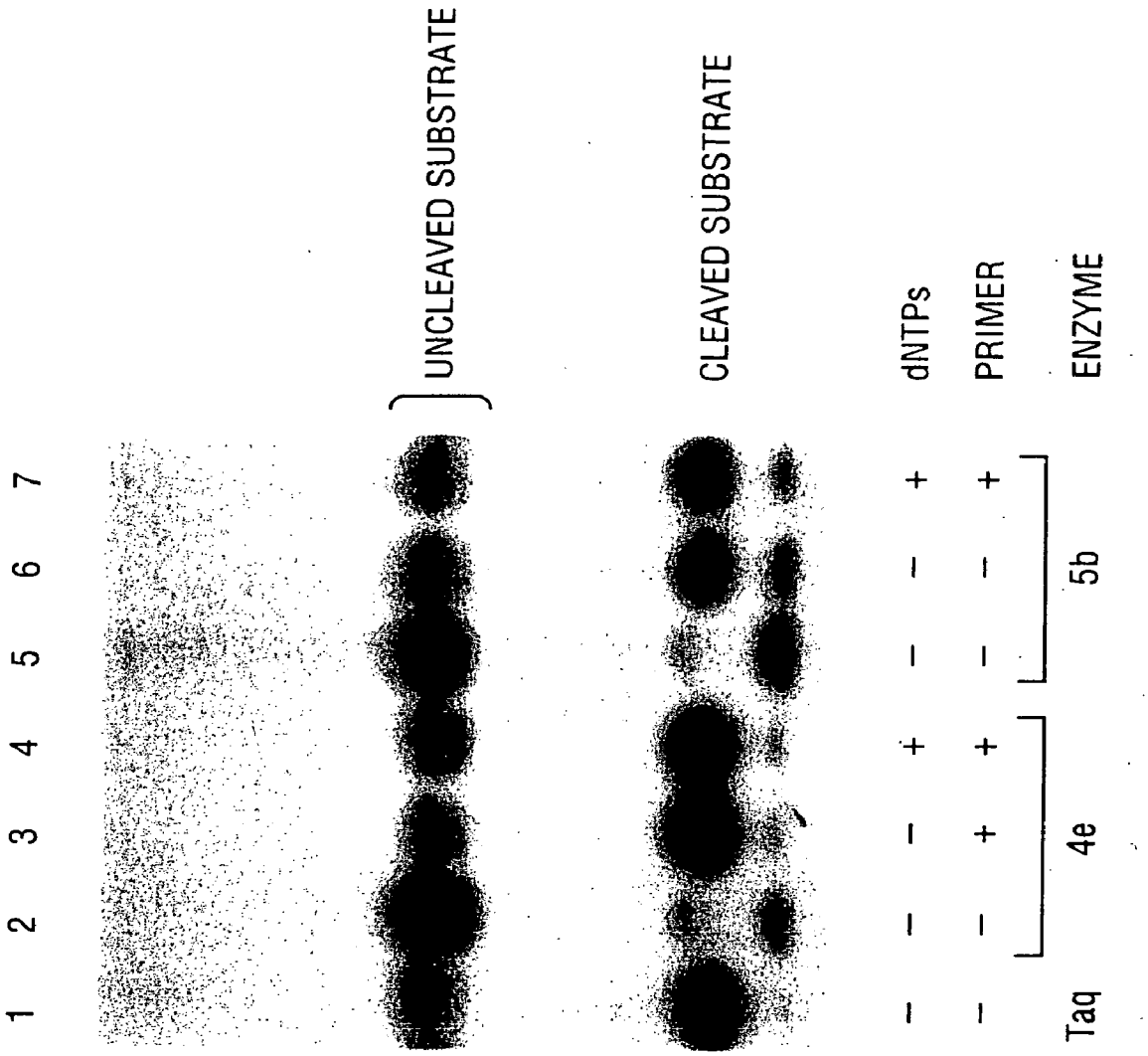

1 2 3 4 5 6 7
UNCLEAVED SUBSTRATE
CLEAVED SUBSTRATE
dNTPs
PRIMER
ENZYME
Taq
4e
5b

FIG. 16

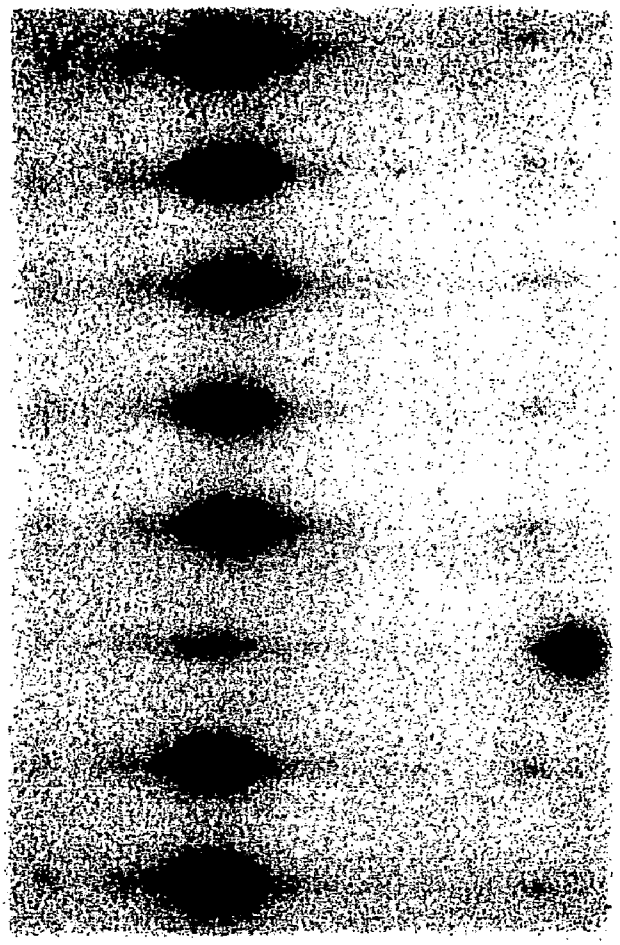

UNINCORPORATED
32P dCTP
INCORPORATED
32P dCMP
ENZYME Taq – Taq 4b 4c 4d 4e 4f
PRIMED M13 – + + + + + +

FIG. 17

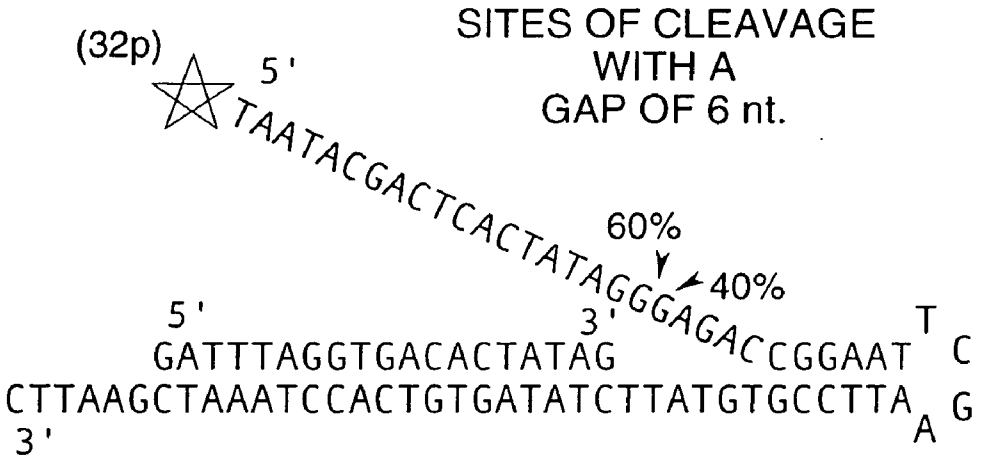

(32p)
5'
TAATACGACTCACTATAGGGAGACCGGAAT
SITES OF CLEAVAGE
WITH A
GAP OF 6 nt.
60%
40%
5'
3'
GATTTAGGTGACACTATAG
T
C
CTTAAGCTAAATCCACTGTGATATCTTATGTGCCTTA
A
G
3'

FIG. 18A

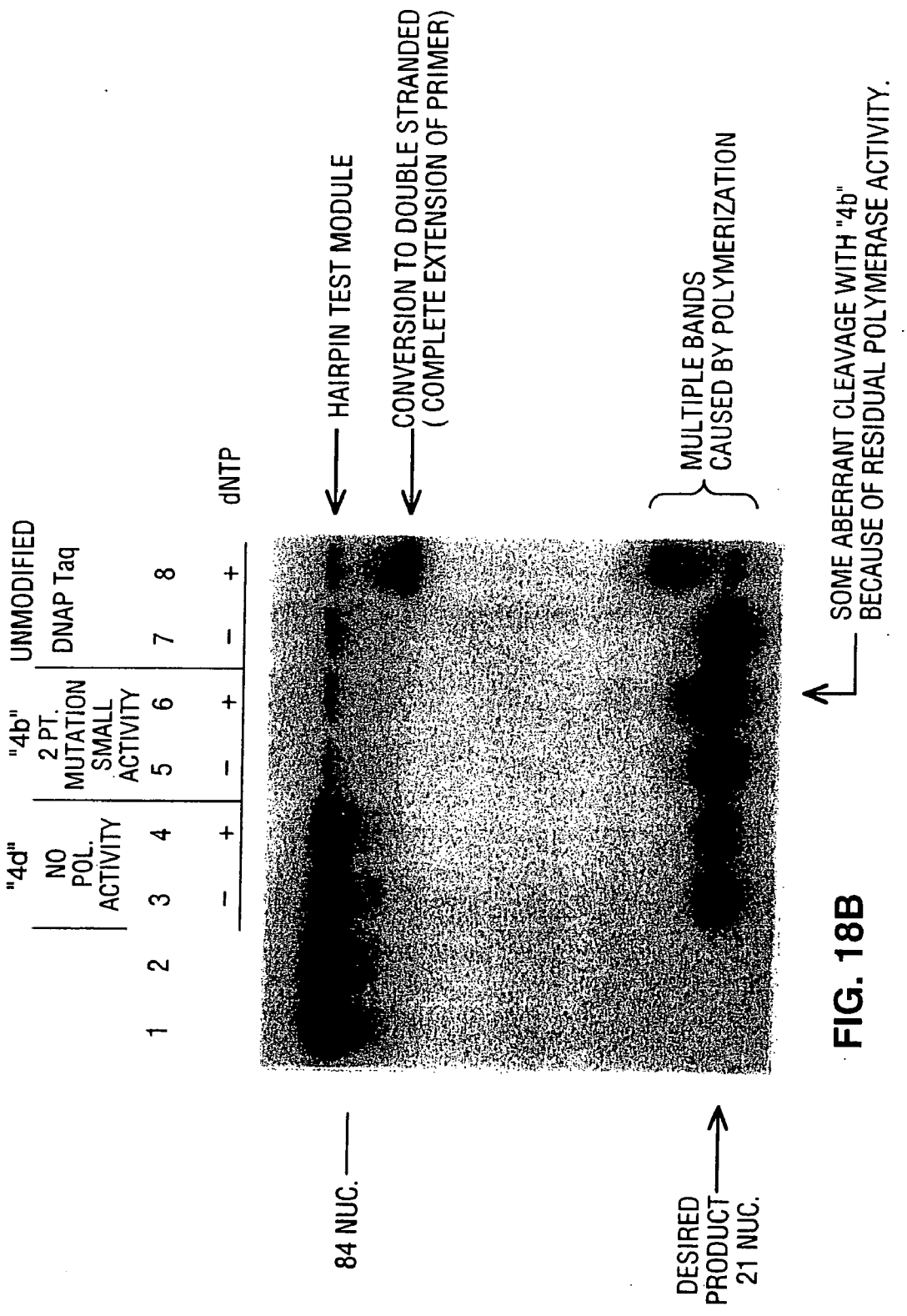

1 2 3 4 5 6 7 8
"4d" NO POL. ACTIVITY
"4b" 2 PT. MUTATION SMALL ACTIVITY
UNMODIFIED DNAP Taq
dNTP
– + – + – +
HAIRPIN TEST MODULE
CONVERSION TO DOUBLE STRANDED (COMPLETE EXTENSION OF PRIMER)
MULTIPLE BANDS CAUSED BY POLYMERIZATION
SOME ABERRANT CLEAVAGE WITH "4b" BECAUSE OF RESIDUAL POLYMERASE ACTIVITY.
84 NUC.
DESIRED PRODUCT 21 NUC.

FIG. 18B

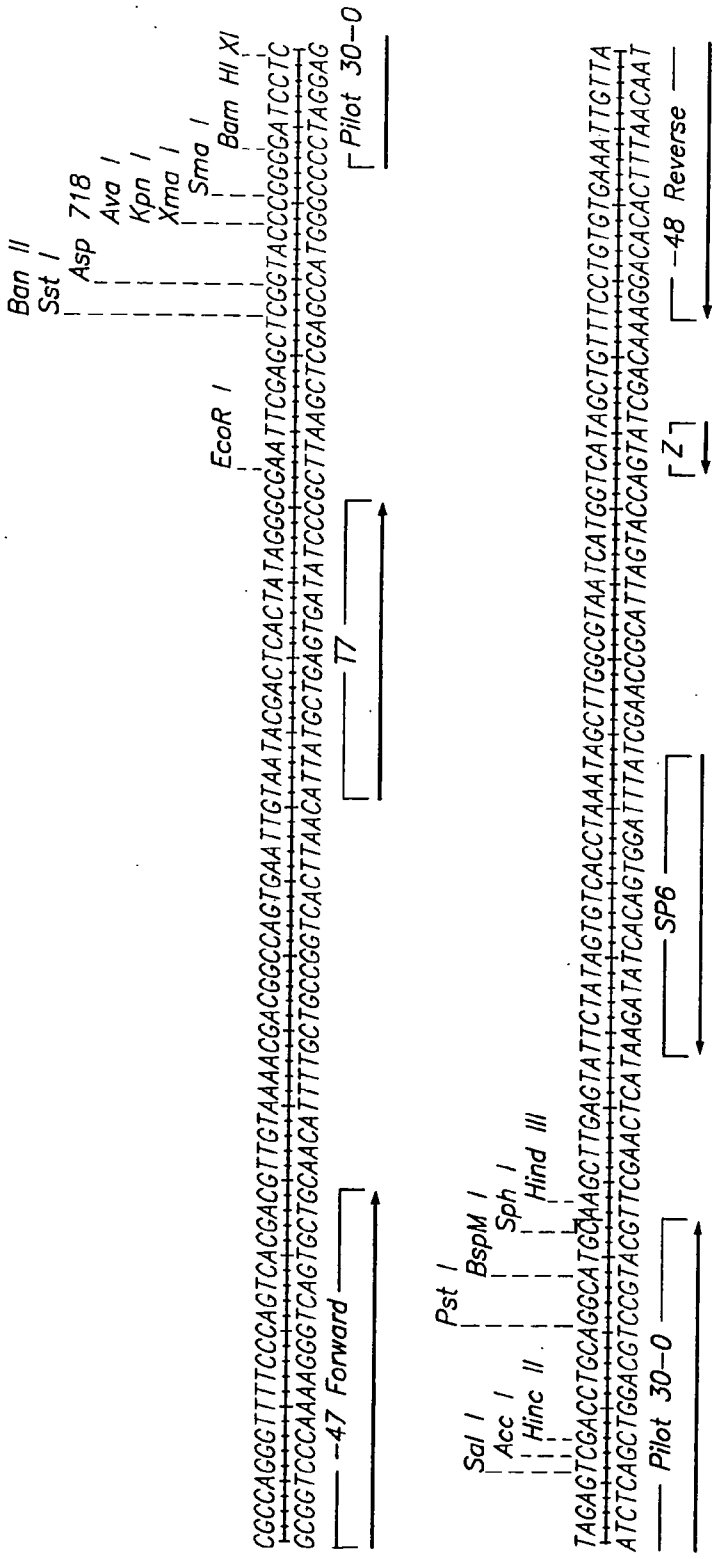

Ban II
Sst I
Asp 718
Ava I
Kpn I
Xma I
Sma I
Bam HI XI
EcoR I
Pilot 30-0
CGCCAGGGTTTTCCCAGTCACGACGTTGTAAAACGACGGCCAGTGAATTGTAATACGACTCACTATAGGGCGAATTCGAGCTCGGTACCCGGGGATCCTC
GCGGTCCCAAAAGGGTCAGTGCTGCAACATTTTGCTGCCGGTCACTTAACATTATGCTGAGTGATATCCCGCTTAAGCTCGAGCCATGGGCCCCTAGGAG
-47 Forward
T7
Pst I
BspM I
Sal I
Acc I
Sph I
Hinc II
Hind III
TAGAGTCGACCTGCAGGCATGCAAGCTTGAGTATTCTATAGTGTCACCTAAATAGCTTGGCGTAATCATGGTCATAGCTGTTTCCTGTGTGAAATTGTTA
ATCTCAGCTGGACGTCCGTACGTTCGAACTCATAAGATATCACAGTGGATTTATCGAACCGCATTAGTACCAGTATCGACAAAGGACACACTTTAACAAT
Pilot 30-0
SP6
Z
-48 Reverse
TCCGCTCACAATTCCACACAACATACGA
AGGCGAGTGTTAAGGTGTGTTGTATGCT
228
-48 Reverse
206

FIG. 19

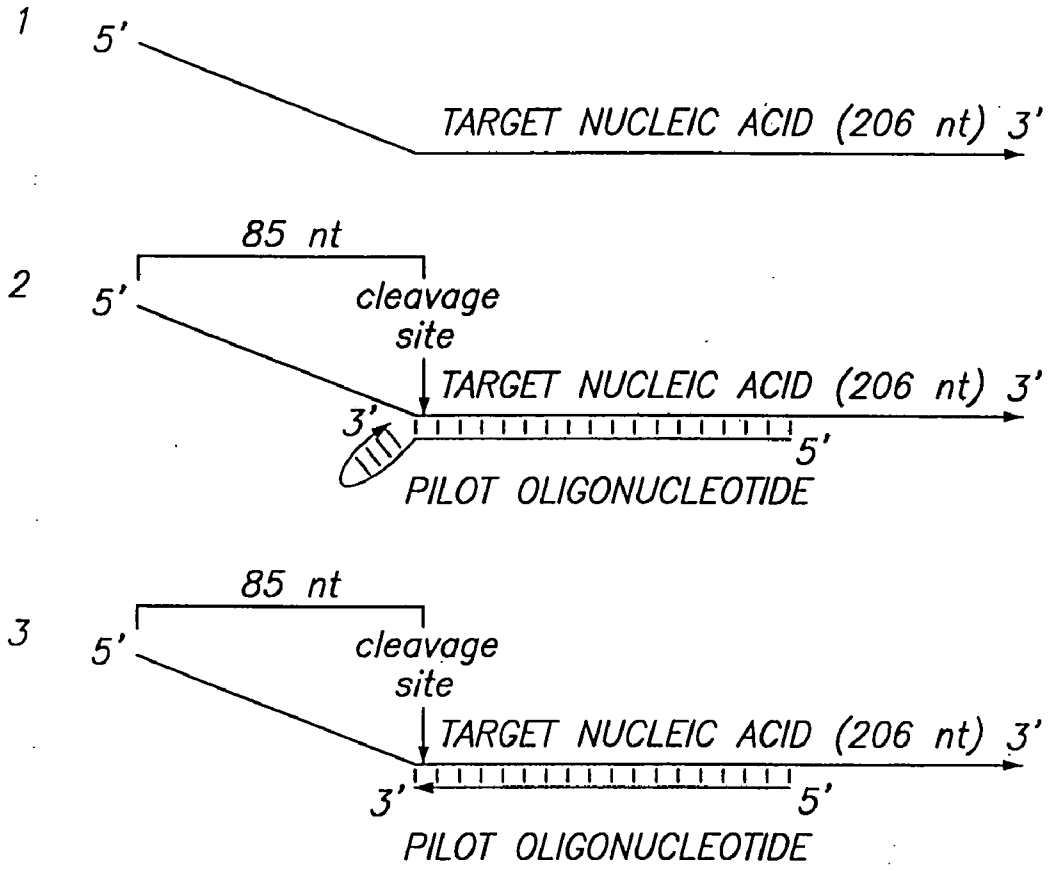

1
5'
TARGET NUCLEIC ACID (206 nt) 3'
85 nt
2
5'
cleavage site
TARGET NUCLEIC ACID (206 nt) 3'
3'
5'
PILOT OLIGONUCLEOTIDE
85 nt
3
5'
cleavage site
TARGET NUCLEIC ACID (206 nt) 3'
3'
5'
PILOT OLIGONUCLEOTIDE

FIG. 20A

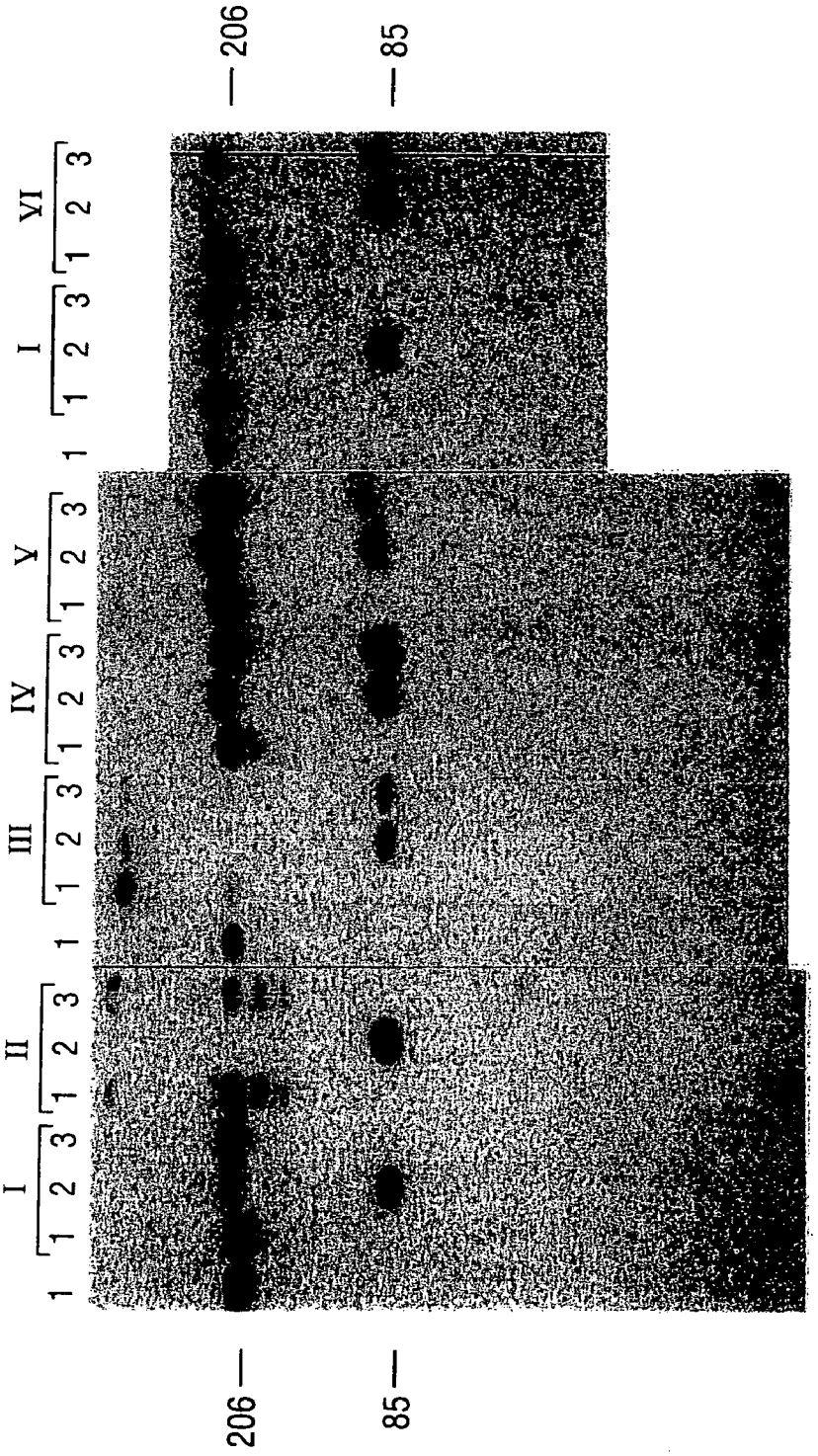


FIG. 20B

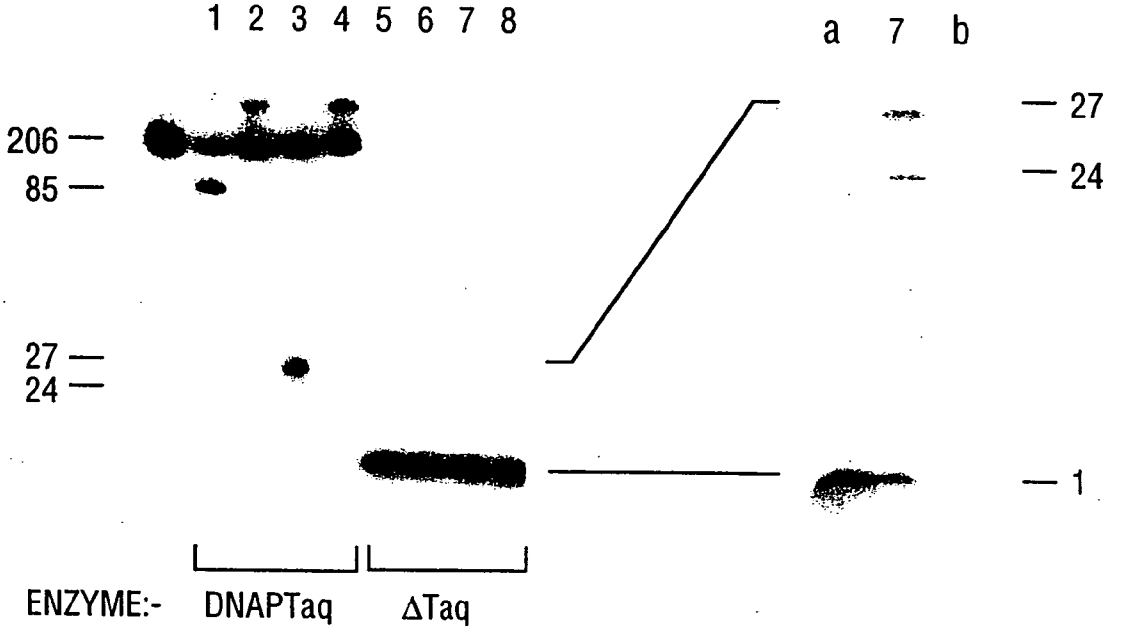


FIG. 21A

FIG. 21B

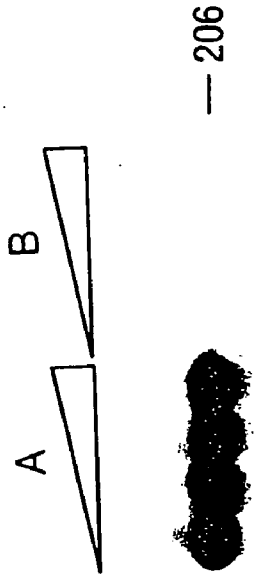
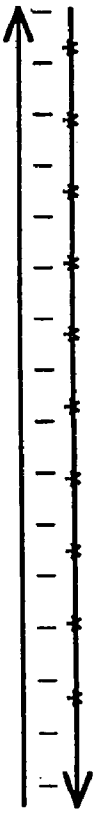


FIG. 22A



* = ^{32}P

FIG. 22B

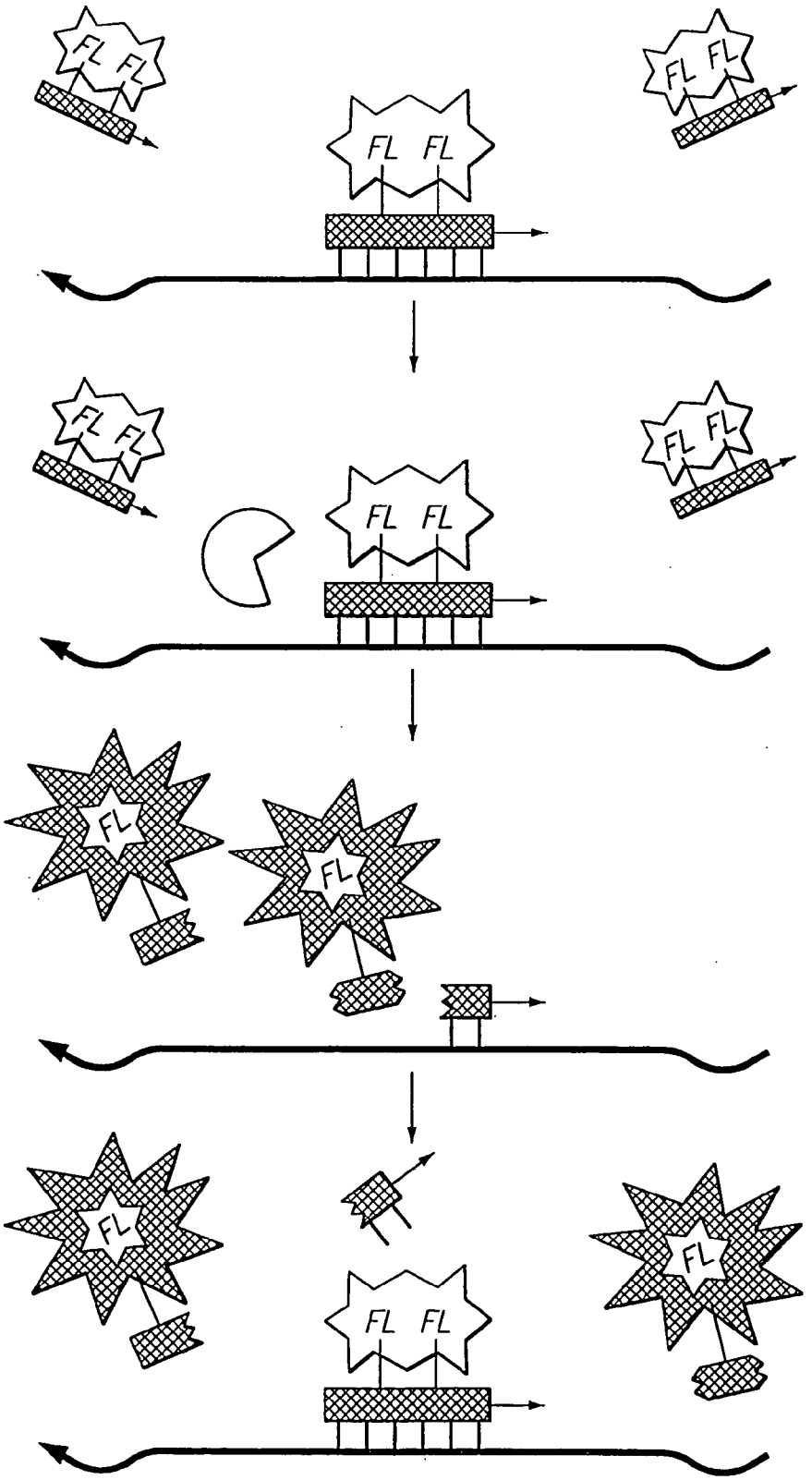


FIG. 23

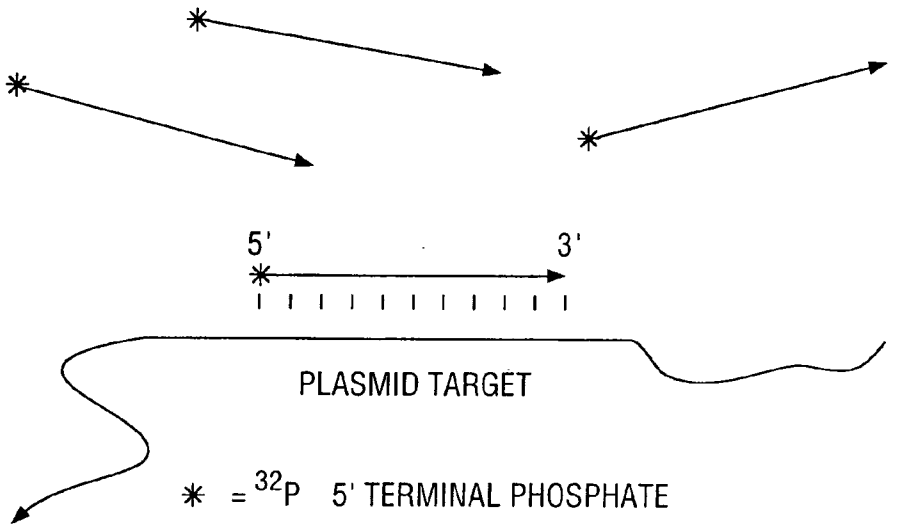


FIG. 24A

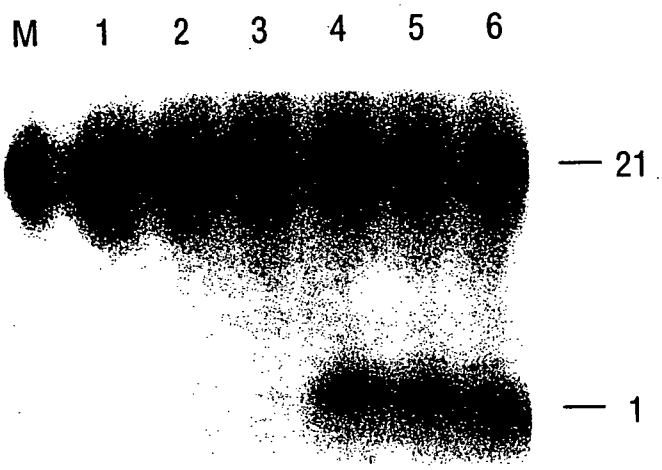


FIG. 24B

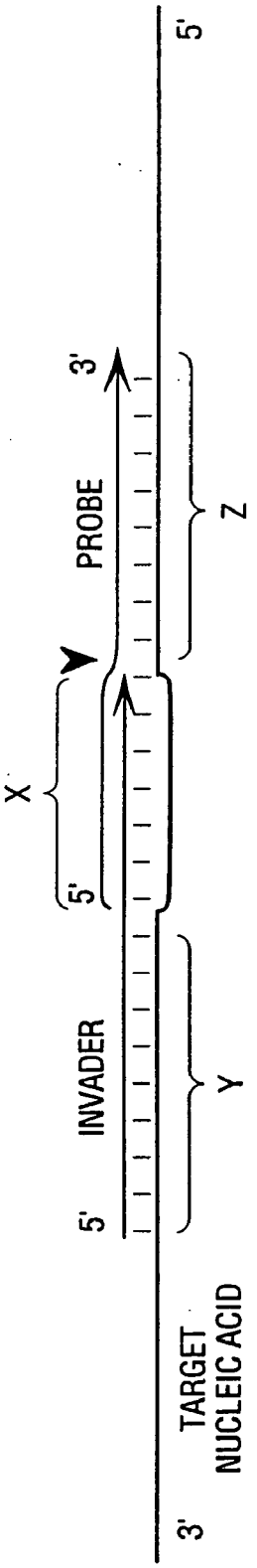


FIG. 25

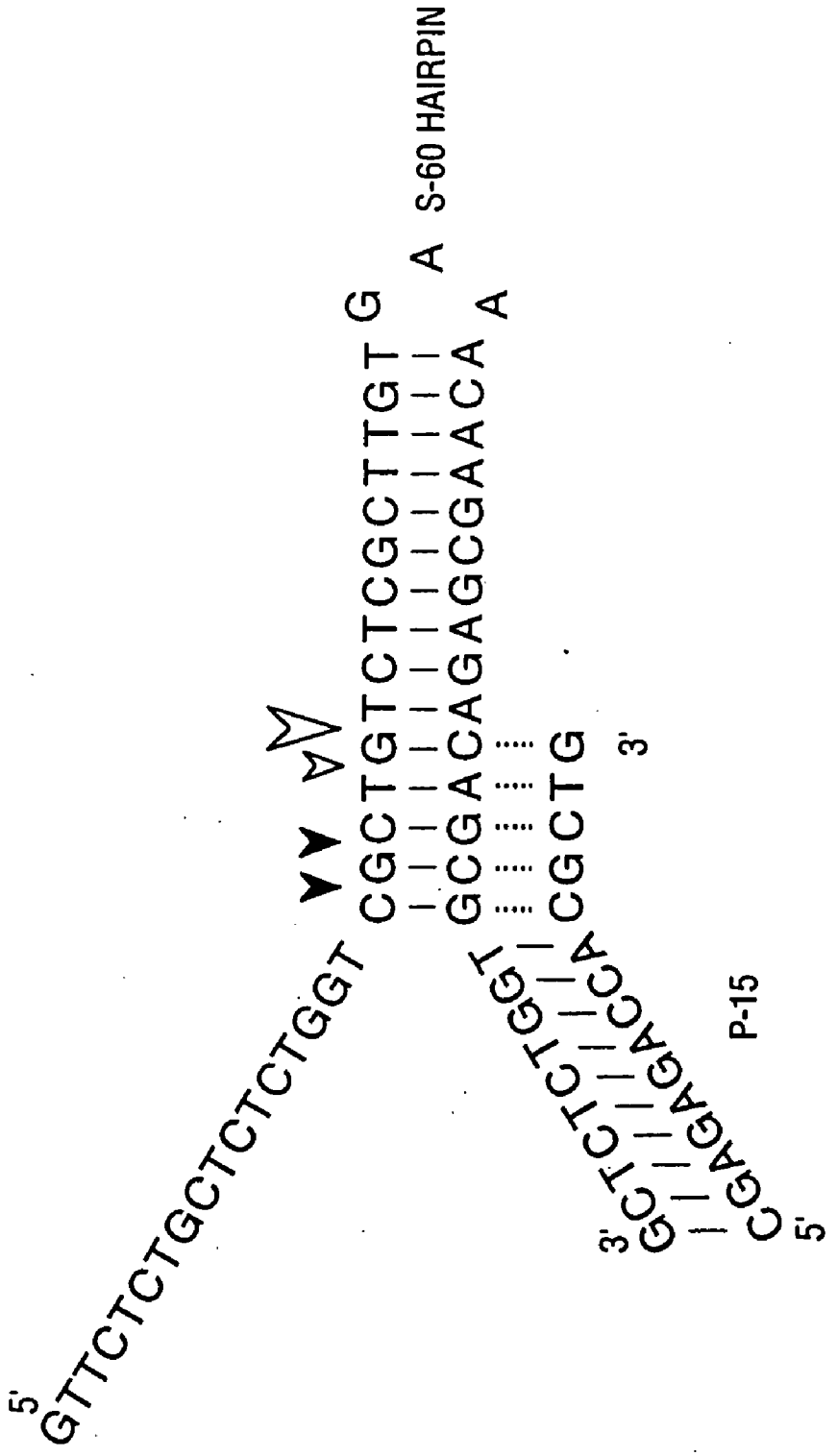

5'
GTTCTCTGCTCTCTGGT
CGCTGTCTCGCTTGT G A S-60 HAIRPIN
GCGACAGAGCGAACA A
3'
CGCTG
3'
GCTCTCTGGT
CTCTCCA
GAGAG
CGAG
5'
P-15

FIG. 26

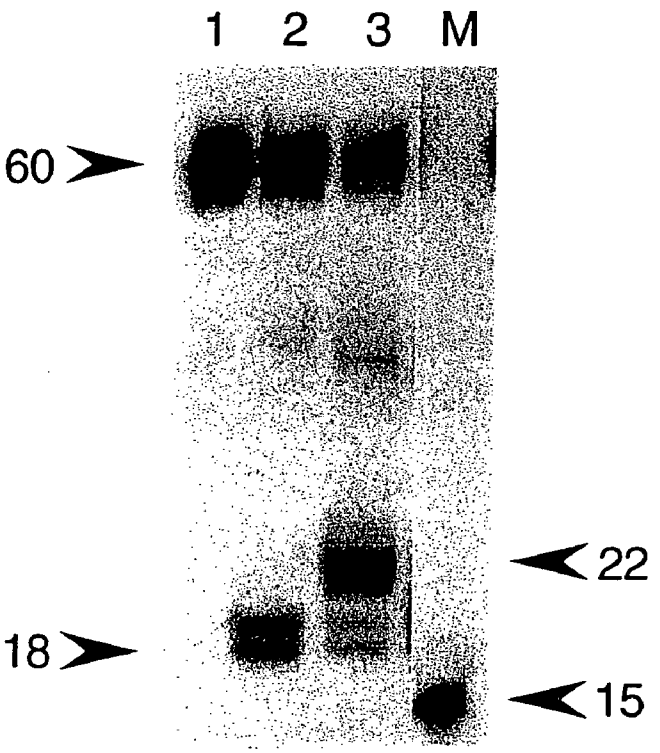


FIG. 27

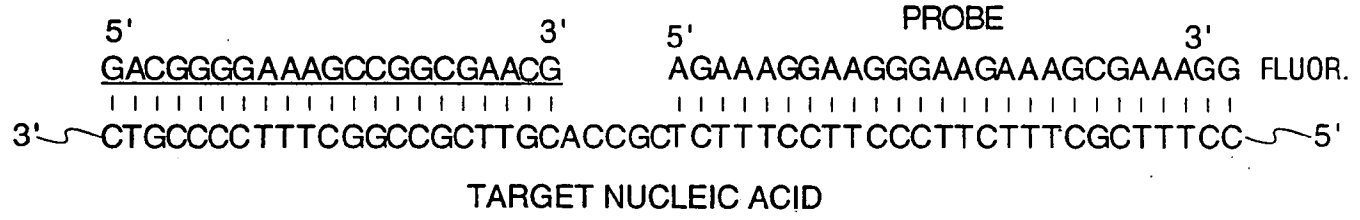


FIG. 28A



FIG. 28B

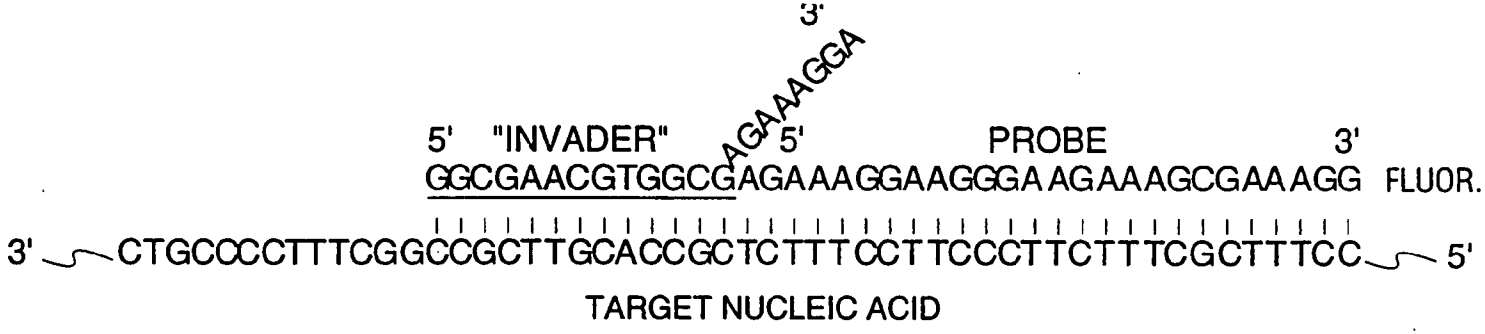


FIG. 28C

FIG. 29

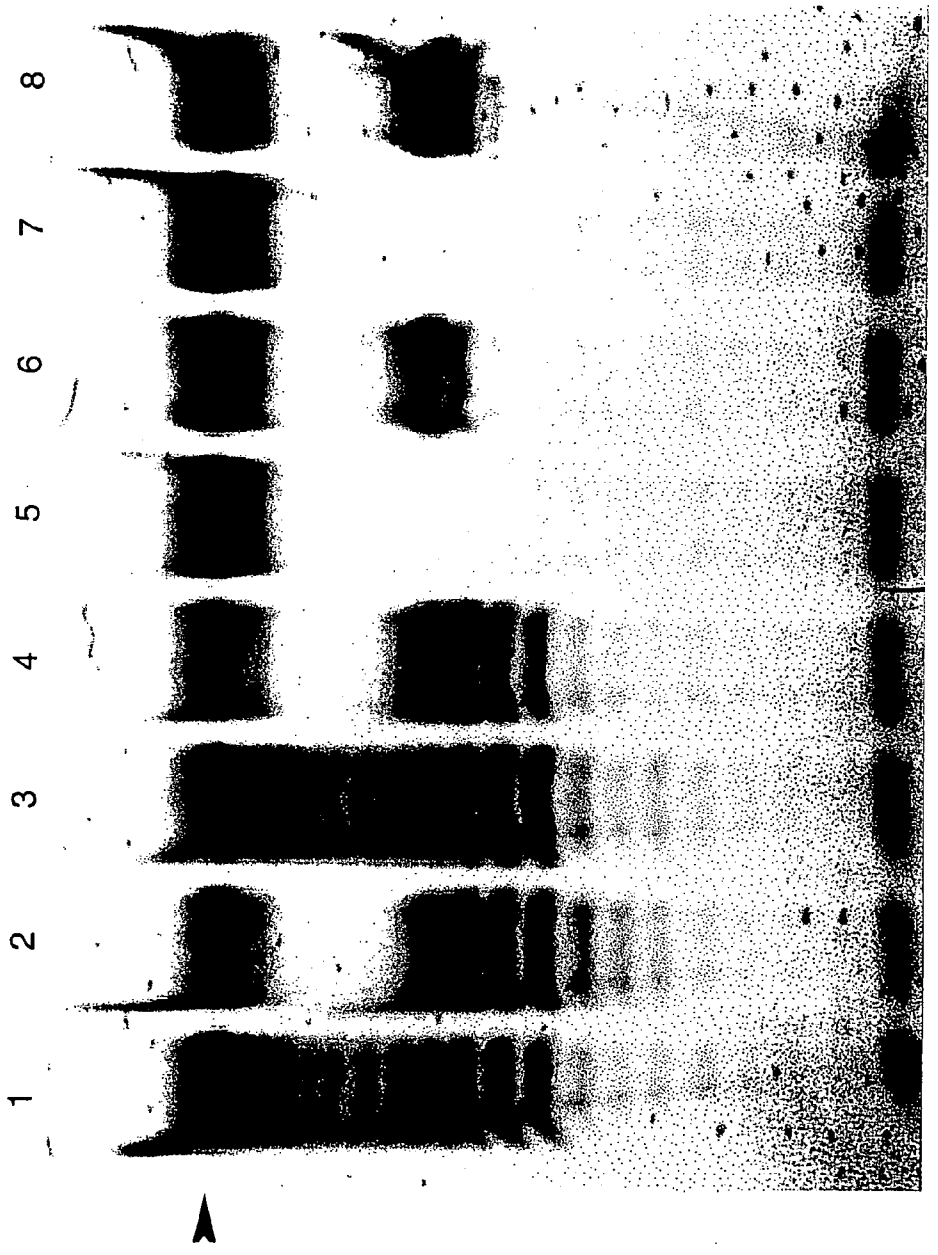
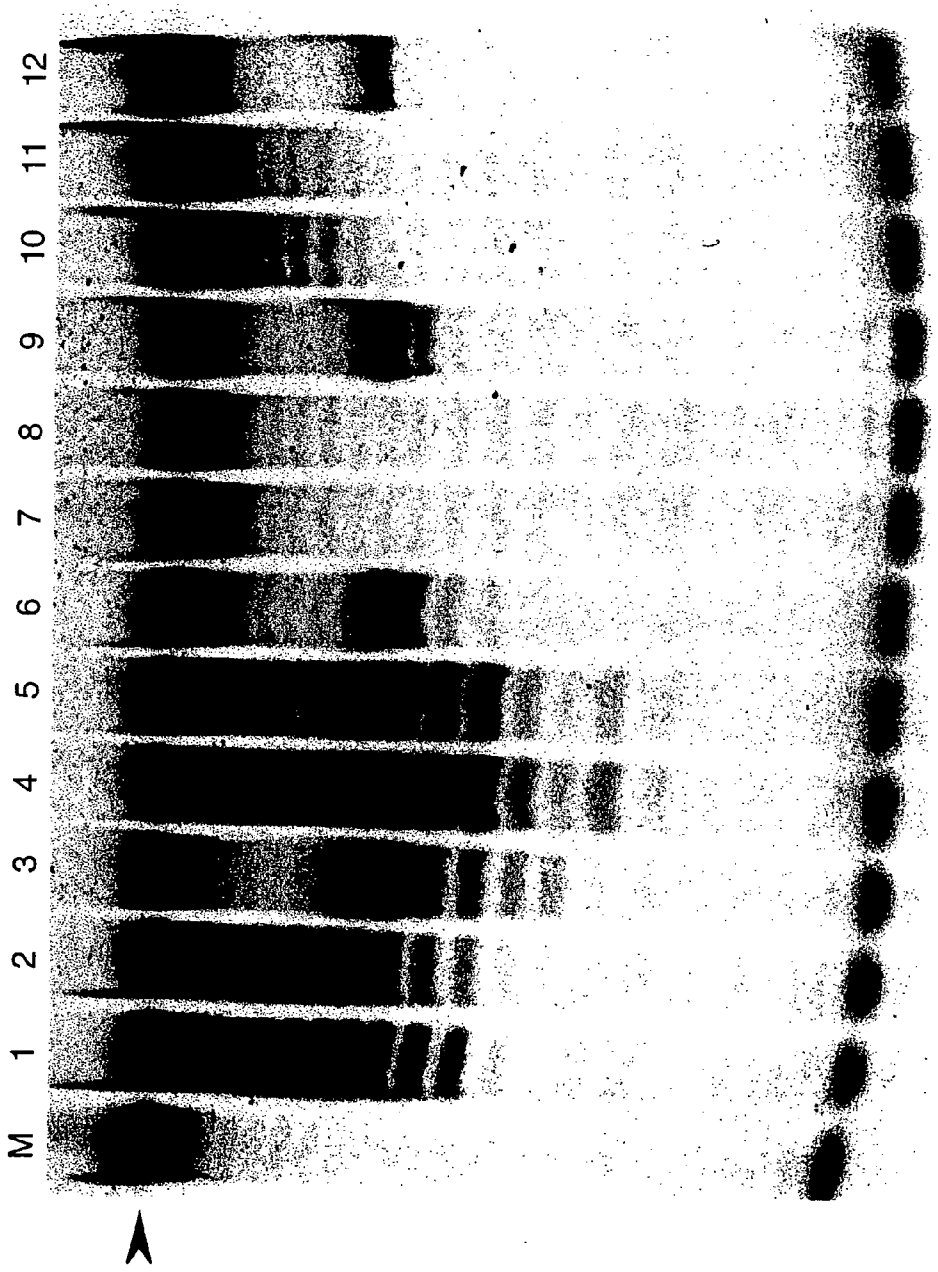


FIG. 30



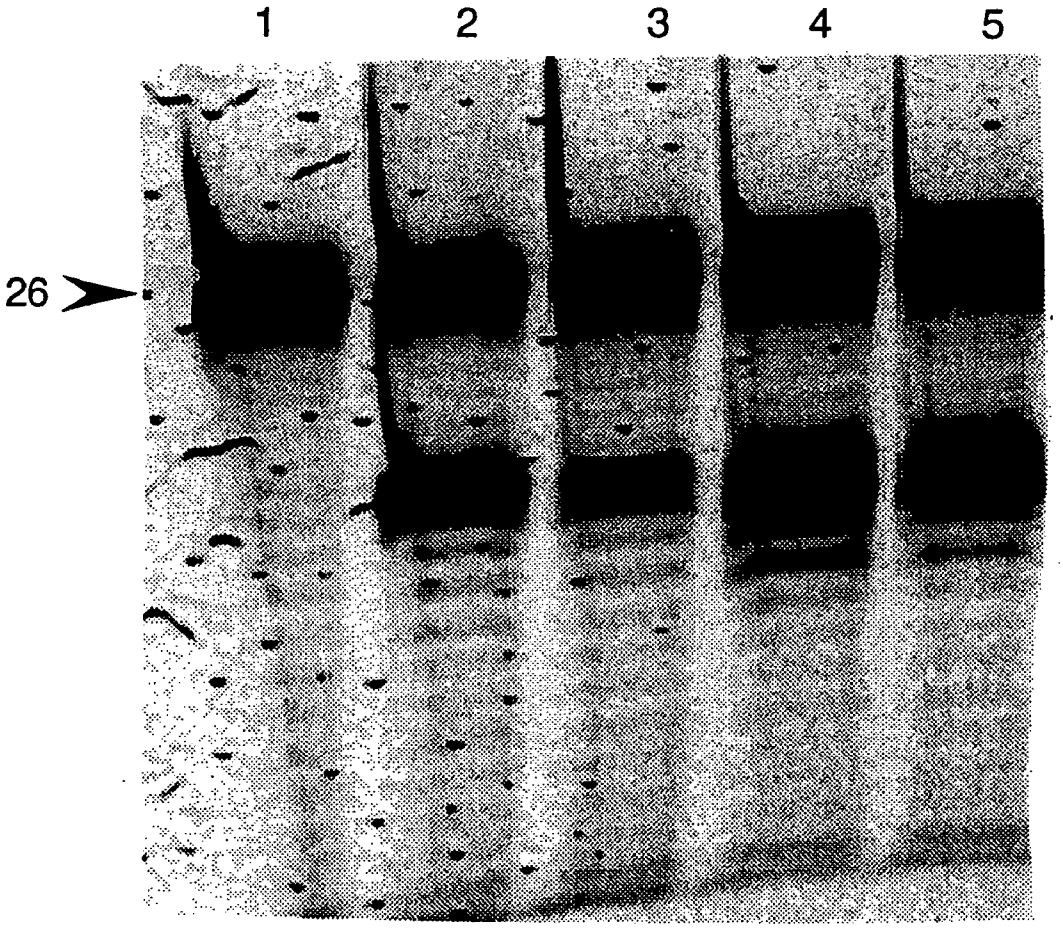


FIG. 31

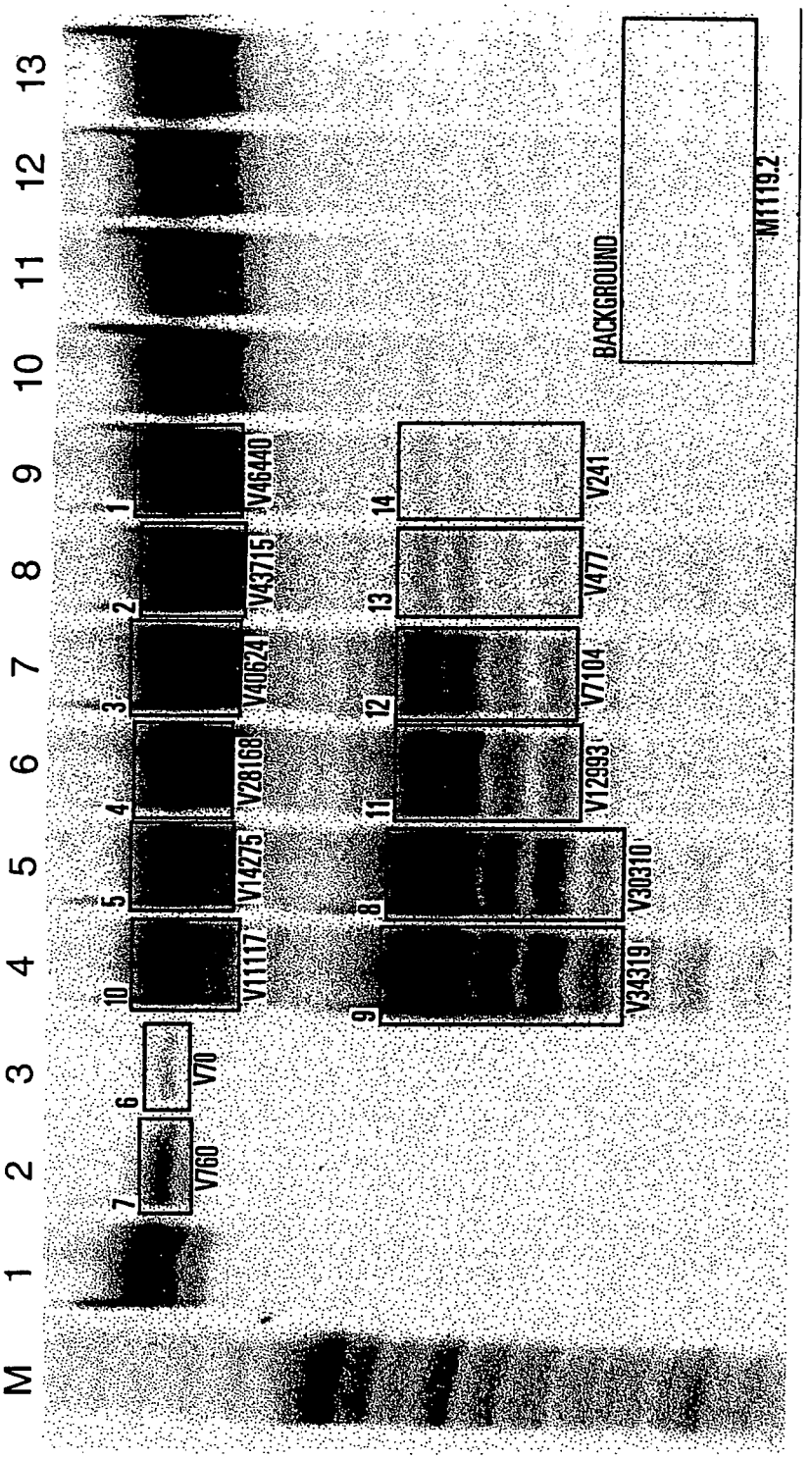

M
1
2
3
4
5
6
7
8
9
10
11
12
13
V760
V70
V11117
V14275
V28168
V40624
V43715
V46440
V34319
V30310
V12993
V7104
V477
V241
BACKGROUND
M1119.2

FIG. 32

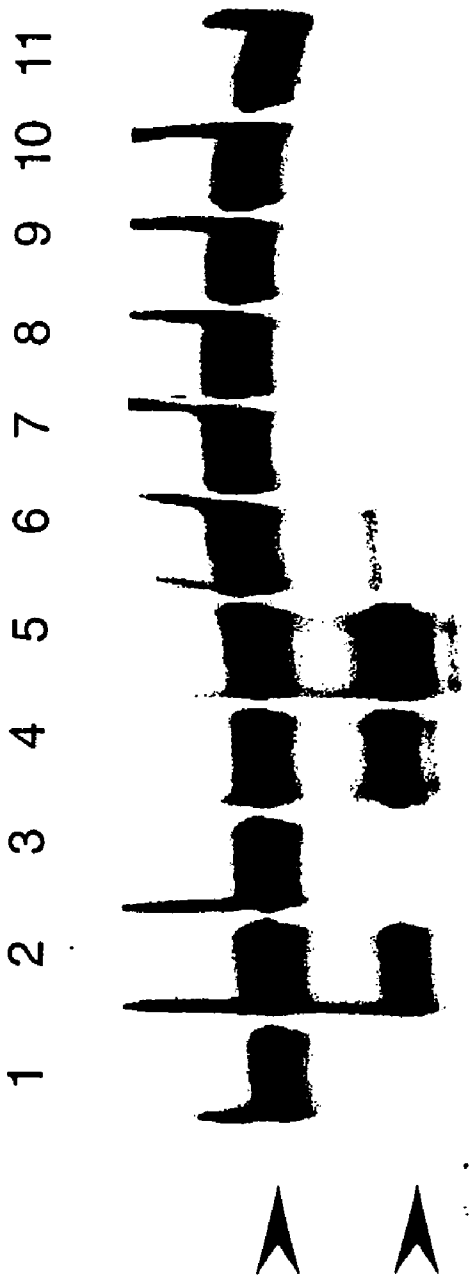


FIG. 33

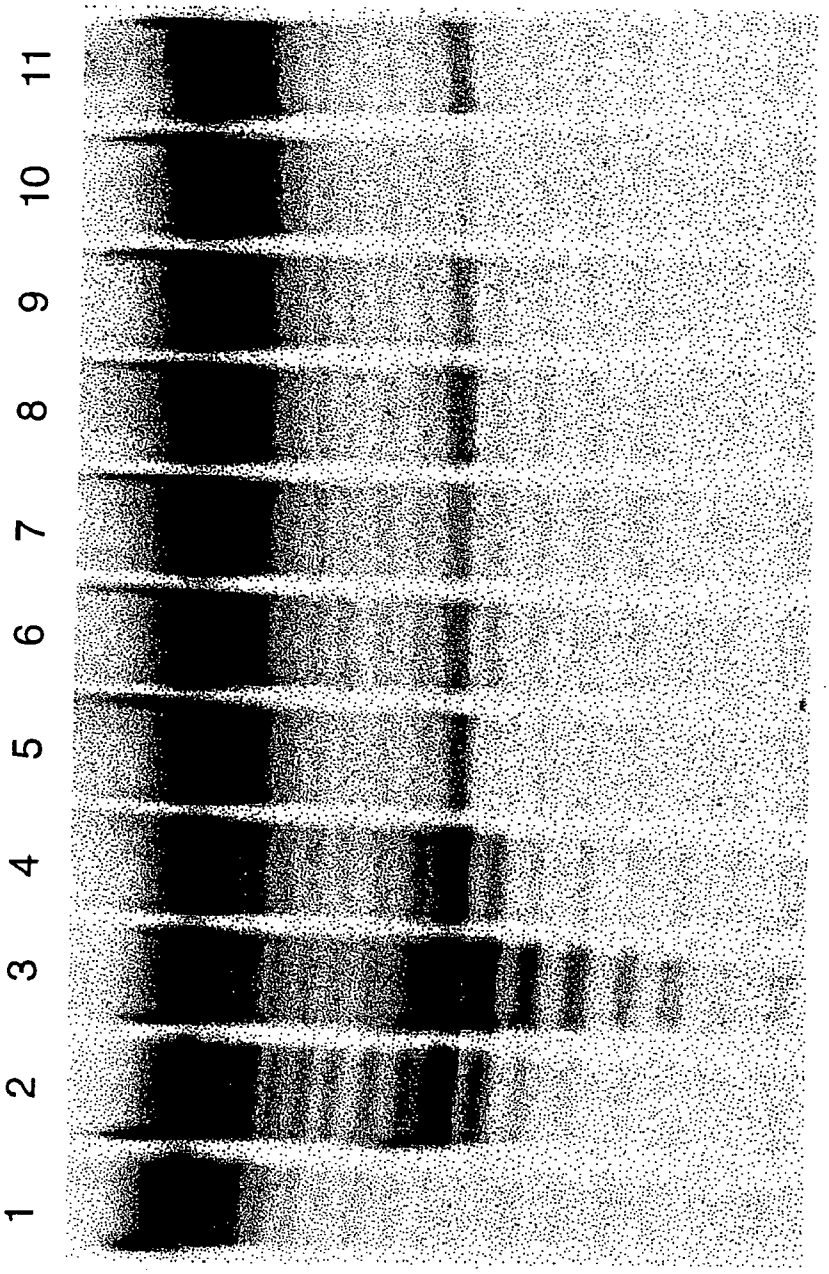


FIG. 34

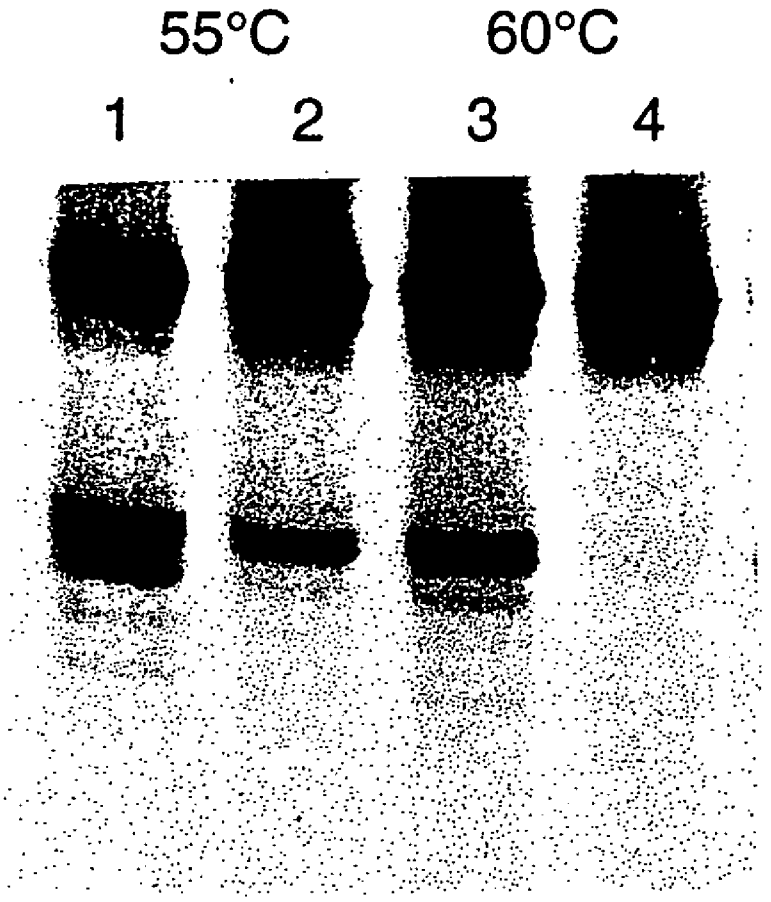


FIG. 35

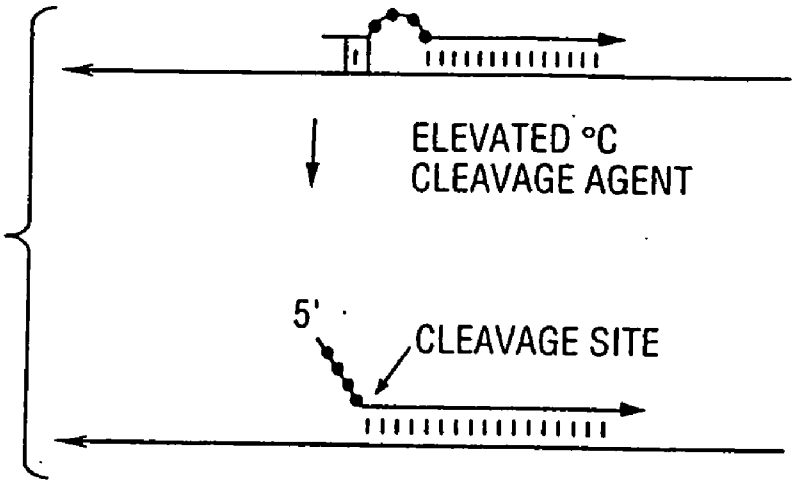


FIG. 36A

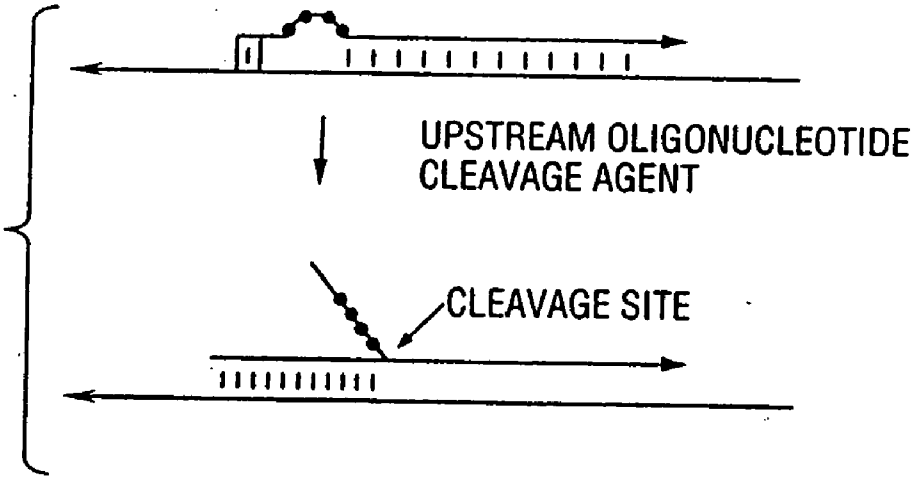


FIG. 36B

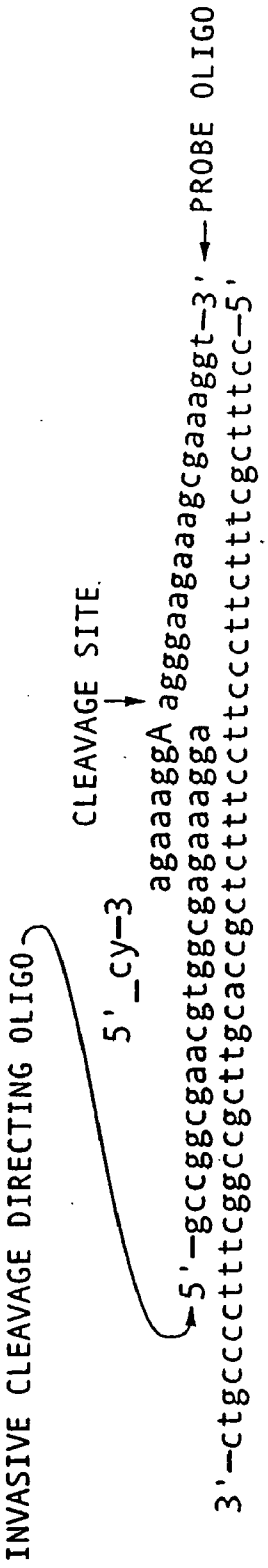

INVASIVE CLEAVAGE DIRECTING OLIGO
5'_cy-3
CLEAVAGE SITE
agaaaggA agggaagaaagcgaaaggt-3' ← PROBE OLIGO
5'-gccgggcgaacgtggcgagaaagga
3'-ctgccccttttcggccgcttgcaccgctctttccttcctttcgctttcc-5'

FIG. 37

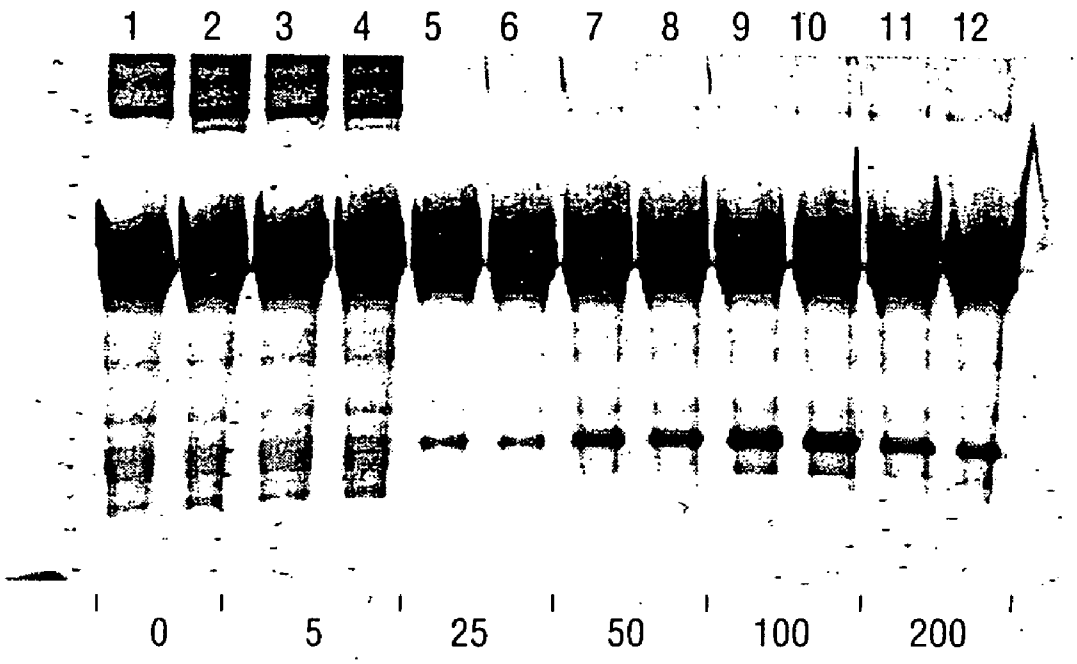


FIG. 38

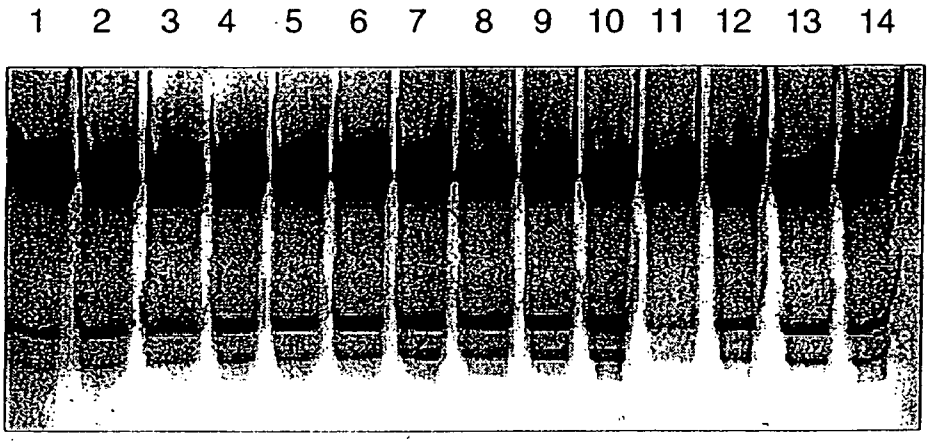


FIG. 39

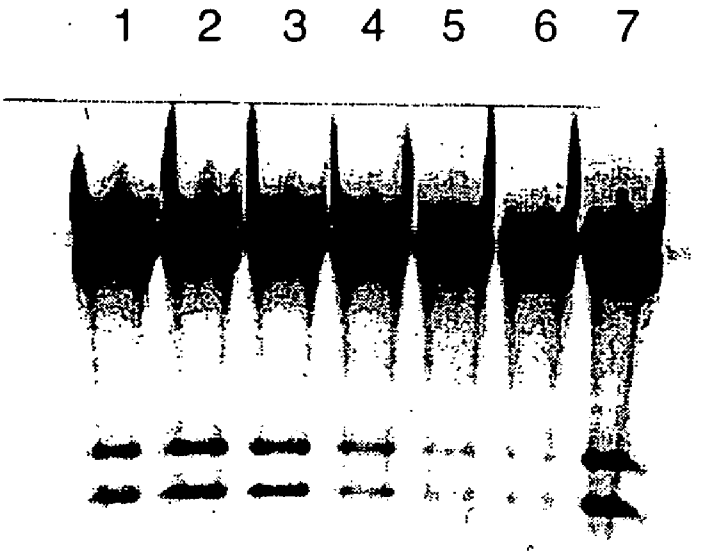


FIG. 40

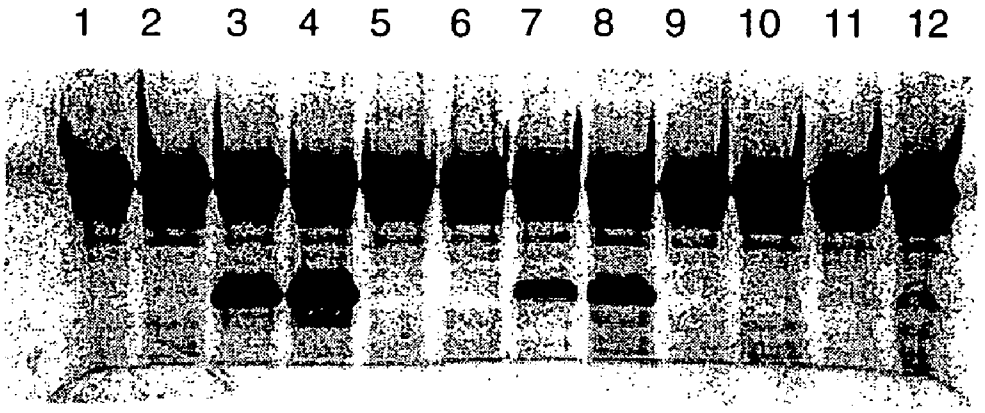


FIG. 41

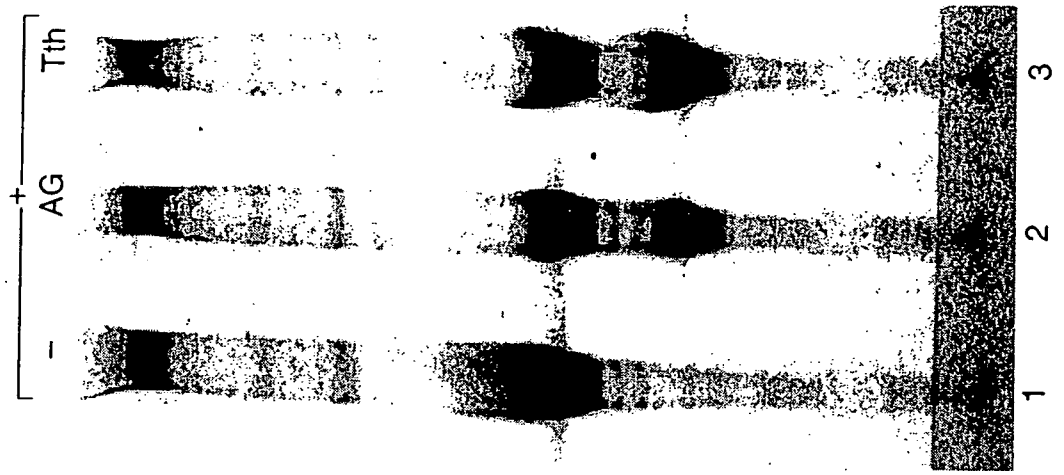


FIG. 42B

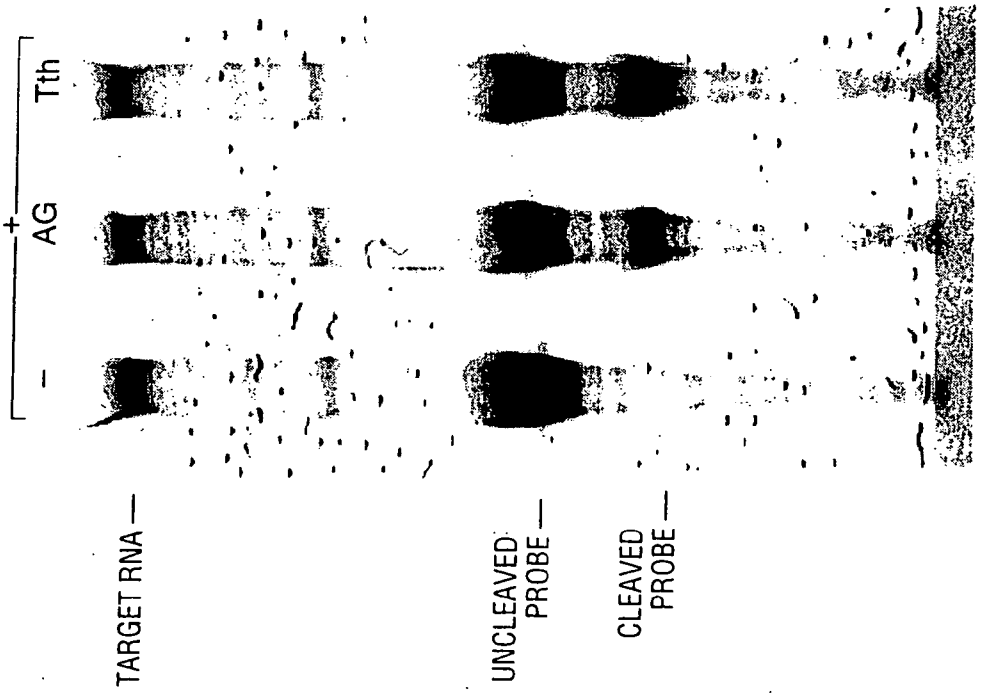


FIG. 42A

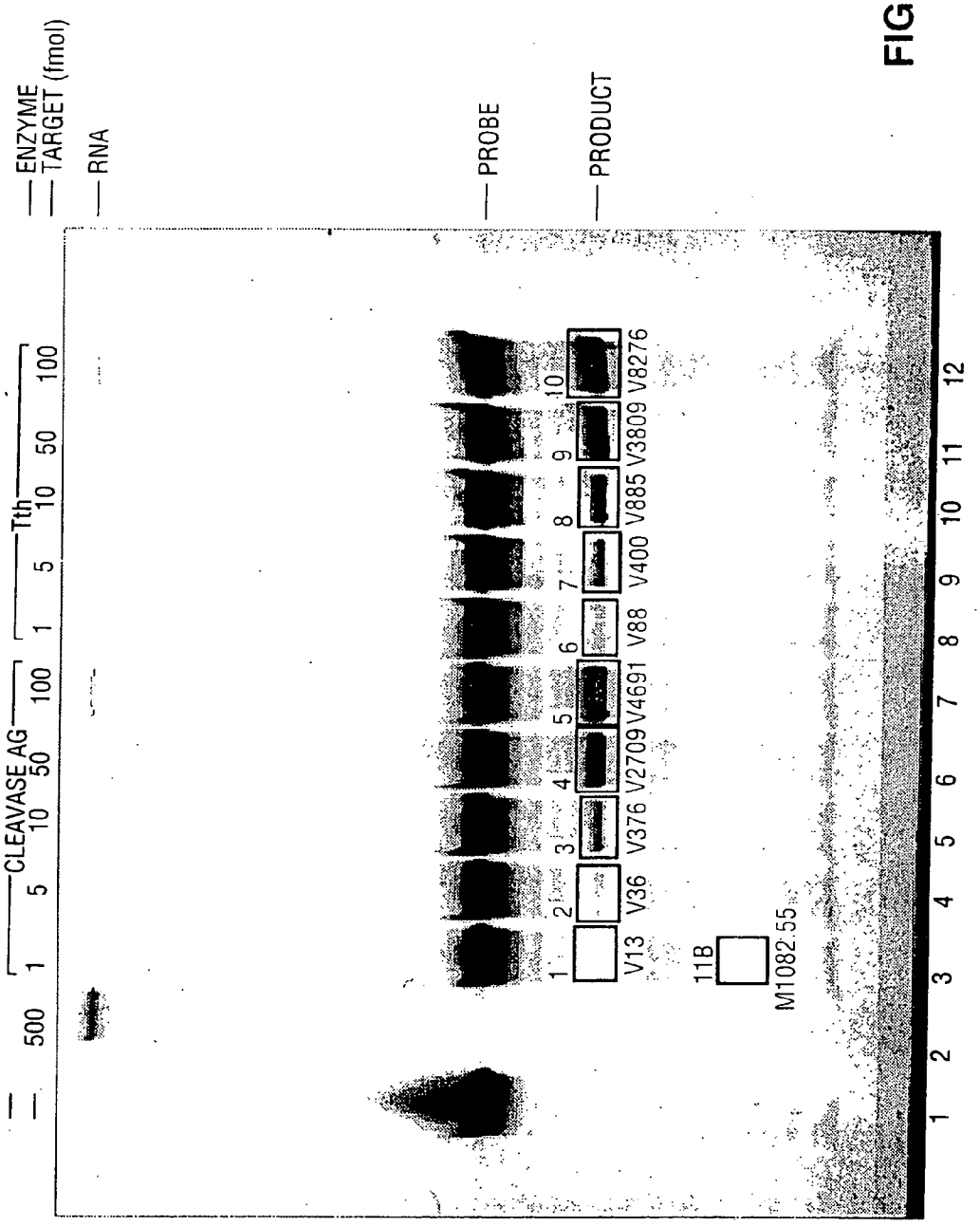

ENZYME
TARGET (fmol)
RNA
PROBE
PRODUCT
CLEAVASE AG
Tth
500
1
5
10
50
100
1
5
10
50
100
V13
V36
V376
V2709
V4691
V88
V400
V885
V3809
V8276
11B
M1082.55
1
2
3
4
5
6
7
8
9
10
11
12

FIG. 43

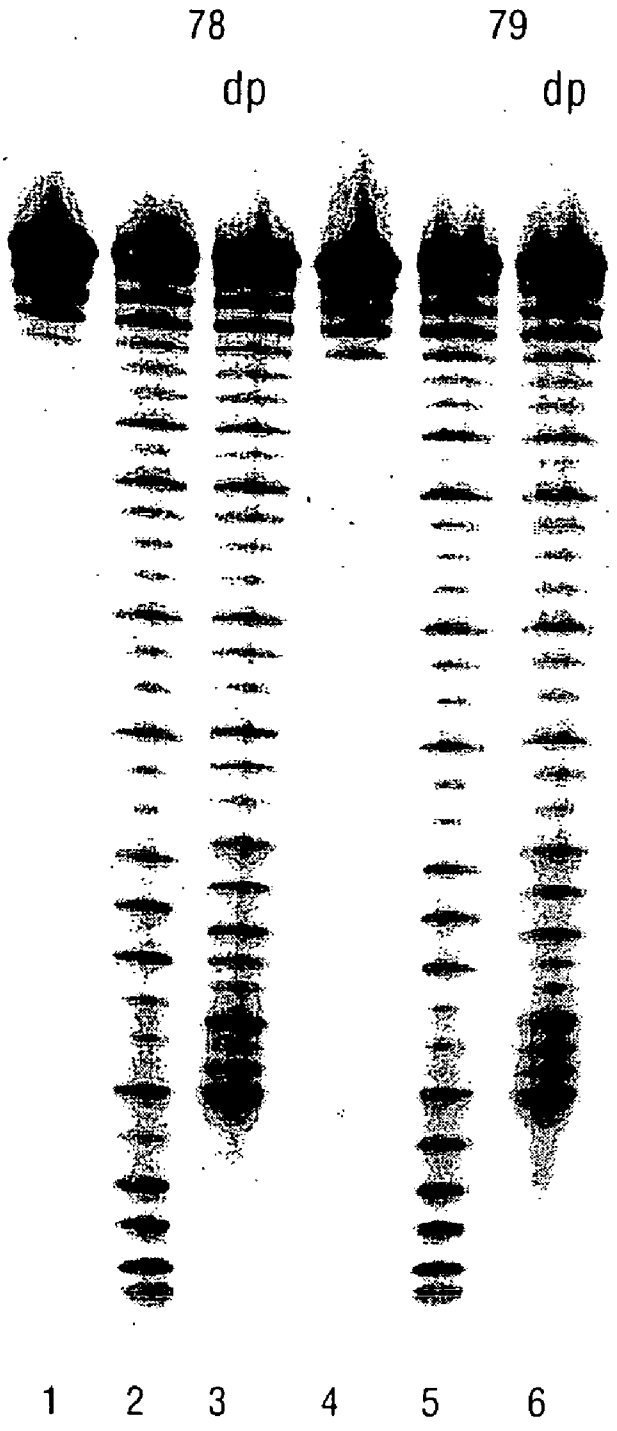


FIG. 44

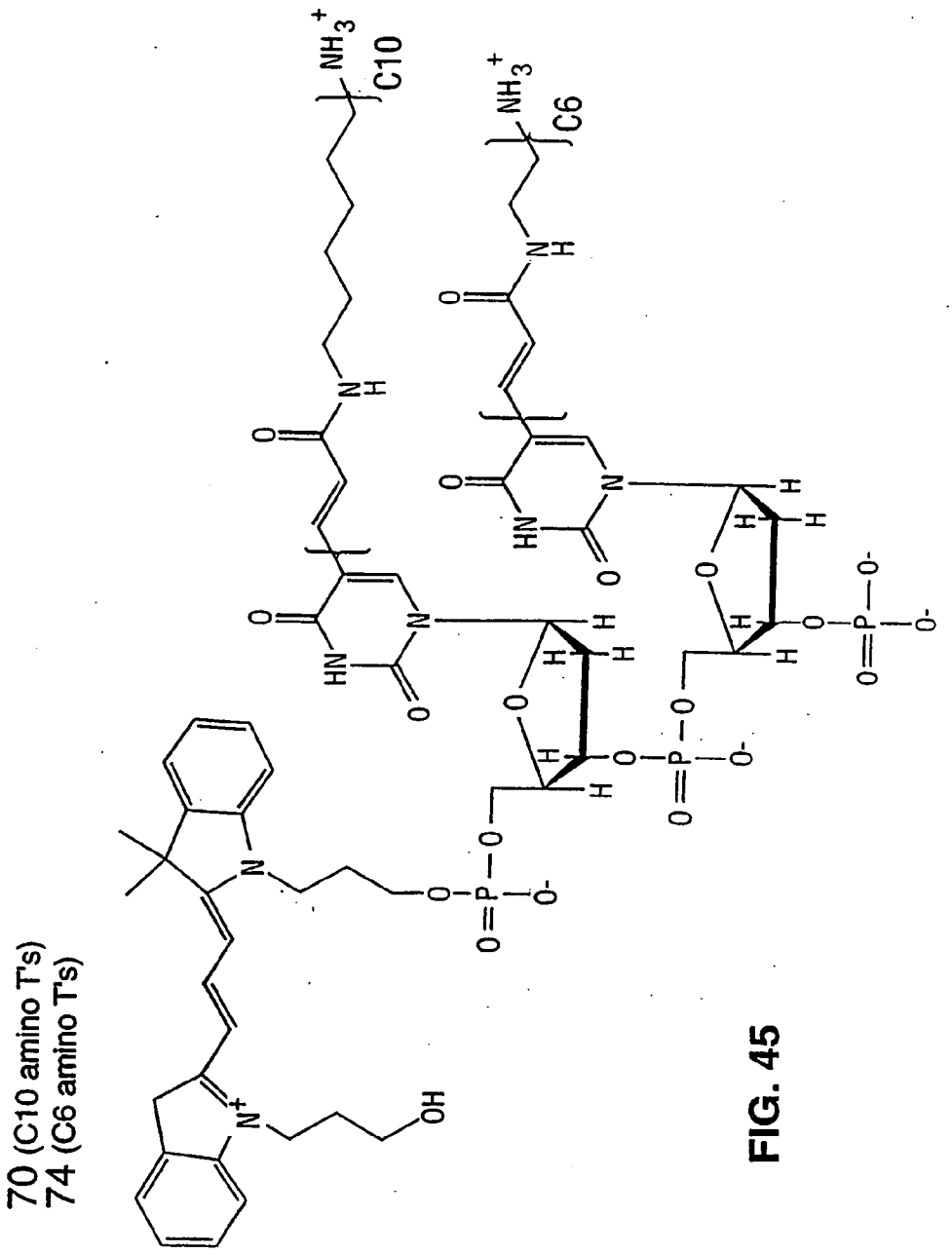


FIG. 45

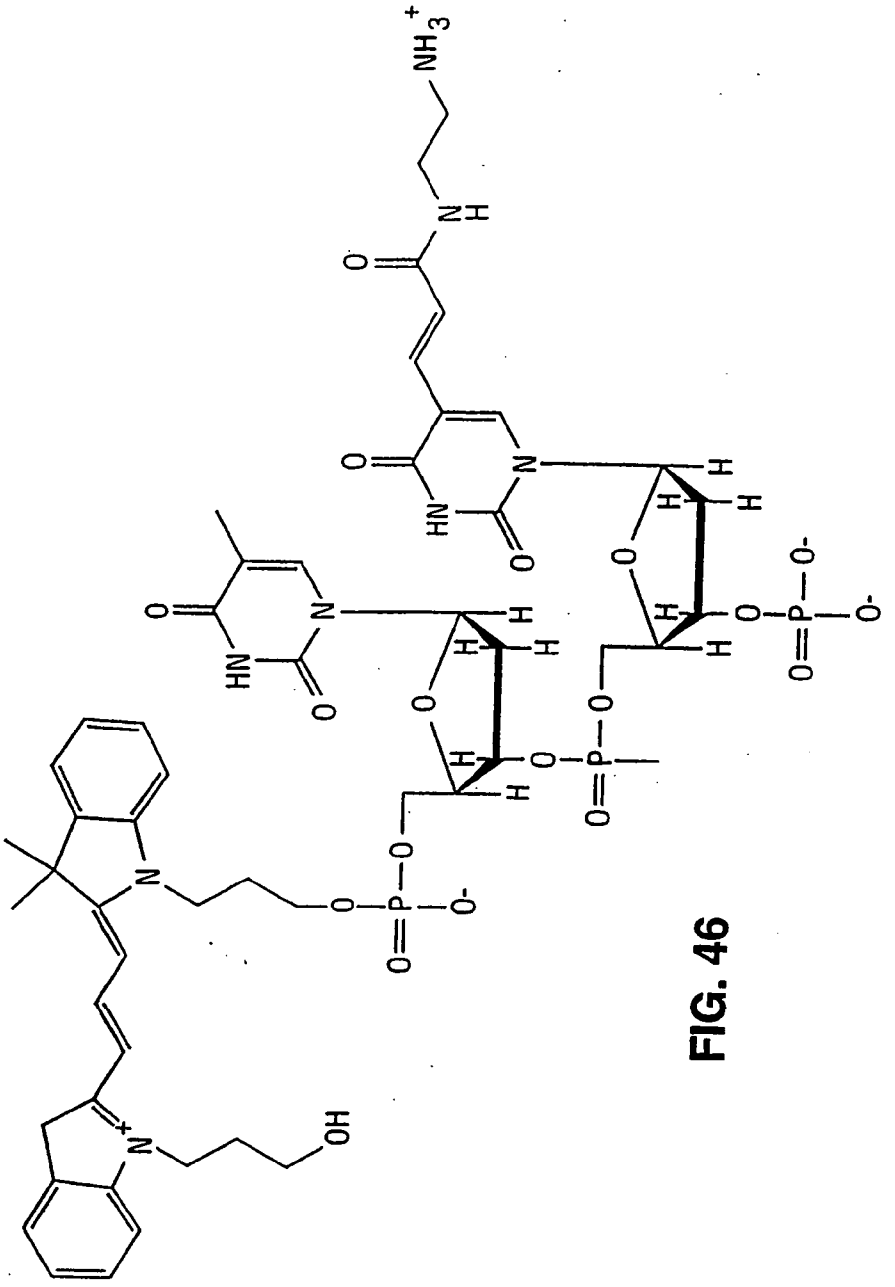


FIG. 46

75

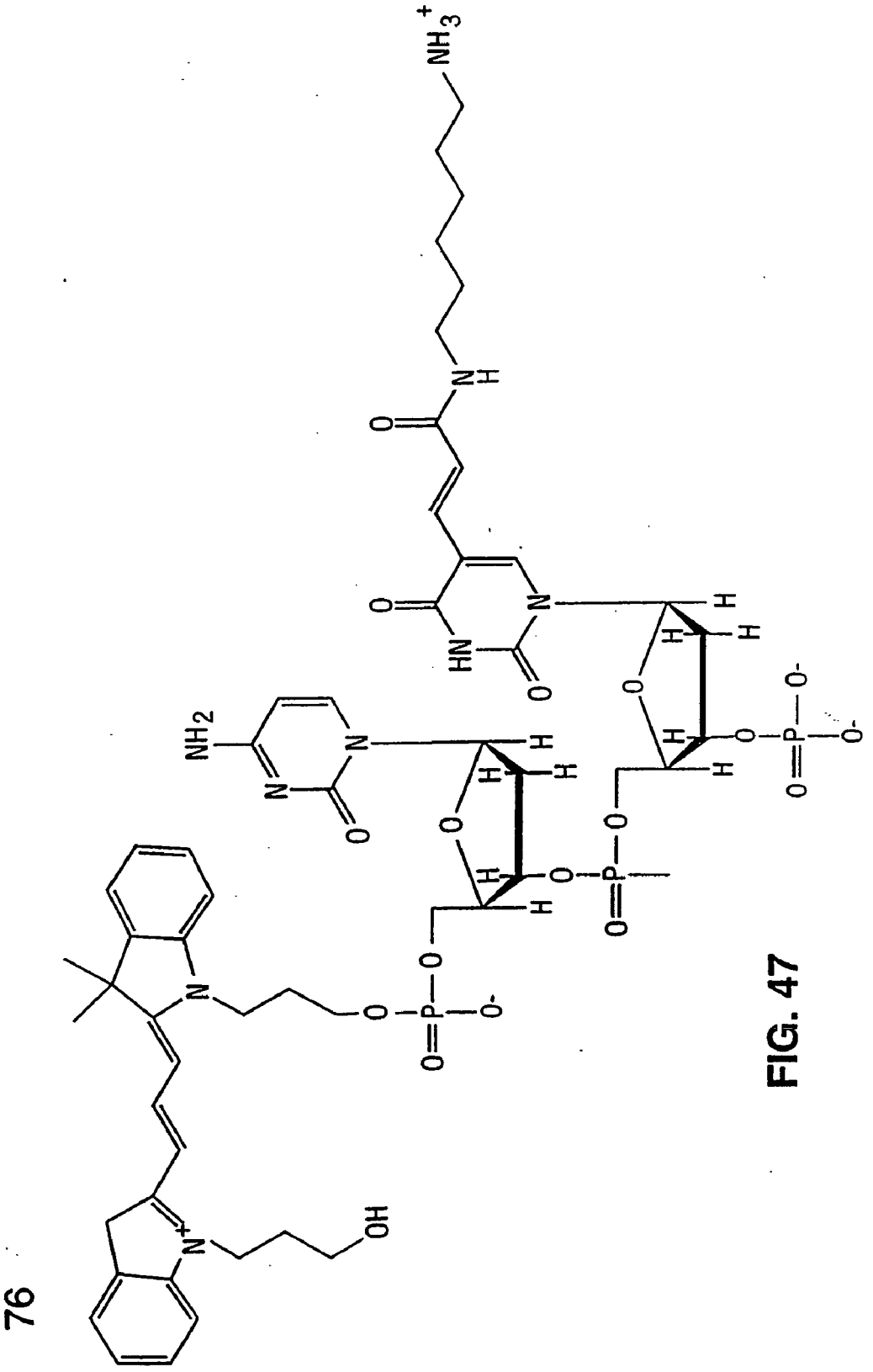


FIG. 47

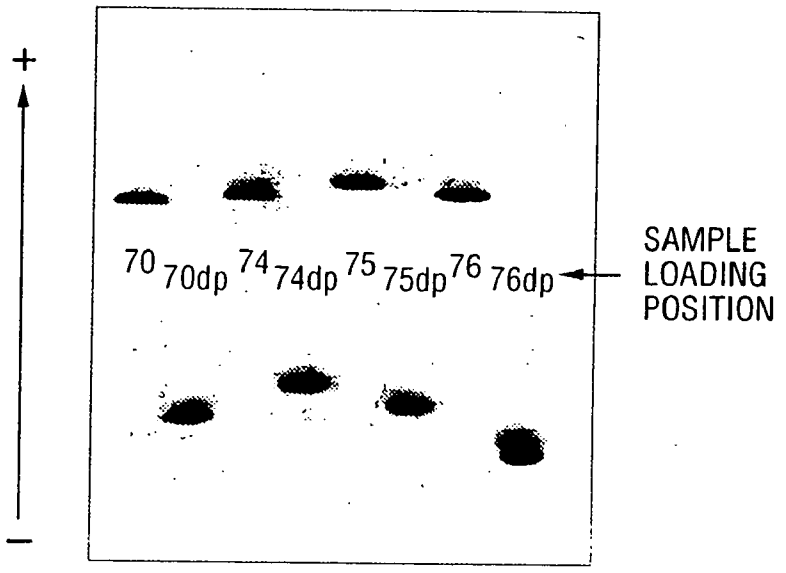


FIG. 48

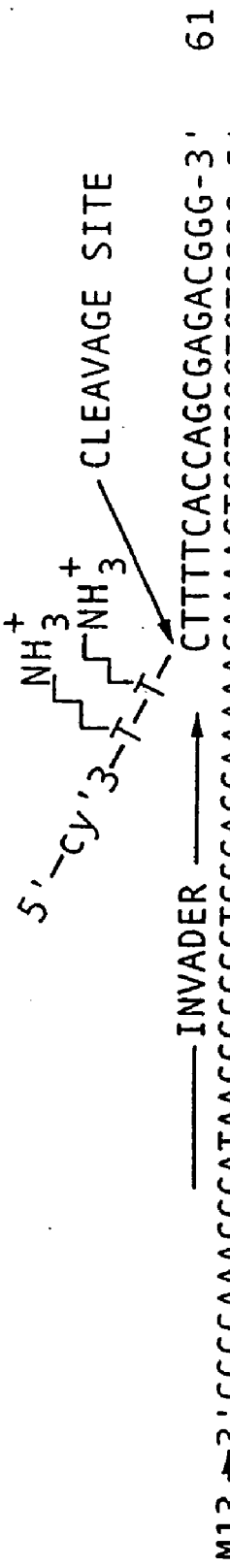

5'-Cy3-T-T-NH3+ NH3+
CLEAVAGE SITE
INVADER
CTTTTCACCAGCGAGACGGG-3'
61
M13 →3'CGCCAAACGCATAACCCGCGGTCCCACCAAAAAGAAAAGTGGTCGCTCTGCCC-5'
0987654321098765432 1
123456789
67 → ATTGGGCGCCAGGGTGGTTTTTT

FIG. 49A

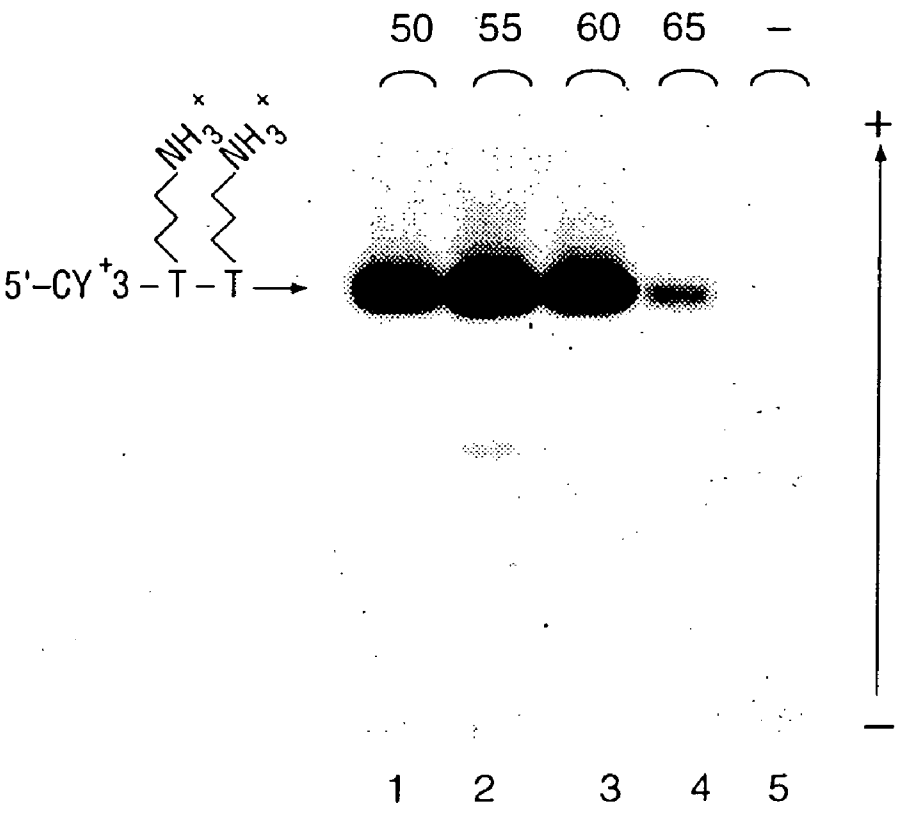


FIG. 49B

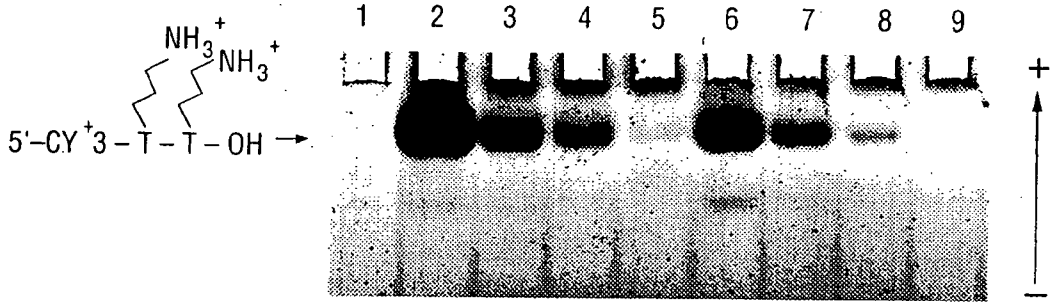


FIG. 50

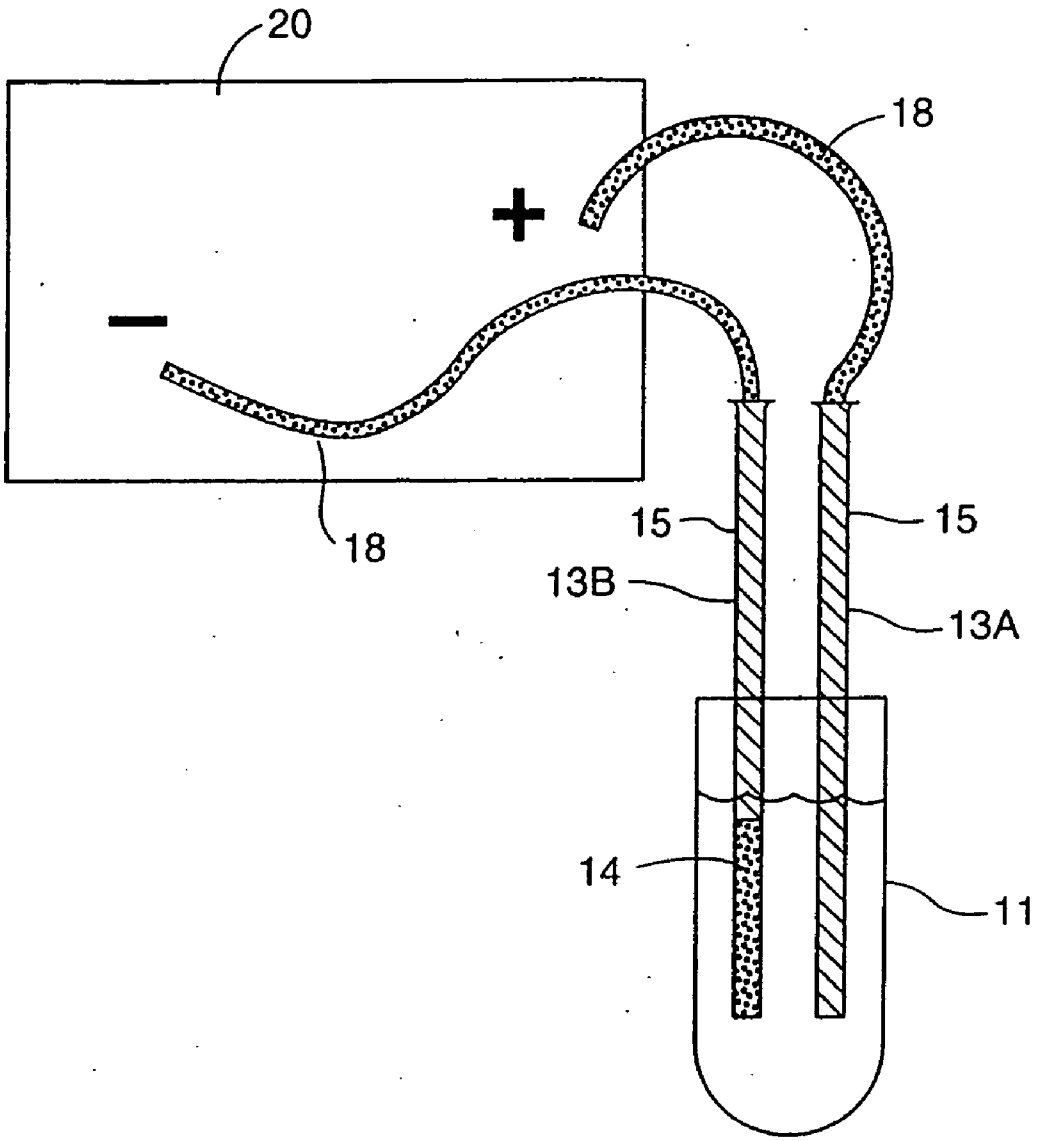


FIG. 51

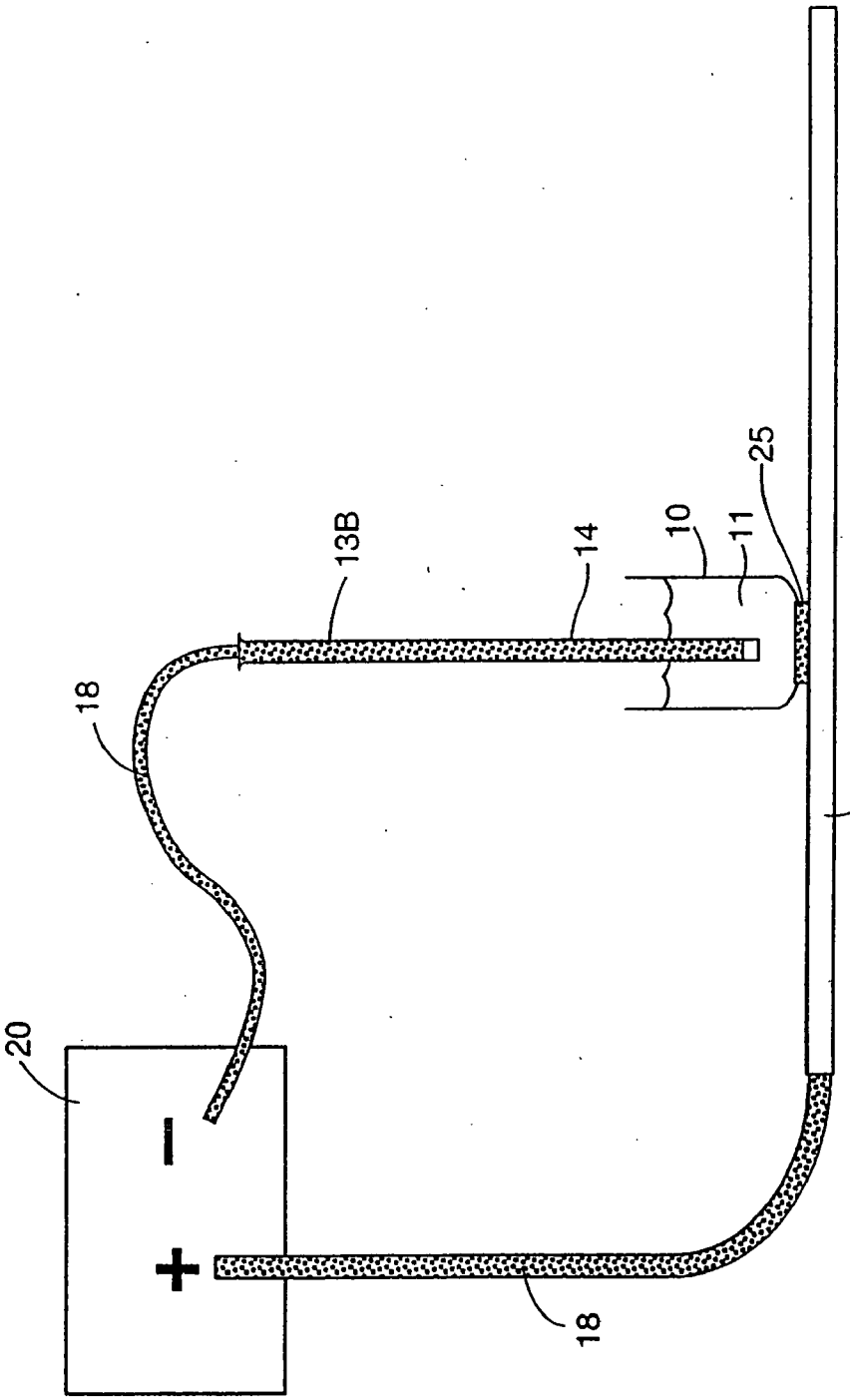


FIG. 52

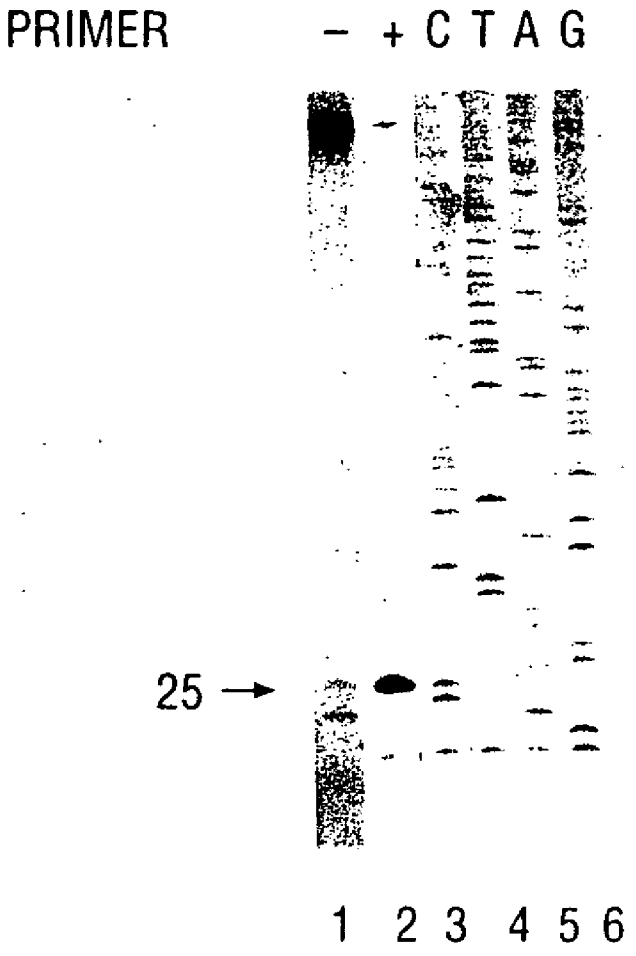


FIG. 53



FIG. 54A

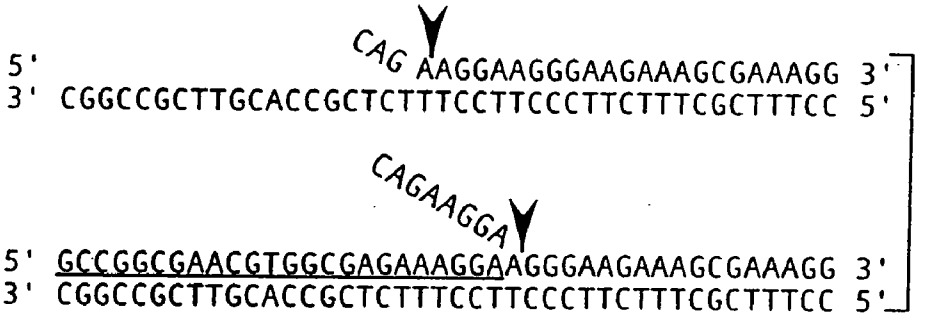


FIG. 54B

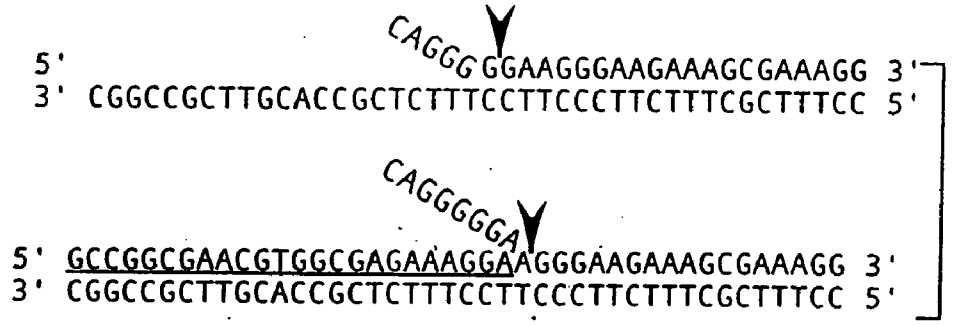
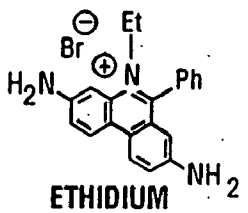


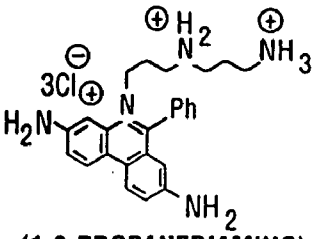
FIG. 54C



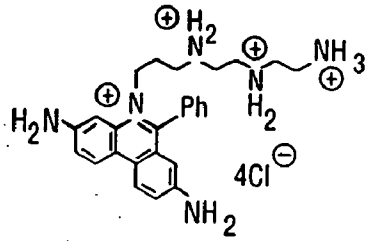
FIG. 54D



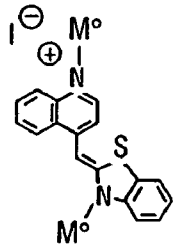
ETHIDIUM BROMIDE



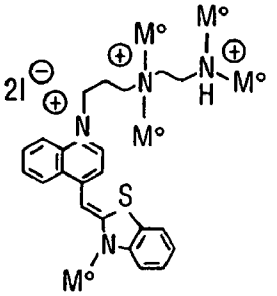
(1,3-PROPANEDIAMINO)-PROPIDIUM



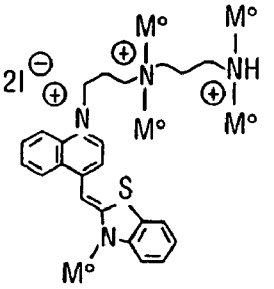
(DIETHYLENETRIAMINO)-PROPIDIUM



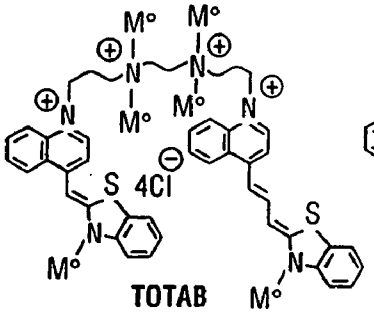
THIAZOLE ORANGE



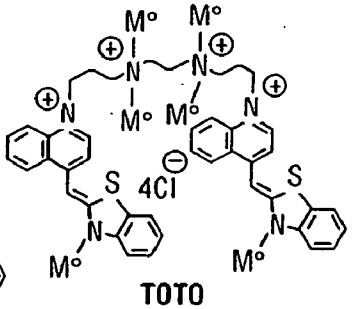
(N-N'-TETRAMETHYL-1,2-ETHANEDIAMINO)-PROPYL THIAZOLE ORANGE



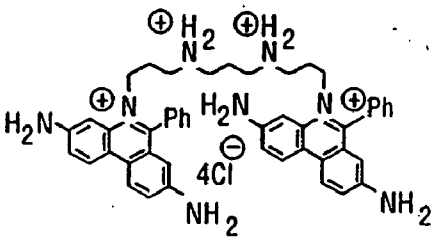
(N-N'-TETRAMETHYL-1,3-PROPANEDIAMINO)-PROPYL THIAZOLE ORANGE



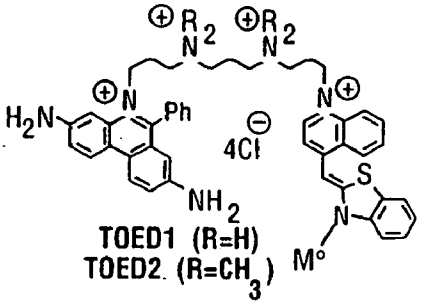
TOTAB



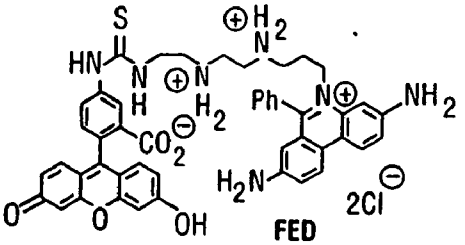
TOTO



EthD



TOED1 (R=H)
TOED2 (R=CH_3)



FED

FIG. 55

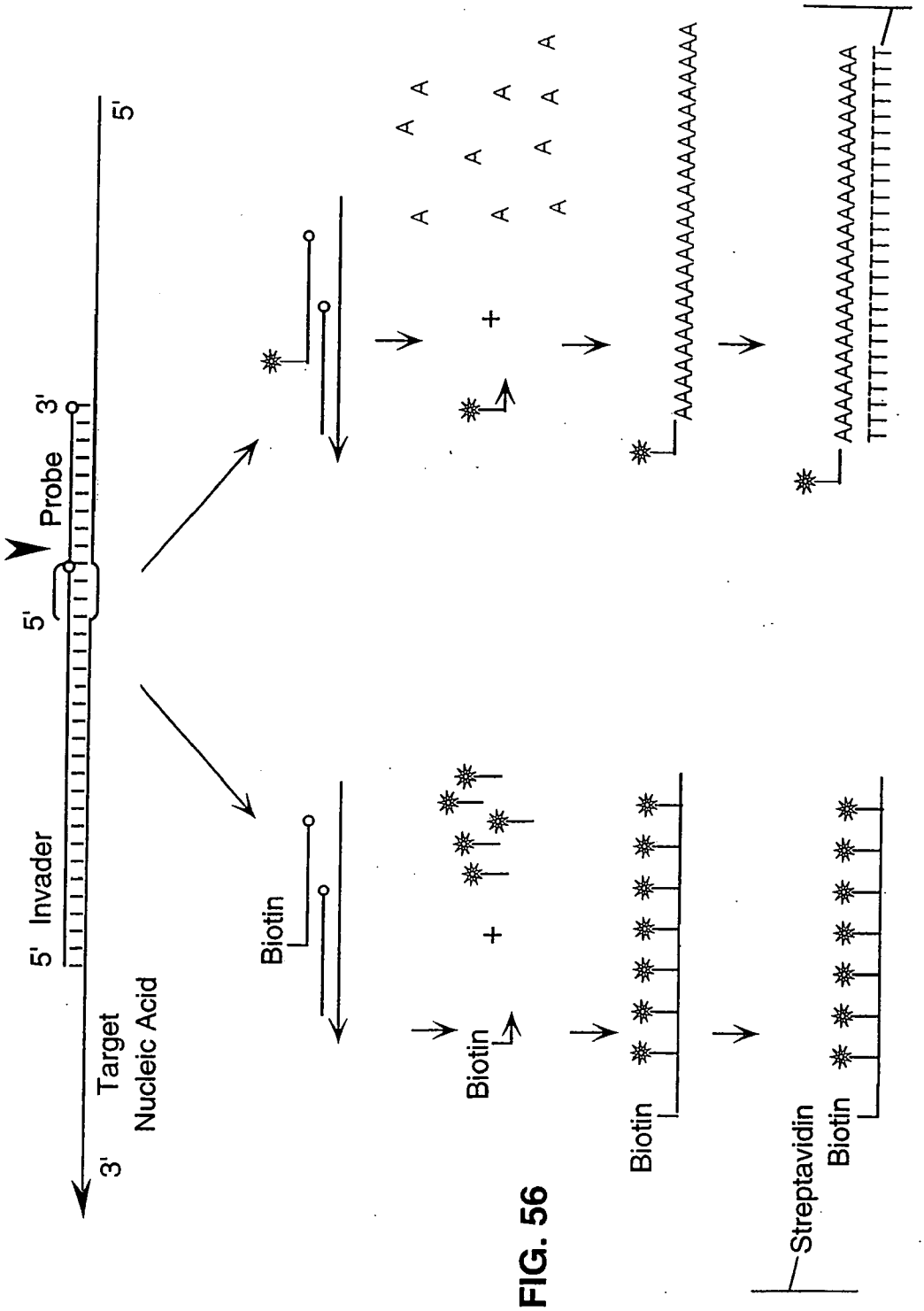

5'
3'
Probe
5'
5' Invader
Target
Nucleic Acid
3'
Biotin
Biotin
Biotin
Streptavidin
Biotin
A A A A A A A A A A A A
AAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAA
TTTTTTTTTTTTTTTTTTTTTTTTT

FIG. 56

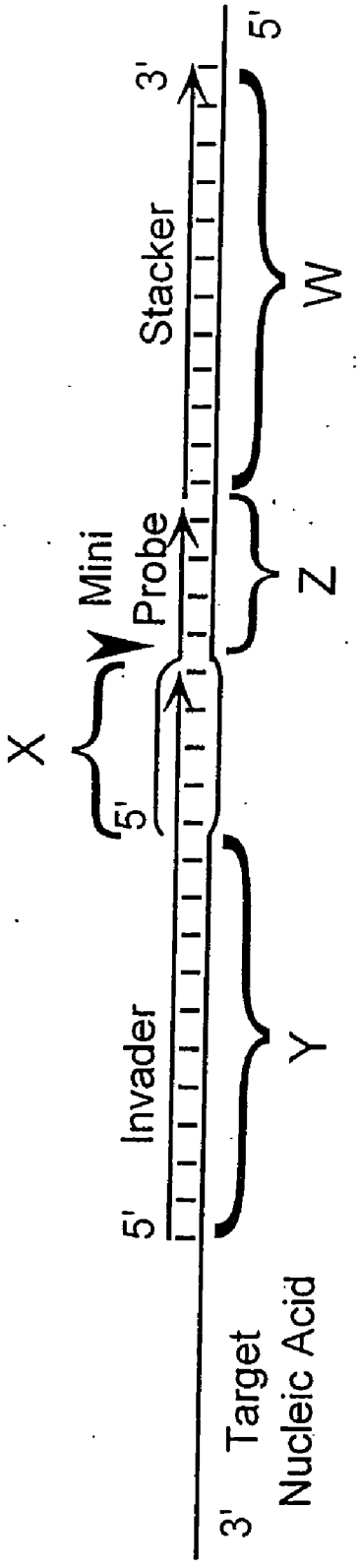


FIG. 57

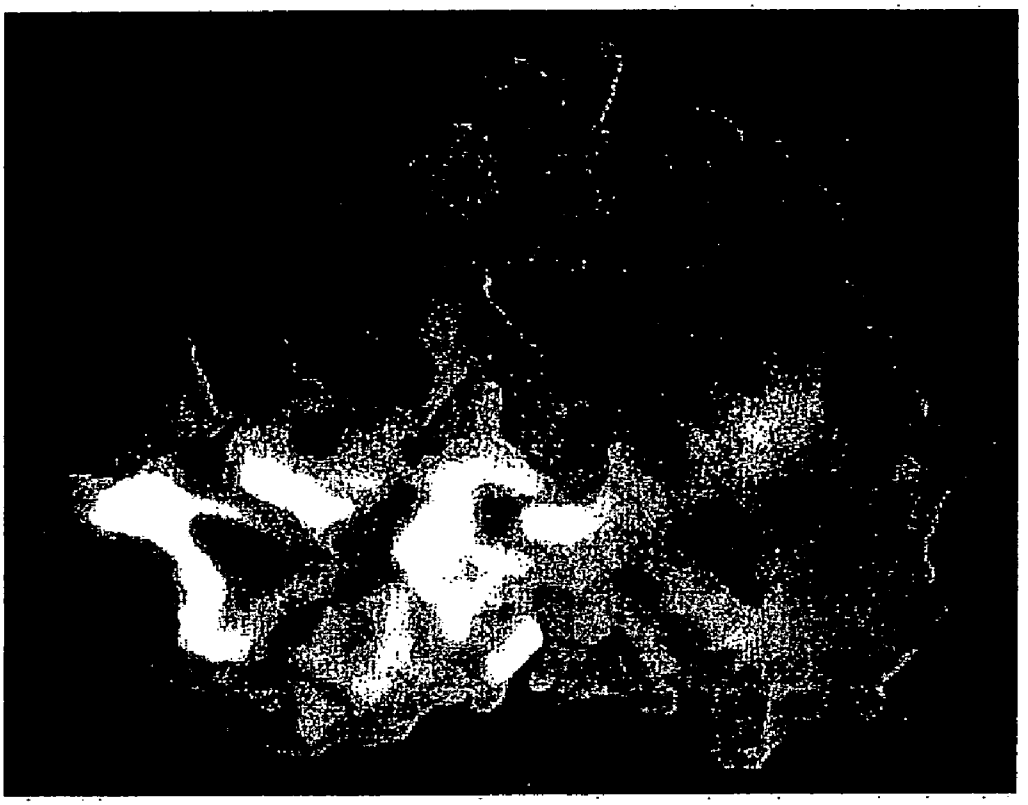


FIG. 58

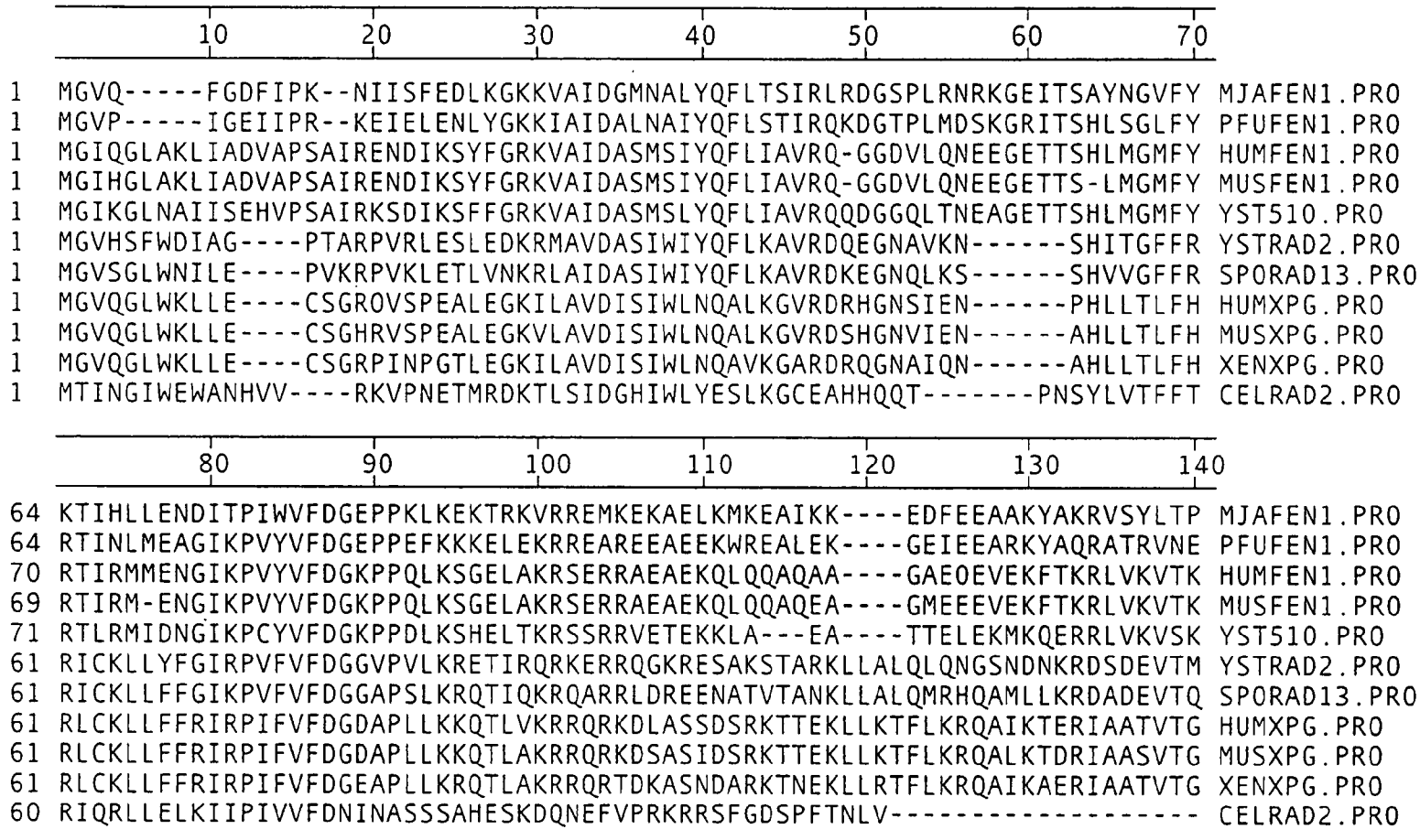

10 20 30 40 50 60 70
1 MGVQ-----FGDFIPK--NIISFEDLKGKKVAIDGMNALYQFLTSIRLRDGSPLRNRKGEITSAYNGVFY MJAFEN1.PRO
1 MGVP-----IGEIIPR--KEIELENLYGKKIAIDALNAIYQFLSTIRQKDGTPLMDSKGRITSHLSGLFY PFUFEN1.PRO
1 MGIQGLAKLIADVAPSAIRENDIKSYFGRKVAIDASMSIYQFLIAVRQ-GGDVLQNEEGETTSHLMGMFY HUMFEN1.PRO
1 MGIHGLAKLIADVAPSAIRENDIKSYFGRKVAIDASMSIYQFLIAVRQ-GGDVLQNEEGETTS-LMGMFY MUSFEN1.PRO
1 MGIKGLNAIISEHVPSAIRKSDIKSFFGRKVAIDASMSLYQFLIAVRQQDGGQLTNEAGETTSHLMGMFY YST510.PRO
1 MGVHSFWDIAG----PTARPVRLESLEDKRMAVDASIWIYQFLKAVRDQEGNAVKN------SHITGFFR YSTRAD2.PRO
1 MGVSGLWNILE----PVKRPVKLETLVNKRLAIDASIWIYQFLKAVRDKEGNQLKS------SHVVGFFR SPORAD13.PRO
1 MGVQGLWKLLE----CSGROVSPEALEGKILAVDISIWLNQALKGVRDRHGNSIEN------PHLLTLFH HUMXPG.PRO
1 MGVQGLWKLLE----CSGHRVSPEALEGKVLAVDISIWLNQALKGVRDSHGNVIEN------AHLLTLFH MUSXPG.PRO
1 MGVQGLWKLLE----CSGRPINPGTLEGKILAVDISIWLNQAVKGARDRQGNAIQN------AHLLTLFH XENXPG.PRO
1 MTINGIWEWANHVV----RKVPNETMRDKTLSIDGHIWLYESLKGCEAHHQQT-------PNSYLVTFFT CELRAD2.PRO
80 90 100 110 120 130 140
64 KTIHLLENDITPIWVFDGEPPKLKEKTRKVRREMKEKAELKMKEAIKK----EDFEEAAKYAKRVSYLTP MJAFEN1.PRO
64 RTINLMEAGIKPVYVFDGEPPEFKKKELEKRREAREEAEEKWREALEK----GEIEEARKYAQRATRVNE PFUFEN1.PRO
70 RTIRMMENGIKPVYVFDGKPPQLKSGELAKRSERRAEAEKQLQQAQAA----GAEQEVEKFTKRLVKVTK HUMFEN1.PRO
69 RTIRM-ENGIKPVYVFDGKPPQLKSGELAKRSERRAEAEKQLQQAQEA----GMEEEVEKFTKRLVKVTK MUSFEN1.PRO
71 RTLRMIDNGIKPCYVFDGKPPDLKSHELTKRSSRRVETEKKLA---EA----TTELEKMKQERRLVKVSK YST510.PRO
61 RICKLLYFGIRPVFVFDGGVPVLKRETIRQRKERRQGKRESAKSTARKLLALQLQNGSNDNKRDSDEVTM YSTRAD2.PRO
61 RICKLLFFGIKPVFVFDGGAPSLKRQTIQKRQARRLDREENATVTANKLLALQMRHQAMLLKRDADEVTQ SPORAD13.PRO
61 RLCKLLFFRIRPIFVFDGDAPLLKKQTLVKRRQRKDLASSDSRKTTEKLLKTFLKRQAIKTERIAATVTG HUMXPG.PRO
61 RLCKLLFFRIRPIFVFDGDAPLLKKQTLAKRRQRKDSASIDSRKTTEKLLKTFLKRQALKTDRIAASVTG MUSXPG.PRO
61 RLCKLLFFRIRPIFVFDGEAPLLKRQTLAKRRQRTDKASNDARKTNEKLLRTFLKRQAIKAERIAATVTG XENXPG.PRO
60 RIQRLLELKIIPIVVFDNINASSSAHESKDQNEFVPRKRRSFGDSPFTNLV------------------ CELRAD2.PRO

FIG. 59A

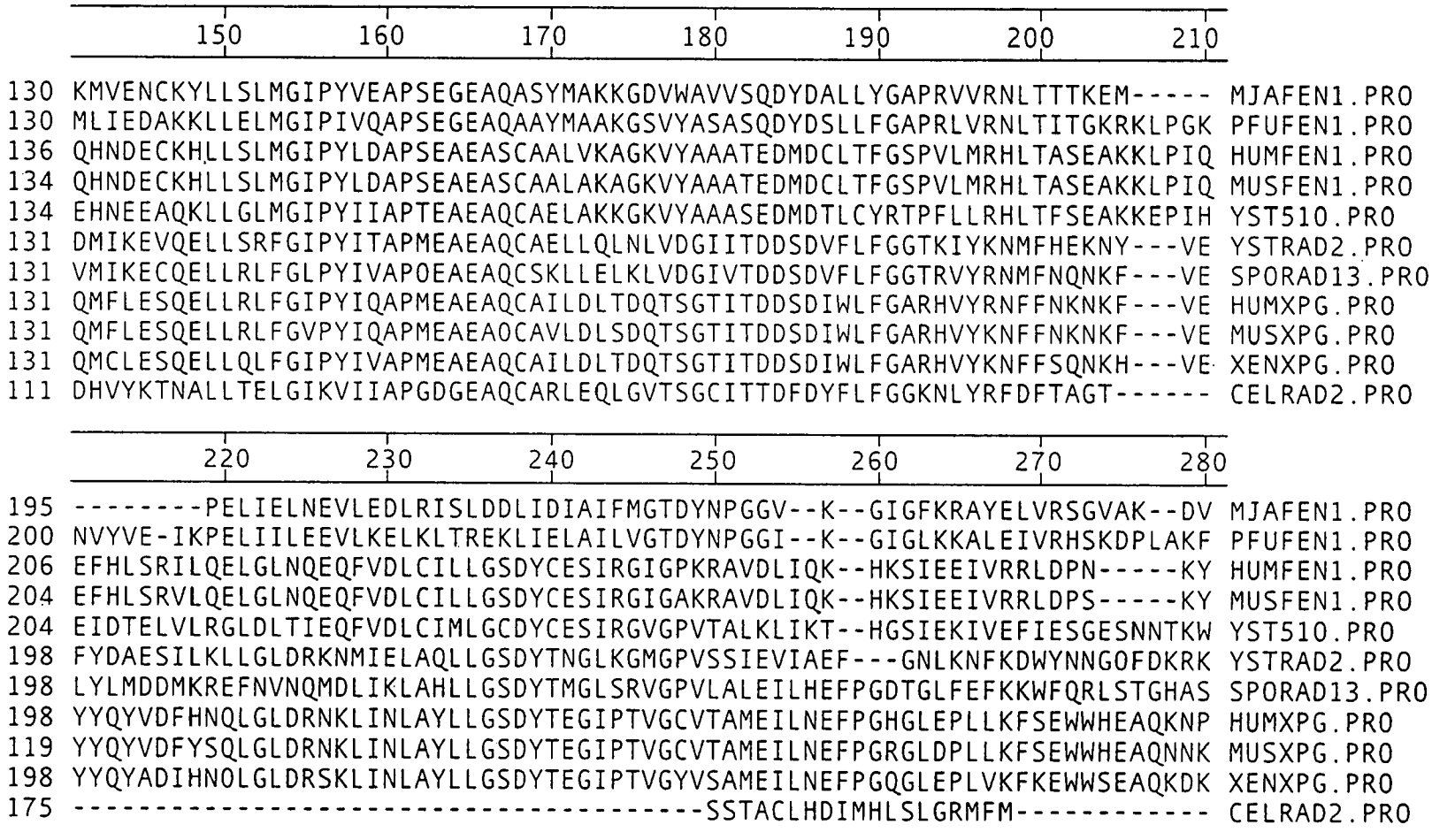

150 160 170 180 190 200 210
130 KMVENCKYLLSLMGIPYVEAPSEGEAQASYMAKKGDVWAVVSQDYDALLYGAPRVVRNLTTTKEM----- MJAFEN1.PRO
130 MLIEDAKKLLELMGIPIVQAPSEGEAQAAYMAAKGSVYASASQDYDSLLFGAPRLVRNLTITGKRKLPGK PFUFEN1.PRO
136 QHNDECKHLLSLMGIPYLDAPSEAEASCAALVKAGKVYAAATEDMDCLTFGSPVLMRHLTASEAKKLPIQ HUMFEN1.PRO
134 QHNDECKHLLSLMGIPYLDAPSEAEASCAALAKAGKVYAAATEDMDCLTFGSPVLMRHLTASEAKKLPIQ MUSFEN1.PRO
134 EHNEEAQKLLGLMGIPYIIAPTEAEAQCAELAKKGKVYAAASEDMDTLCYRTPFLLRHLTFSEAKKEPIH YST510.PRO
131 DMIKEVQELLSRFGIPYITAPMEAEAQCAELLQLNLVDGIITDDSDVFLFGGTKIYKNMFHEKNY---VE YSTRAD2.PRO
131 VMIKECQELLRLFGLPYIVAPQEAEAQCSKLLELKLVDGIVTDDSDVFLFGGTRVYRNMFNQNKF---VE SPORAD13.PRO
131 QMFLESQELLRLFGIPYIQAPMEAEAQCAILDLTDQTSGTITDDSDIWLFGARHVYRNFFNKNKF---VE HUMXPG.PRO
131 QMFLESQELLRLFGVPYIQAPMEAEAQCAVLDLSDQTSGTITDDSDIWLFGARHVYKNFFNKNKF---VE MUSXPG.PRO
131 QMCLESQELLQLFGIPYIVAPMEAEAQCAILDLTDQTSGTITDDSDIWLFGARHVYKNFFSQNKH---VE XENXPG.PRO
111 DHVYKTNALLTELGIKVIIAPGDGEAQCARLEQLGVTSGCITTDFDYFLFGGKNLYRFDFTAGT------ CELRAD2.PRO
220 230 240 250 260 270 280
195 --------PELIELNEVLEDLRISLDDLIDIAIFMGTDYNPGGV--K--GIGFKRAYELVRSGVAK--DV MJAFEN1.PRO
200 NVYVE-IKPELIILEEVLKELKLTREKLIELAILVGTDYNPGGI--K--GIGLKKALEIVRHSKDPLAKF PFUFEN1.PRO
206 EFHLSRILQELGLNQEQFVDLCILLGSDYCESIRGIGPKRAVDLIQK--HKSIEEIVRRLDPN-----KY HUMFEN1.PRO
204 EFHLSRVLQELGLNQEQFVDLCILLGSDYCESIRGIGAKRAVDLIQK--HKSIEEIVRRLDPS-----KY MUSFEN1.PRO
204 EIDTELVLRGLDLTIEQFVDLCIMLGCDYCESIRGVGPVTALKLIKT--HGSIEKIVEFIESGESNNTKW YST510.PRO
198 FYDAESILKLLGLDRKNMIELAQLLGSDYTNGLKGMGPVSSIEVIAEF---GNLKNFKDWYNNGQFDKRK YSTRAD2.PRO
198 LYLMDDMKREFNVNQMDLIKLAHLLGSDYTMGLSRVGPVLALEILHEFPGDTGLFEFKKWFQRLSTGHAS SPORAD13.PRO
198 YYQYVDFHNQLGLDRNKLINLAYLLGSDYTEGIPTVGCVTAMEILNEFPGHGLEPLLKFSEWWHEAQKNP HUMXPG.PRO
119 YYQYVDFYSQLGLDRNKLINLAYLLGSDYTEGIPTVGCVTAMEILNEFPGRGLDPLLKFSEWWHEAQNNK MUSXPG.PRO
198 YYQYADIHNQLGLDRSKLINLAYLLGSDYTEGIPTVGYVSAMEILNEFPGQGLEPLVKFKEWWSEAQKDK XENXPG.PRO
175 ----------SSTACLHDIMHLSLGRMFM---------- CELRAD2.PRO

FIG. 59B

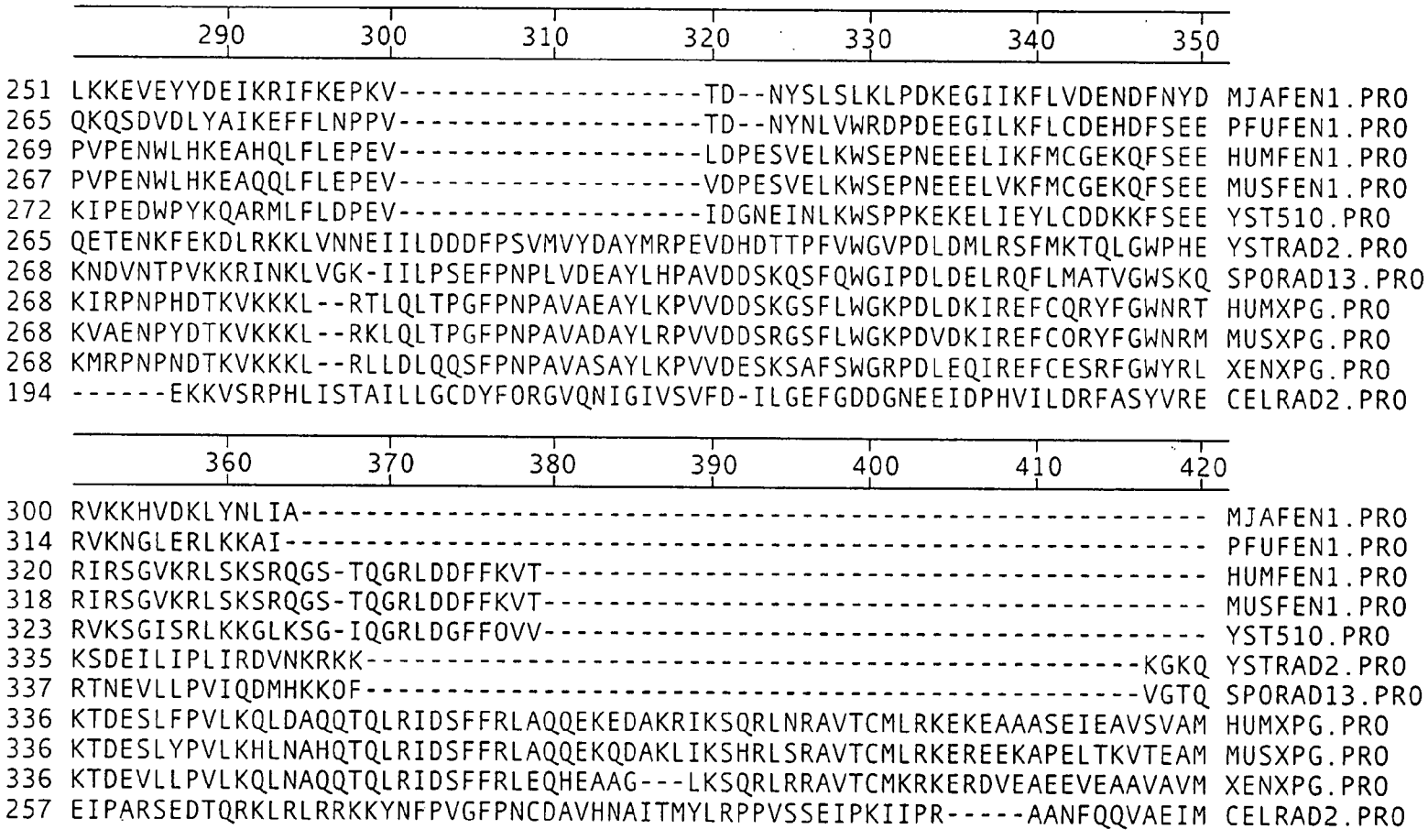

290 300 310 320 330 340 350
251 LKKEVEYYDEIKRIFKEPKV----------TD--NYSLSLKLPDKEGIIKFLVDENDFNYD MJAFEN1.PRO
265 QKQSDVDLYAIKEFFLNPPV----------TD--NYNLVWRDPDEEGILKFLCDEHDFSEE PFUFEN1.PRO
269 PVPENWLHKEAHQLFLEPEV----------LDPESVELKWSEPNEEELIKFMCGEKQFSEE HUMFEN1.PRO
267 PVPENWLHKEAQQLFLEPEV----------VDPESVELKWSEPNEEELVKFMCGEKQFSEE MUSFEN1.PRO
272 KIPEDWPYKQARMLFLDPEV----------IDGNEINLKWSPPKEKELIEYLCDDKKFSEE YST510.PRO
265 QETENKFEKDLRKKLVNNEIILDDDFPSVMVYDAYMRPEVDHDTTPFVWGVPDLDMLRSFMKTQLGWPHE YSTRAD2.PRO
268 KNDVNTPVKKRINKLVGK-IILPSEFPNPLVDEAYLHPAVDDSKQSFQWGIPDLDELRQFLMATVGWSKQ SPORAD13.PRO
268 KIRPNPHDTKVKKKL--RTLQLTPGFPNPAVAEAYLKPVVDDSKGSFLWGKPDLDKIREFCQRYFGWNRT HUMXPG.PRO
268 KVAENPYDTKVKKKL--RKLQLTPGFPNPAVADAYLRPVVDDSRGSFLWGKPDVDKIREFCORYFGWNRM MUSXPG.PRO
268 KMRPNPNDTKVKKKL--RLLDLQQSFPNPAVASAYLKPVVDESKSAFSWGRPDLEQIREFCESRFGWYRL XENXPG.PRO
194 ------EKKVSRPHLISTAILLGCDYFORGVQNIGIVSVFD-ILGEFGDDGNEEIDPHVILDRFASYVRE CELRAD2.PRO
360 370 380 390 400 410 420
300 RVKKHVDKLYNLIA---------- MJAFEN1.PRO
314 RVKNGLERLKKAI---------- PFUFEN1.PRO
320 RIRSGVKRLSKSRQGS-TQGRLDDFFKVT---------- HUMFEN1.PRO
318 RIRSGVKRLSKSRQGS-TQGRLDDFFKVT---------- MUSFEN1.PRO
323 RVKSGISRLKKGLKSG-IQGRLDGFFOVV---------- YST510.PRO
335 KSDEILIPLIRDVNKRKK----------KGKQ YSTRAD2.PRO
337 RTNEVLLPVIQDMHKKOF----------VGTQ SPORAD13.PRO
336 KTDESLFPVLKQLDAQQTQLRIDSFFRLAQQEKEDAKRIKSQRLNRAVTCMLRKEKEAAASEIEAVSVAM HUMXPG.PRO
336 KTDESLYPVLKHLNAHQTQLRIDSFFRLAQQEKQDAKLIKSHRLSRAVTCMLRKEREEKAPELTKVTEAM MUSXPG.PRO
336 KTDEVLLPVLKQLNAQQTQLRIDSFFRLEQHEAAG---LKSQRLRRAVTCMKRKERDVEAEEVEAAVAVM XENXPG.PRO
257 EIPARSEDTQRKLRLRRKKYNFPVGFPNCDAVHNAITMYLRPPVSSEIPKIIPR-----AANFQQVAEIM CELRAD2.PRO

FIG. 59C

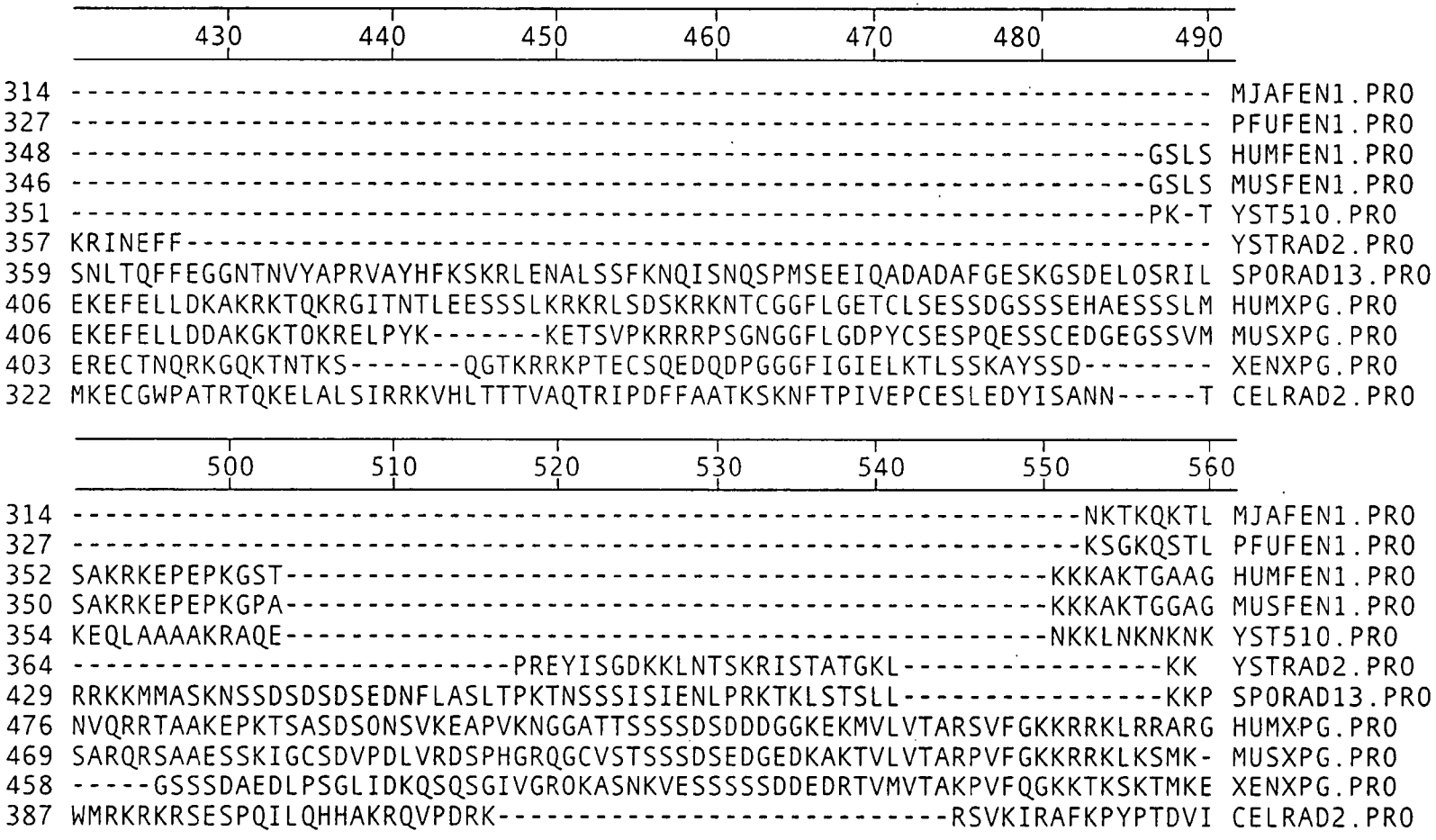

430 440 450 460 470 480 490
314 ---------- MJAFEN1.PRO
327 ---------- PFUFEN1.PRO
348 ----------GSLS HUMFEN1.PRO
346 ----------GSLS MUSFEN1.PRO
351 ----------PK-T YST510.PRO
357 KRINEFF---------- YSTRAD2.PRO
359 SNLTQFFEGGNTNVYAPRVAYHFKSKRLENALSSFKNQISNQSPMSEEIQADADAFGESKGSDELOSRIL SPORAD13.PRO
406 EKEFELLDKAKRKTQKRGITNTLEESSSLKRKRLSDSKRKNTCGGFLGETCLSESSDGSSSEHAESSSLM HUMXPG.PRO
406 EKEFELLDDAKGKTOKRELPYK-------KETSVPKRRRPSGNGGFLGDPYCSESPQESSCEDGEGSSVM MUSXPG.PRO
403 ERECTNQRKGQKTNTKS-------QGTKRRKPTECSQEDQDPGGGFIGIELKTLSSKAYSSD-------- XENXPG.PRO
322 MKECGWPATRTQKELALSIRRKVHLTTTVAQTRIPDFFAATKSKNFTPIVEPCESLEDYISANN-----T CELRAD2.PRO
500 510 520 530 540 550 560
314 ----------NKTKQKTL MJAFEN1.PRO
327 ----------KSGKQSTL PFUFEN1.PRO
352 SAKRKEPEPKGST----------KKKAKTGAAG HUMFEN1.PRO
350 SAKRKEPEPKGPA----------KKKAKTGGAG MUSFEN1.PRO
354 KEQLAAAAKRAQE----------NKKLNKNKNK YST510.PRO
364 ----------PREYISGDKKLNTSKRISTATGKL----------KK YSTRAD2.PRO
429 RRKKMMASKNSSDSDSDSEDNFLASLTPKTNSSSISIENLPRKTKLSTSLL----------KKP SPORAD13.PRO
476 NVQRRTAAKEPKTSASDSONSVKEAPVKNGGATTSSSSDSDDDGGKEKMVLVTARSVFGKKRRKLRRARG HUMXPG.PRO
469 SARQRSAAESSKIGCSDVPDLVRDSPHGRQGCVSTSSSDSEDGEDKAKTVLVTARPVFGKKRRKLKSMK- MUSXPG.PRO
458 -----GSSSDAEDLPSGLIDKQSQSGIVGROKASNKVESSSSSDDEDRTVMVTAKPVFQGKKTKSKTMKE XENXPG.PRO
387 WMRKRKRSESPQILQHHAKRQVPDRK----------RSVKIRAFKPYPTDVI CELRAD2.PRO

FIG. 59D

```
MJAFEN1.PRO
PFUFEN1.PRO
HUMFEN1.PRO
MUSFEN1.PRO
YST510.PRO
YSTRAD2.PRO
SPORAD13.PRO
HUMXPG.PRO
MUSXPG.PRO
XENXPG.PRO
CELRAD2.PRO
```

```
322 DAWFKZ
335 ESWFKR
375 KFKRGK
373 KFRRGK
377 VTKGRR
390 ---RKM
483 SKRRRK
546 RKRKTZ
538 RRKKKT
523 TVKRK
429 ELGDSD
```

FIG. 59E

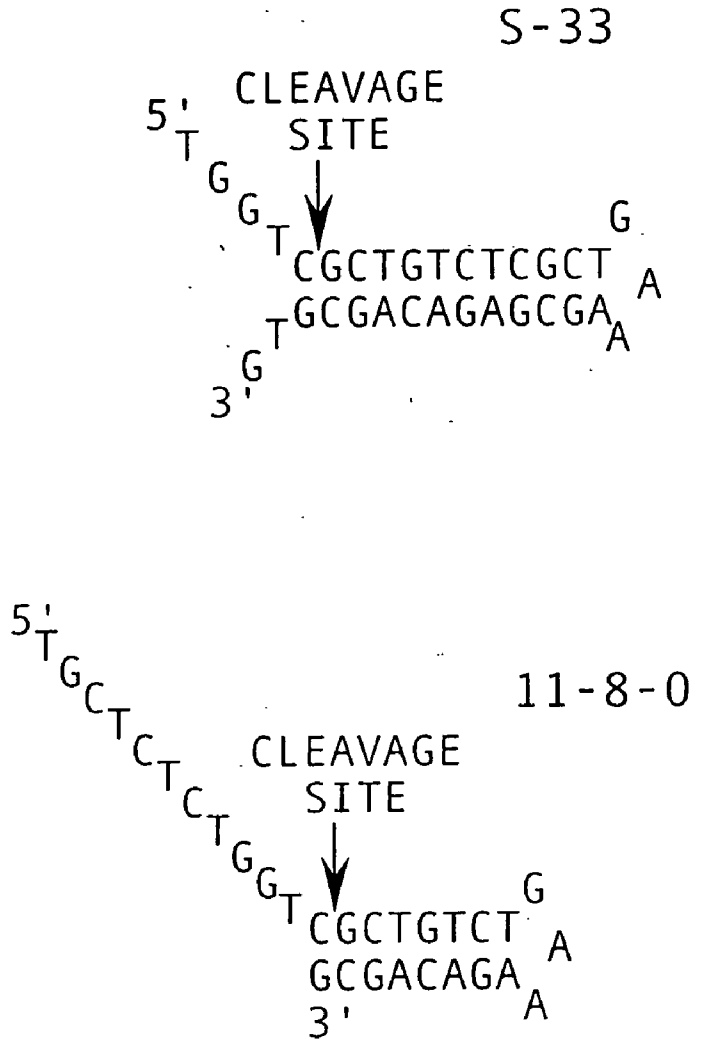

S-33
CLEAVAGE
SITE
5'
T
G
G
T
CGCTGTCTCGCT
G
A
GCGACAGAGCGA
T
A
G
3'
5'
T
G
C
T
C
T
C
T
G
G
T
11-8-0
CLEAVAGE
SITE
CGCTGTCT
G
A
GCGACAGA
A
3'

FIG. 60

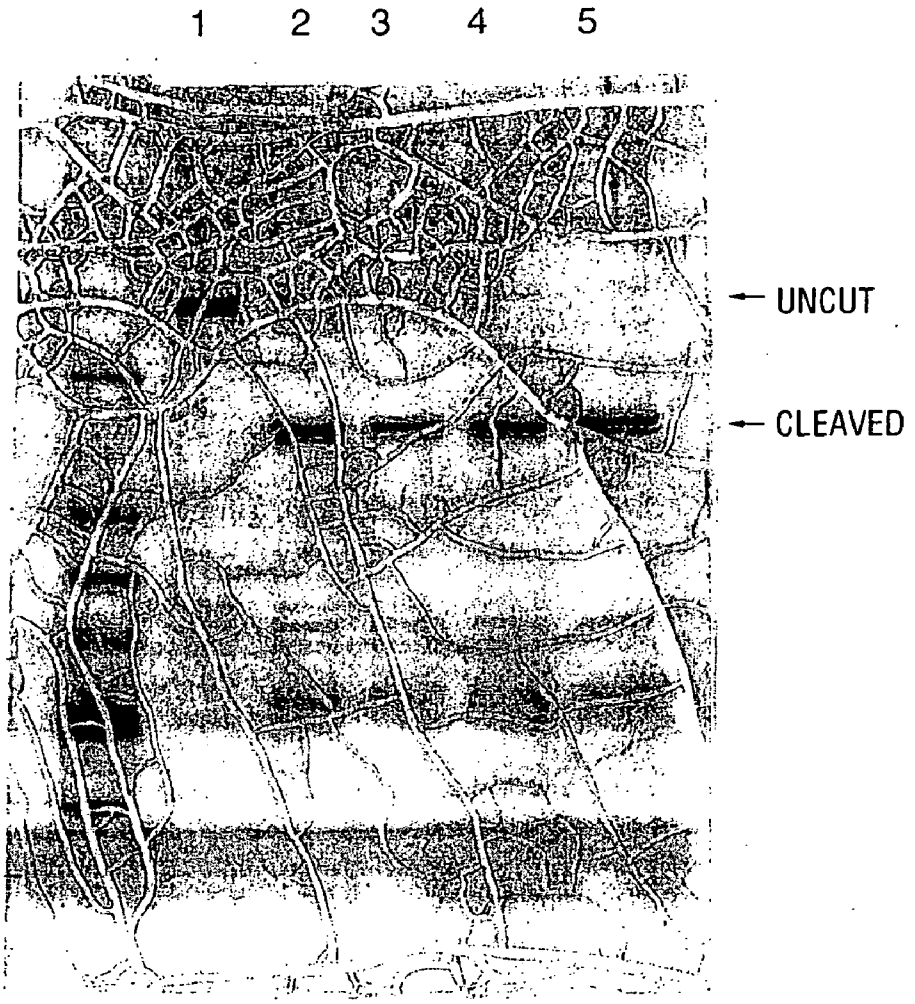


FIG. 61

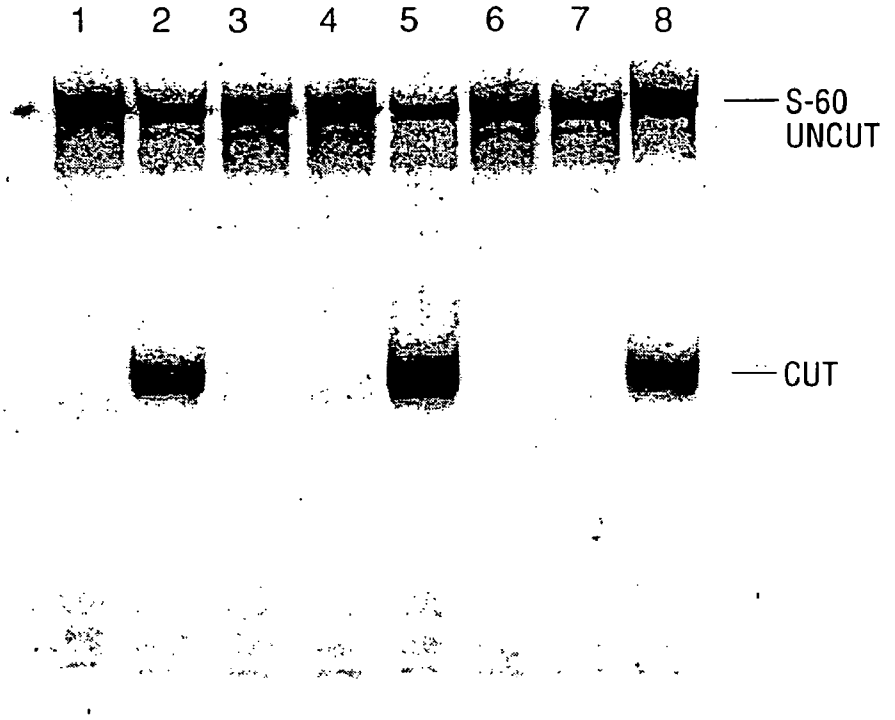


FIG. 62

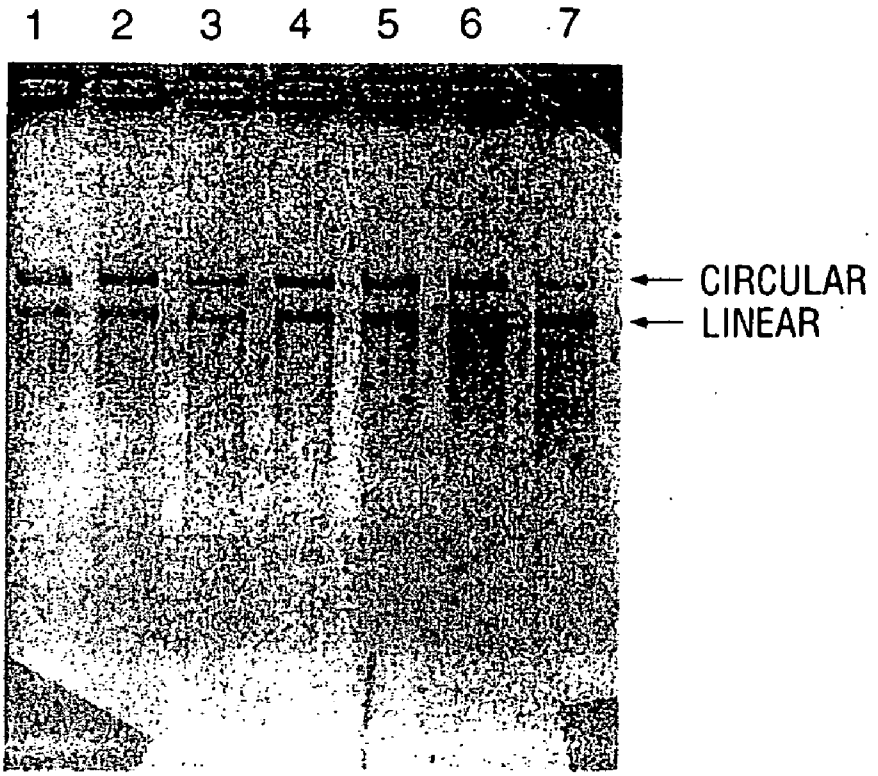


FIG. 63

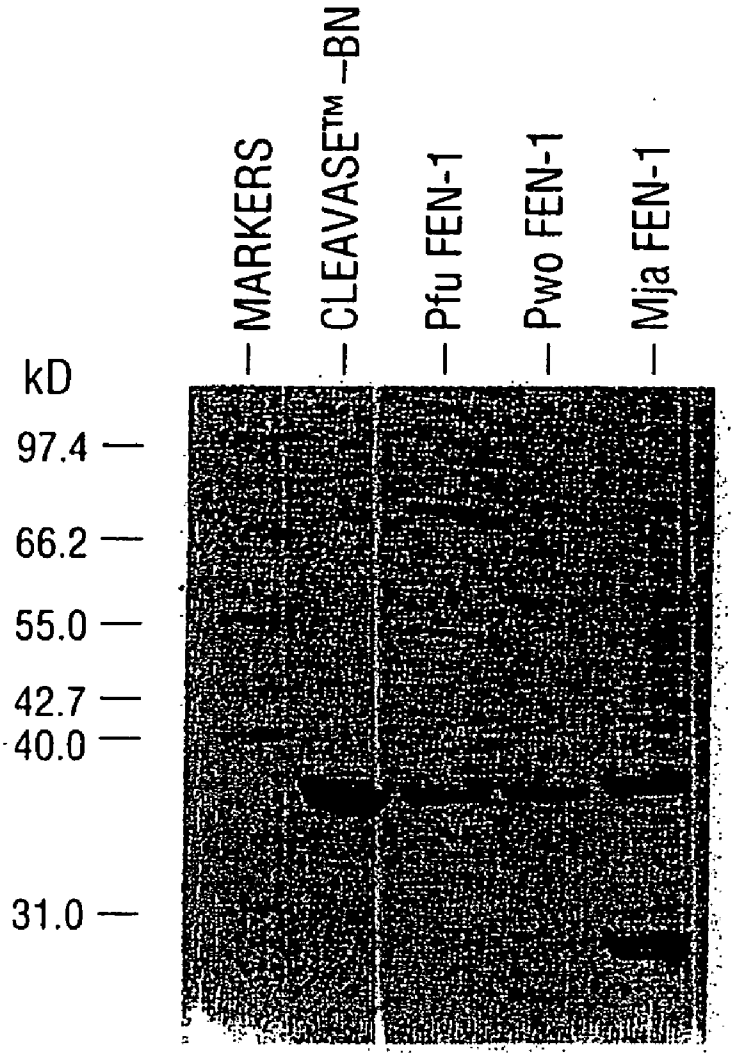

MARKERS
CLEAVASE™ -BN
Pfu FEN-1
Pwo FEN-1
Mja FEN-1
kD
97.4
66.2
55.0
42.7
40.0
31.0

FIG. 64

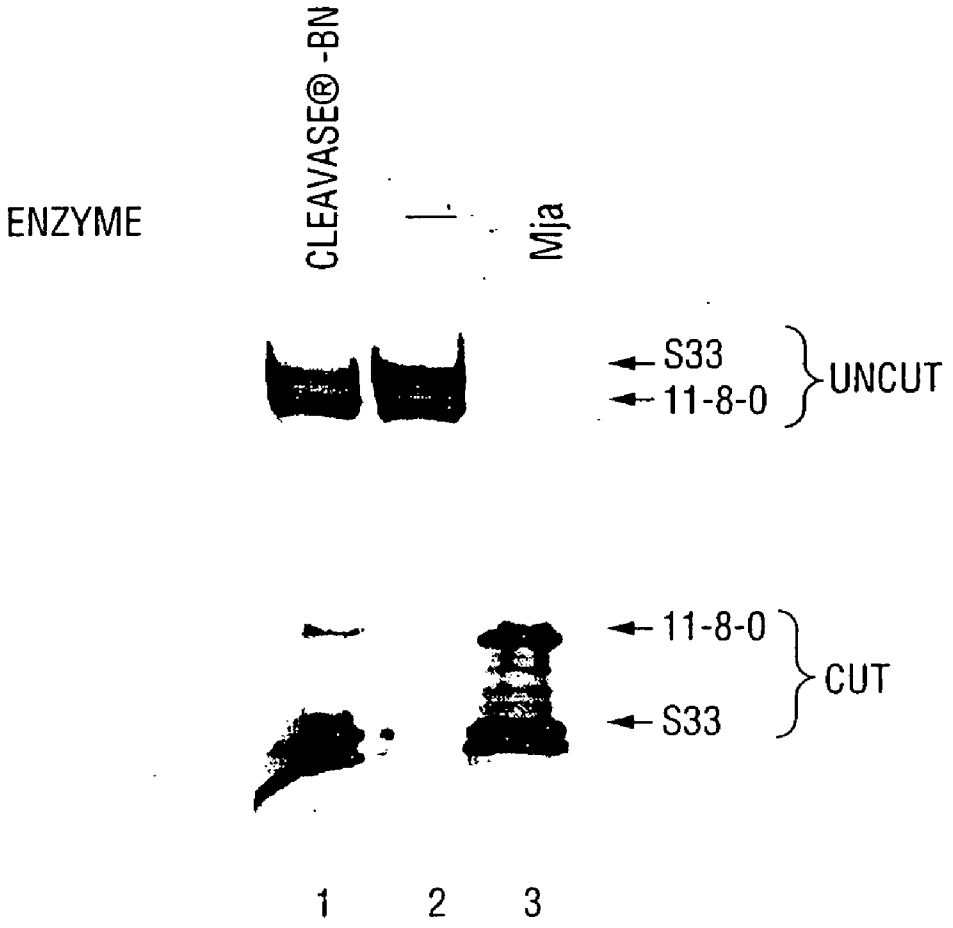
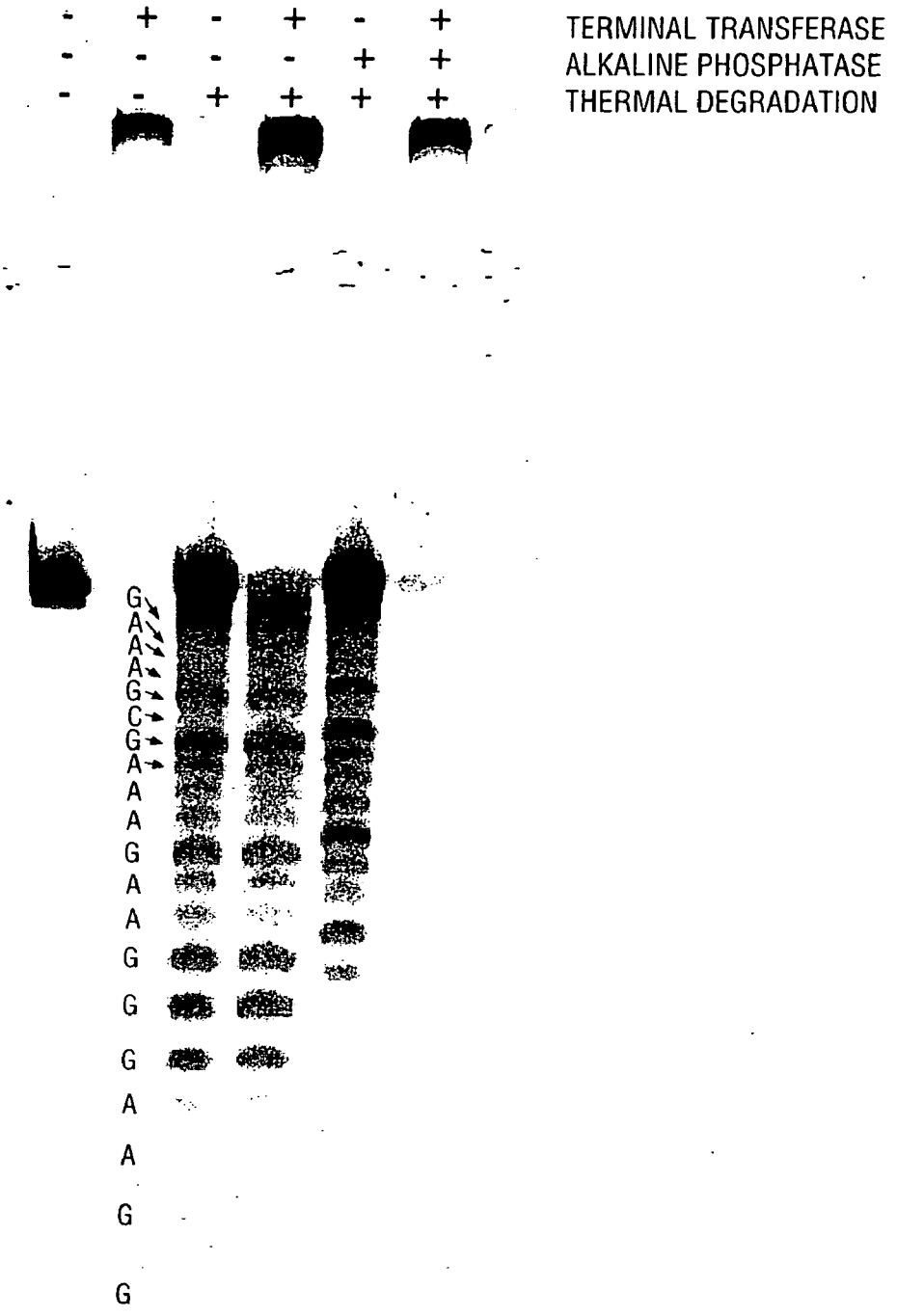


FIG. 65



5'-nAGAAAggaagggaagaaagcgaaagG-3'

FIG. 66

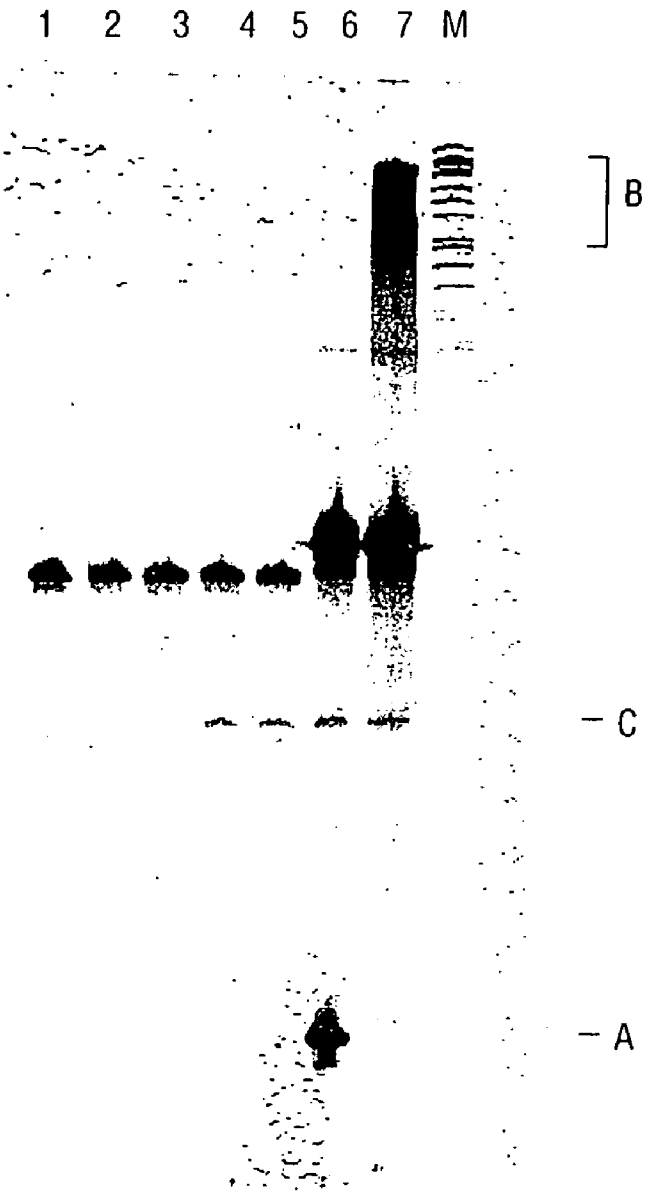


FIG. 67

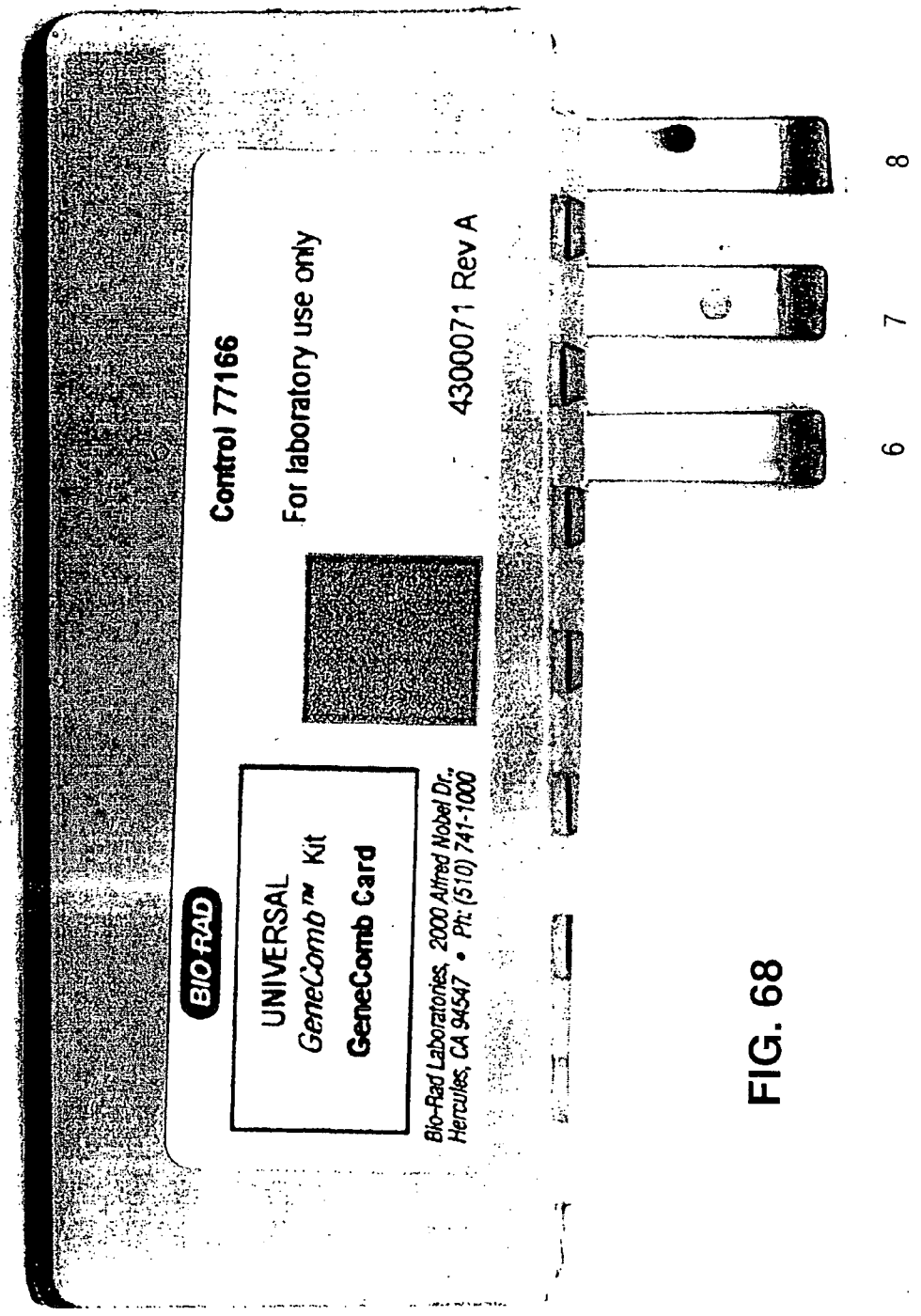

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Hercules, CA 94547 • Ph: (510) 741-1000
6
7
8

FIG. 68

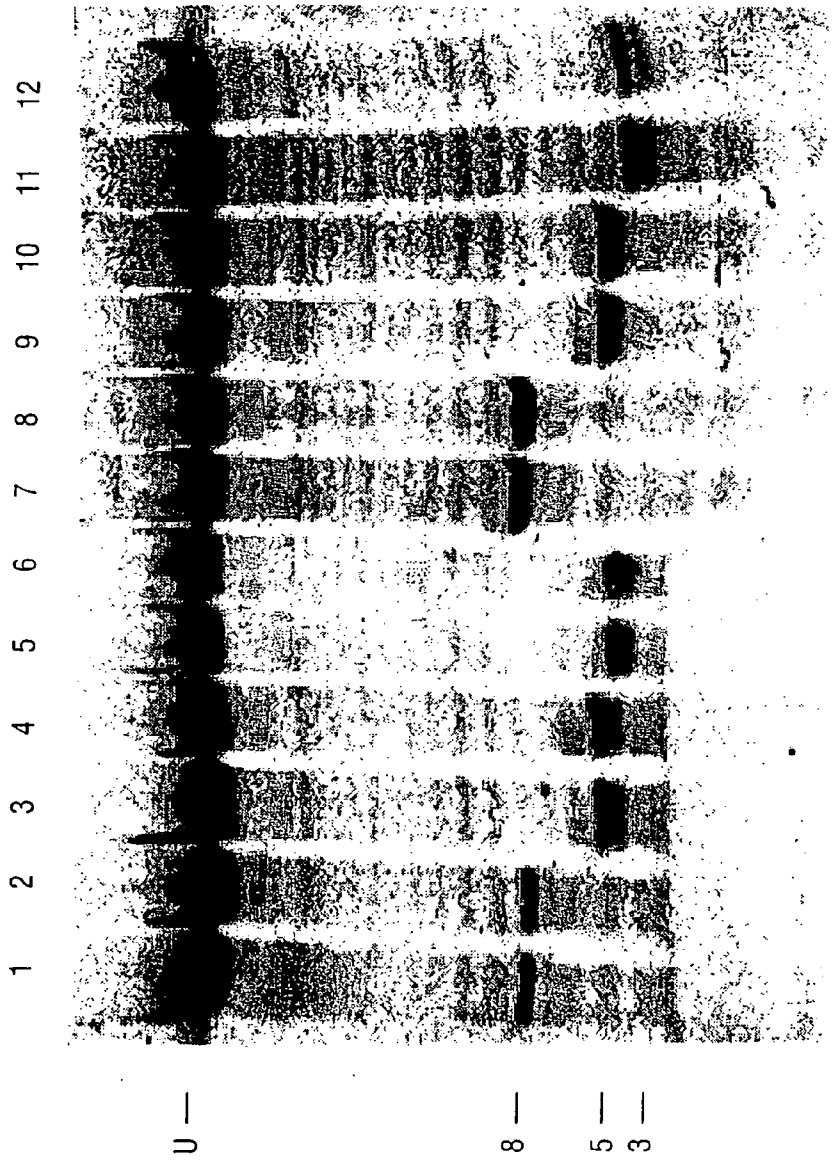


FIG. 69

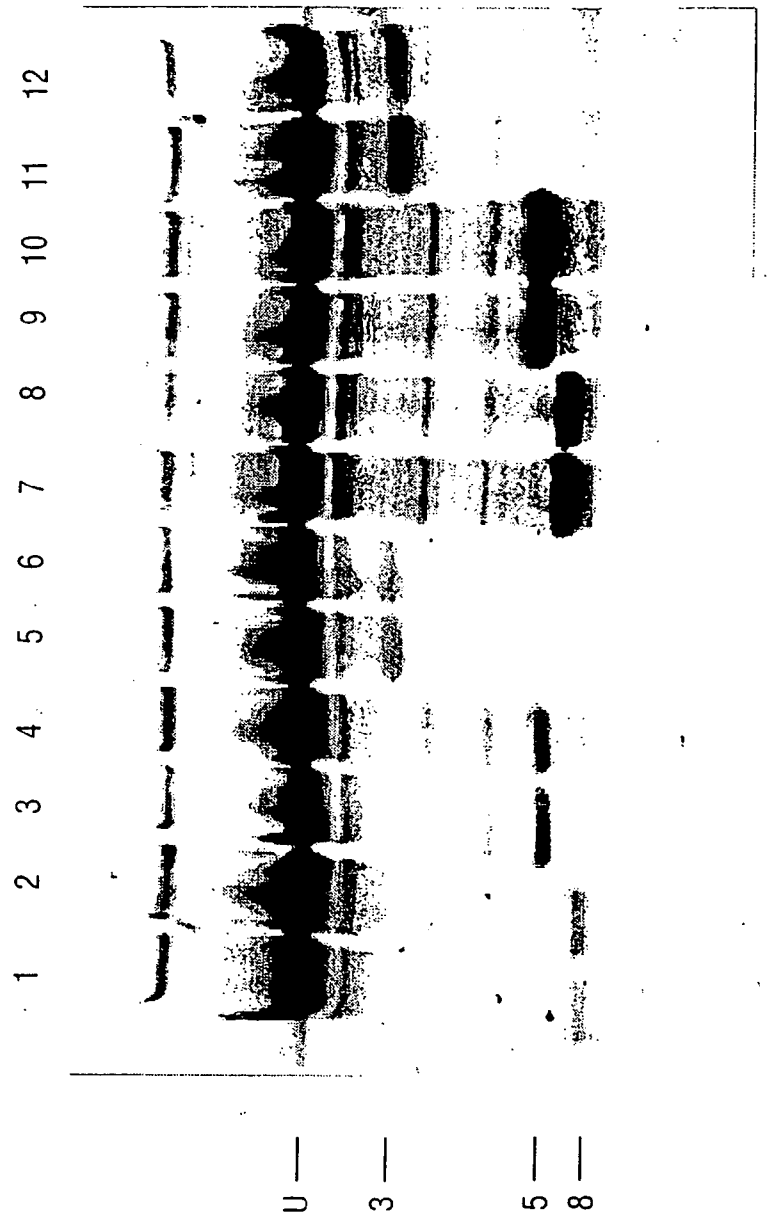


FIG. 70

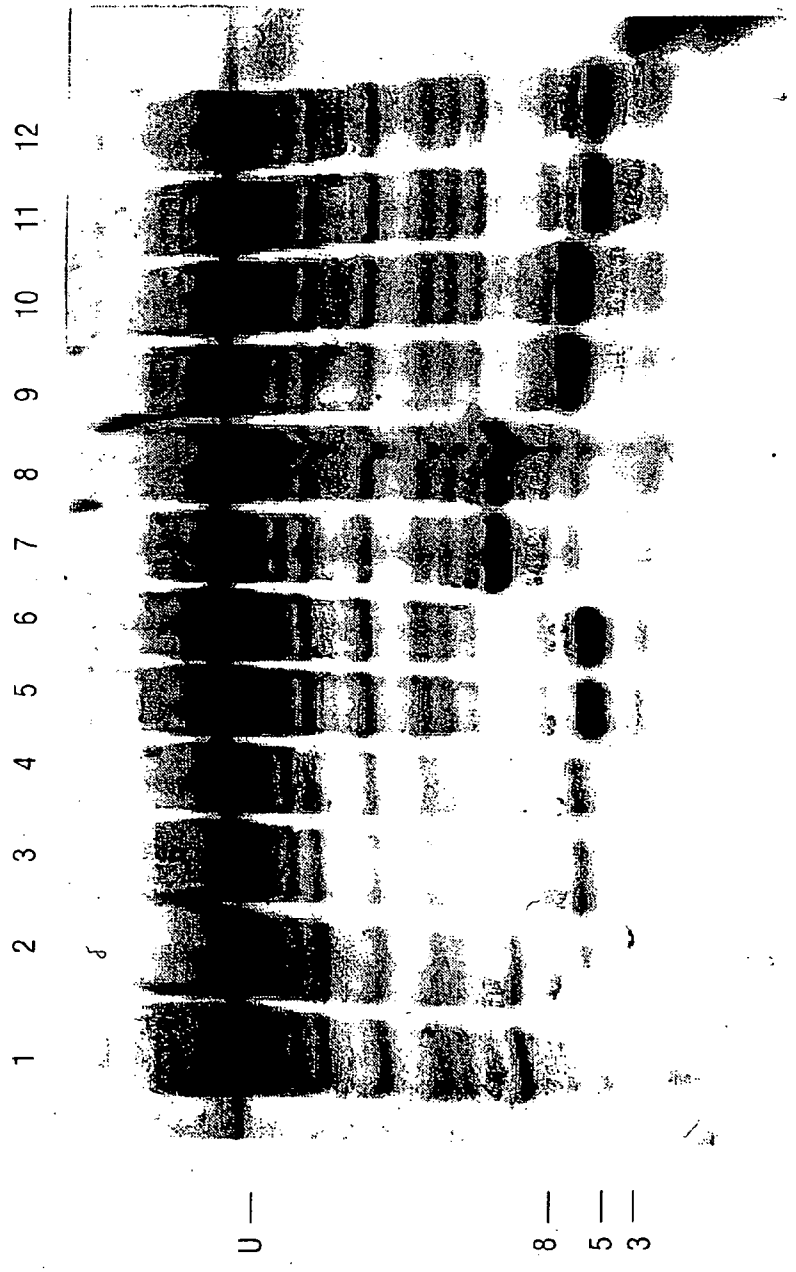


FIG. 71

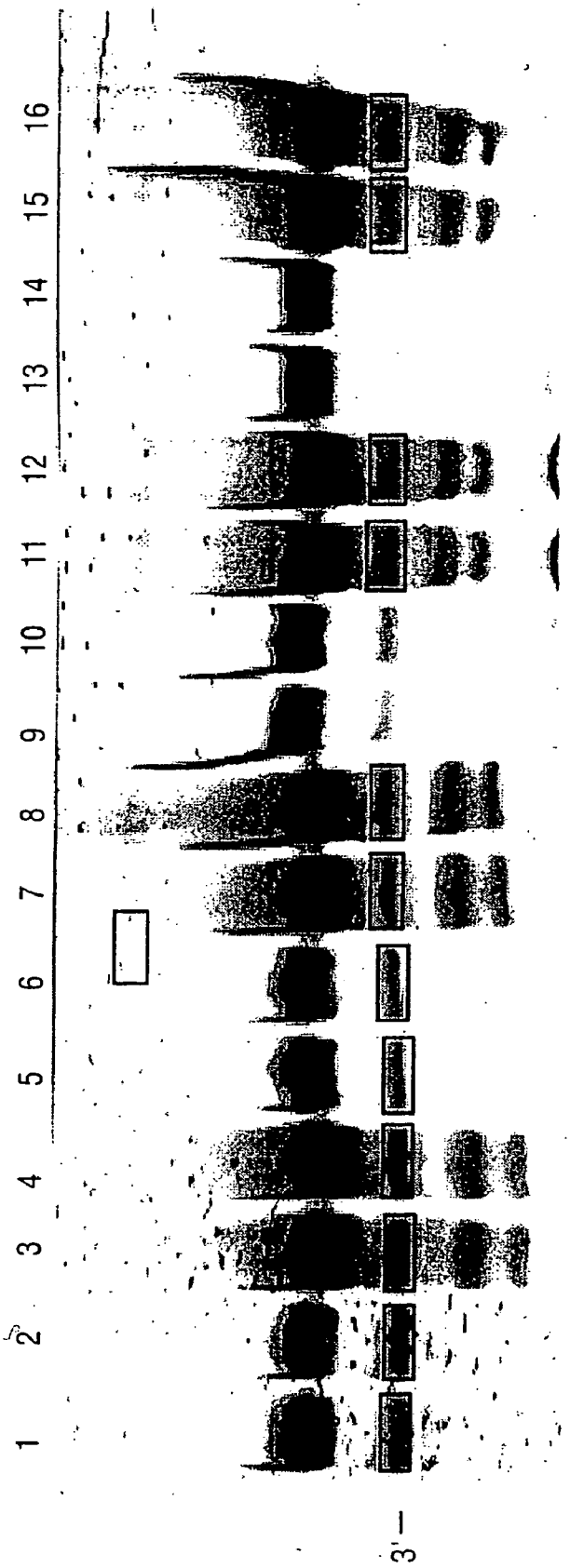


FIG. 72A

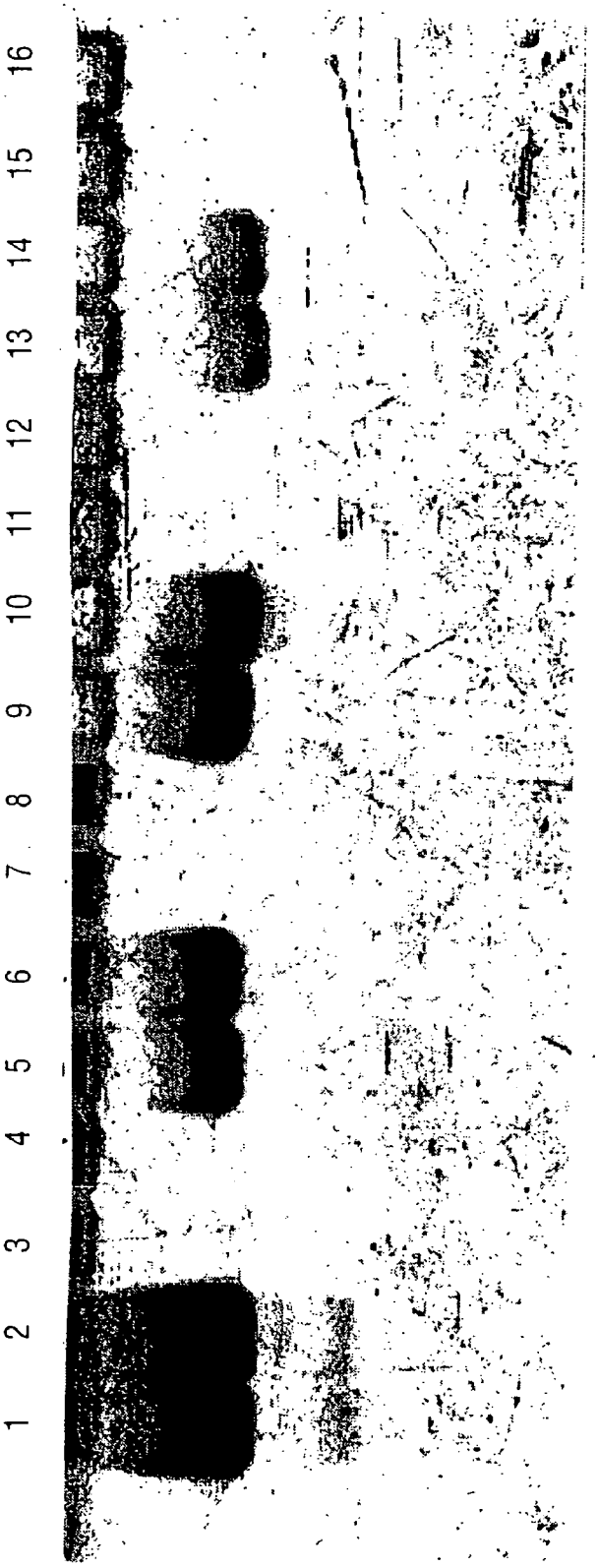
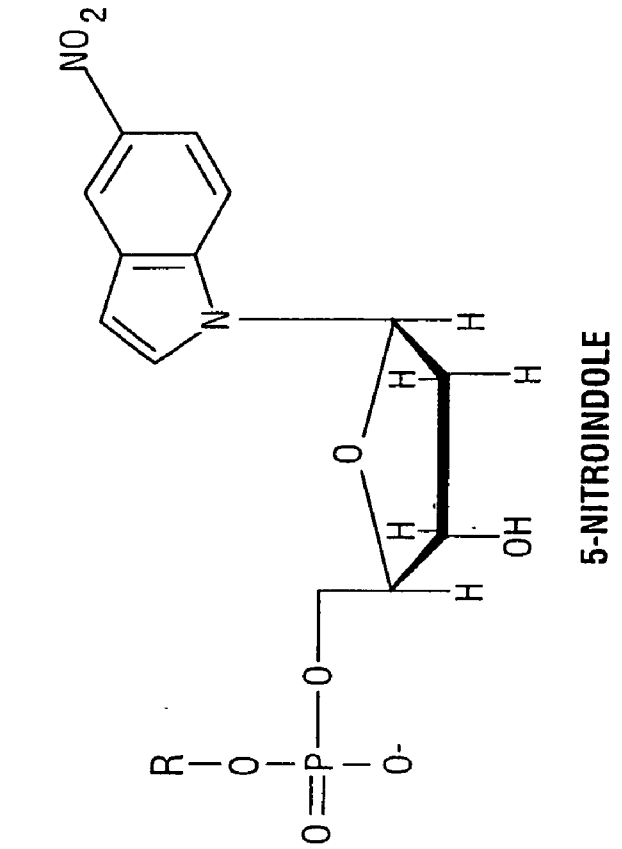
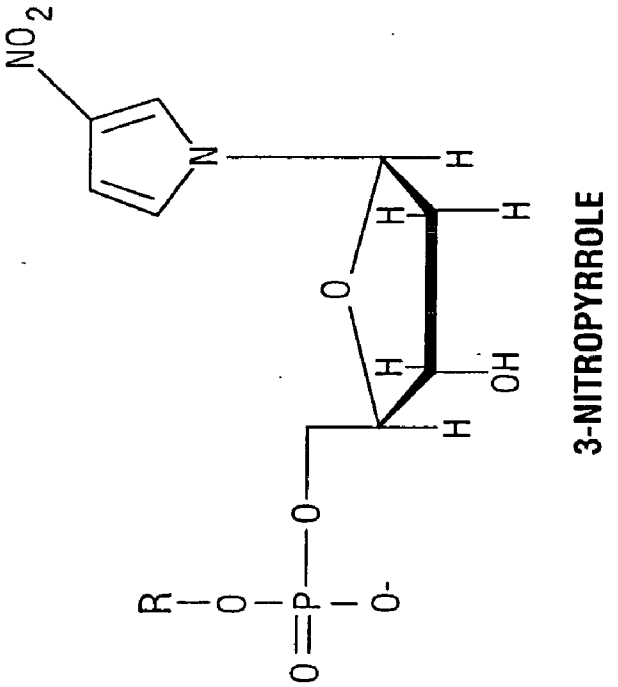


FIG. 72B



5-NITROINDOLE



3-NITROPYRROLE

FIG. 73

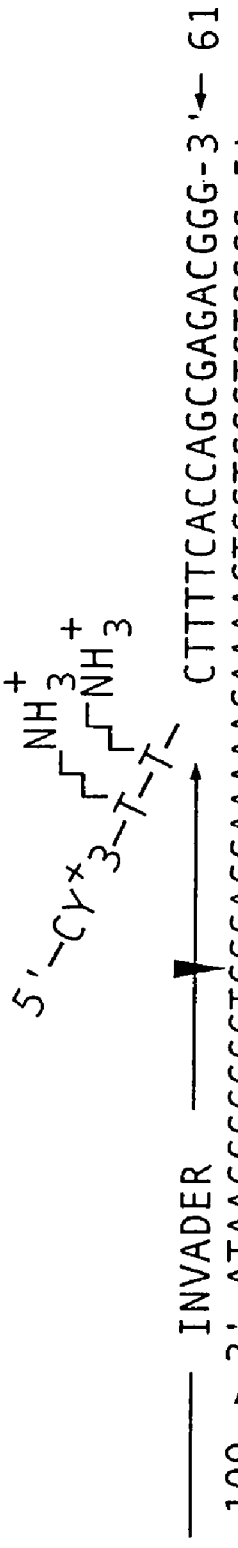

5'-Cy x
3-T-T-
NH3+
NH3+
CTTTTCACCAGCGAGACGGG-3' ← 61
INVADER
109 → 3'-ATAACCCGCGGTCCCACCAAAAAGAAAAGTGGTCGCTCTGCCC-5'
0987654321098765432 1
123456789
TATTGGGCGCCAGGGTGGTTTTT
TATTGGGCGXCAMGGXGGTTTTT
X = 5-nitoindole or 3-nitropyrole
M = mutation site

FIG. 74

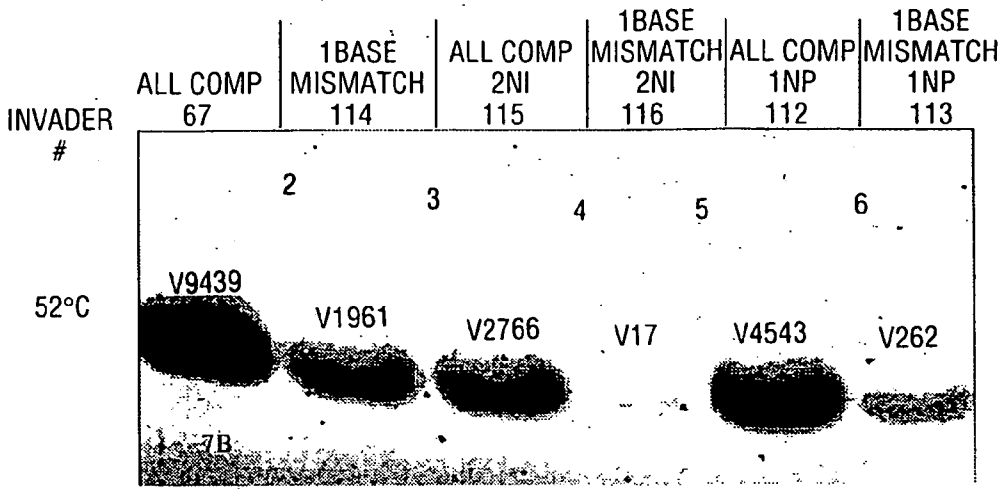


FIG. 75A

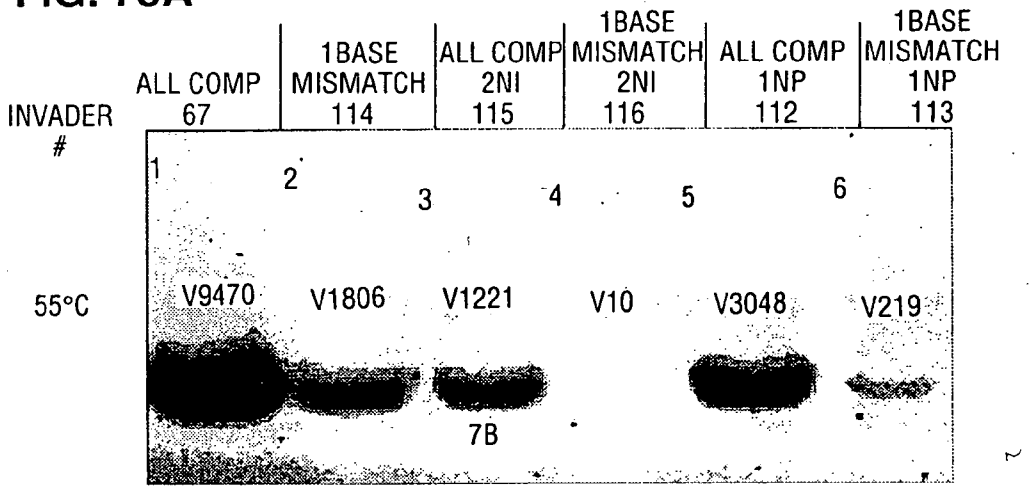


FIG. 75B

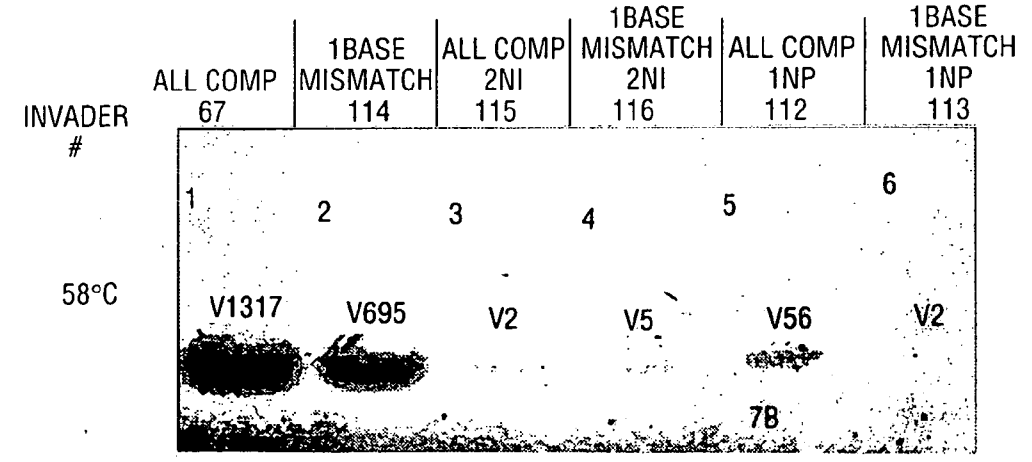


FIG. 75C

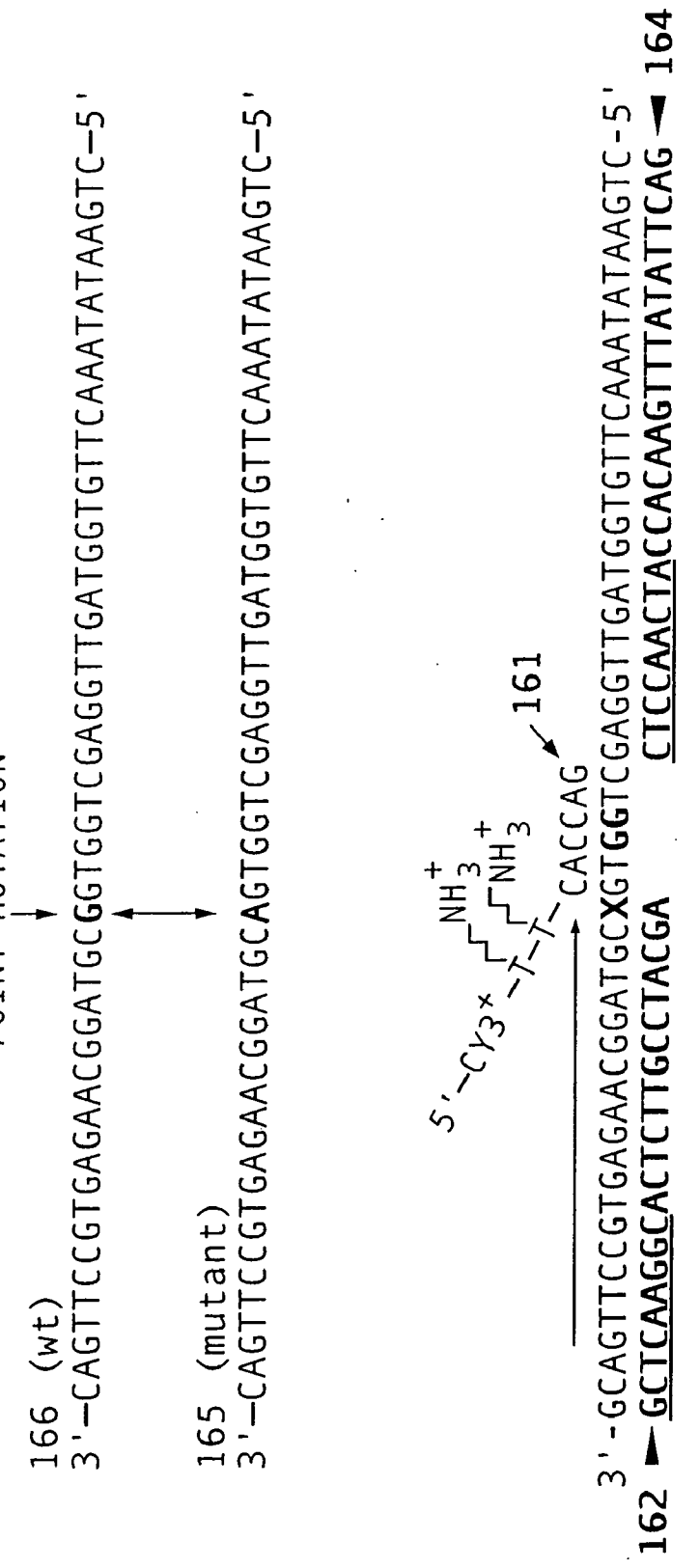

CODON 13
POINT MUTATION
166 (wt)
3'-CAGTTCCGTGAGAACGGATGCGGTGGTCGAGGTTGATGGTGTTCAAATATAAGTC-5'
165 (mutant)
3'-CAGTTCCGTGAGAACGGATGCAGTGGTCGAGGTTGATGGTGTTCAAATATAAGTC-5'
5'-Cy3
NH3+
NH3+
161
CACCAG
3'-GCAGTTCCGTGAGAACGGATGCXGTGGTCGAGGTTGATGGTGTTCAAATATAAGTC-5'
162 GCTCAAGGCACTCTTGCCTACGA CTCCAACTACCACAAGTTTATATTCAG 164

FIG. 76

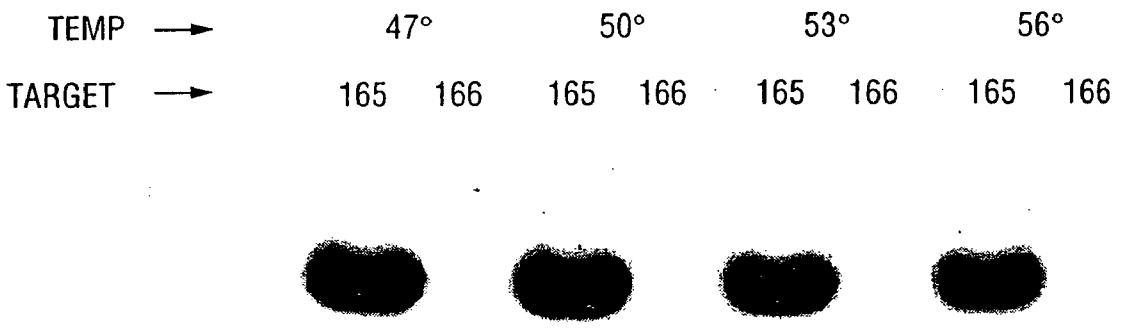


FIG. 77



FIG. 78A

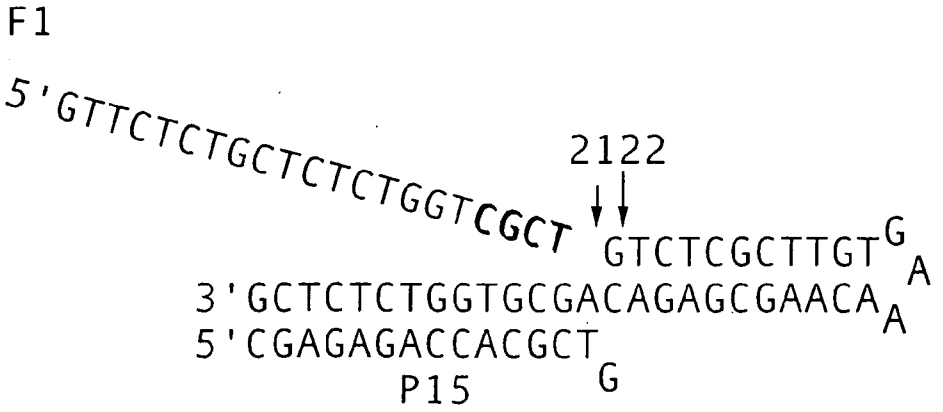


FIG. 78B

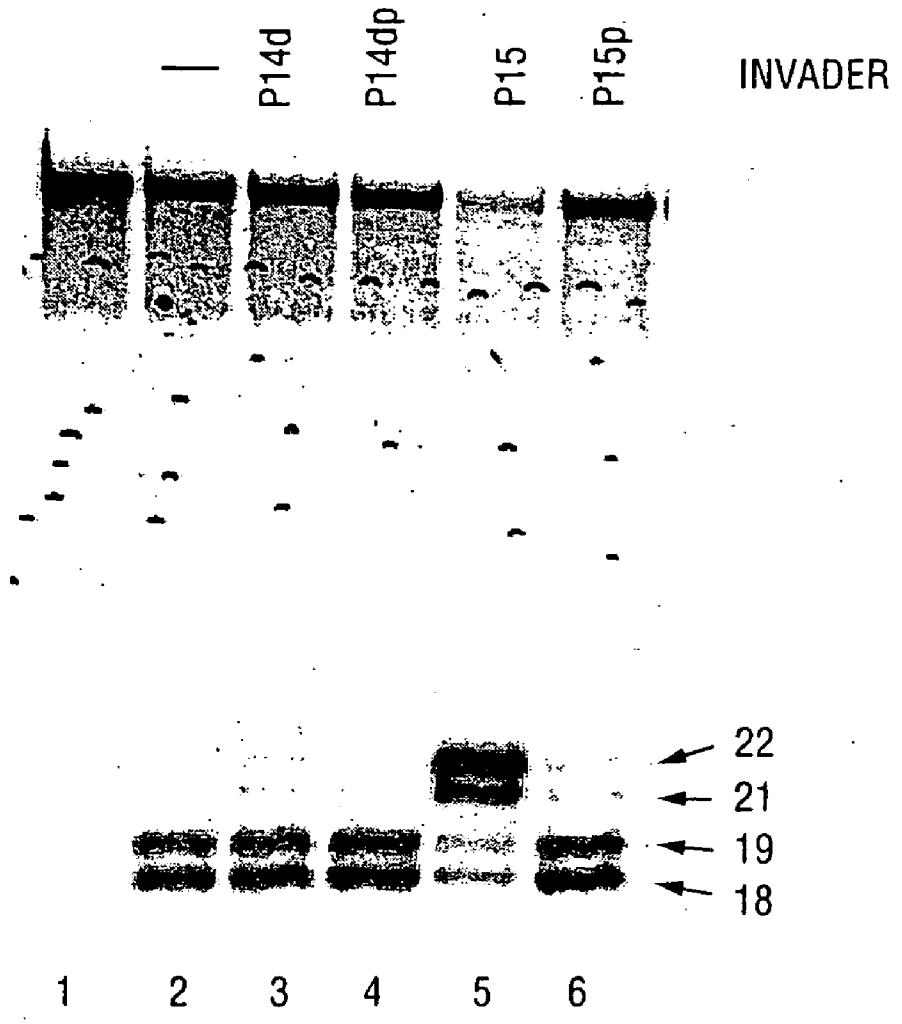
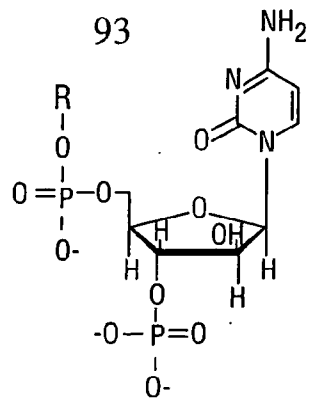
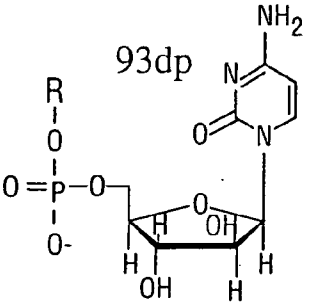


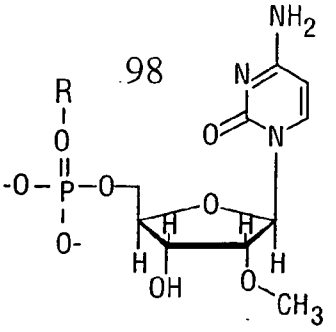
FIG. 78C



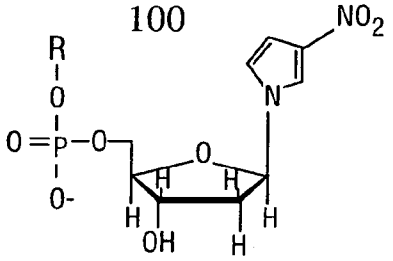
3'-PHOSPHATE C ARABINOSE



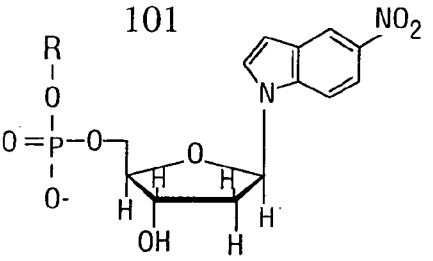
3'-CYTOSINE ARABINOSE



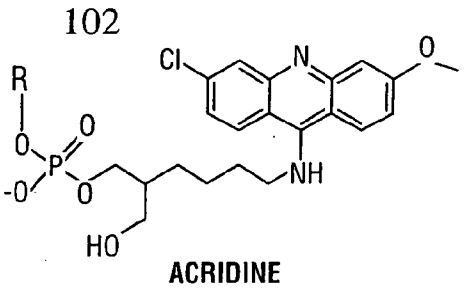
2'-OMETHYL CYTOSINE



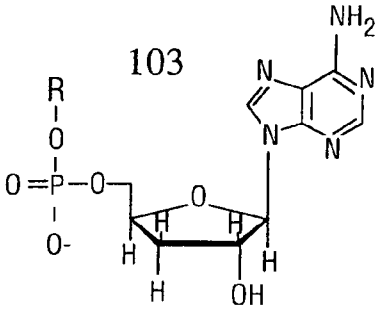
3'-NITROPYROLE



5'-NITROINDOLE

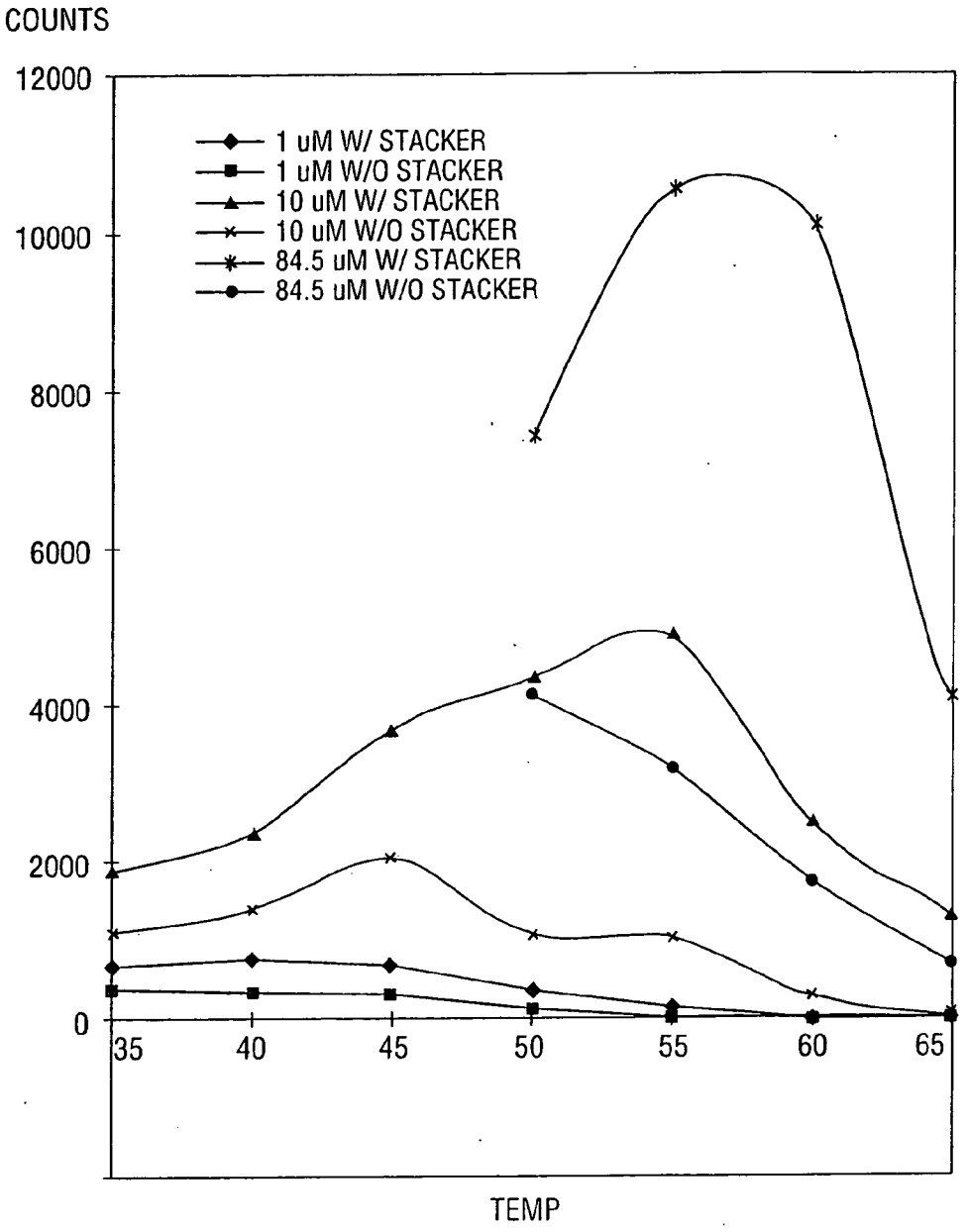


ACRIDINE



3'-DEOXY-ADENINE

FIG. 79



CONCENTRATION OF PROBE W/ AND W/O STACKER vs TEMP

FIG. 80

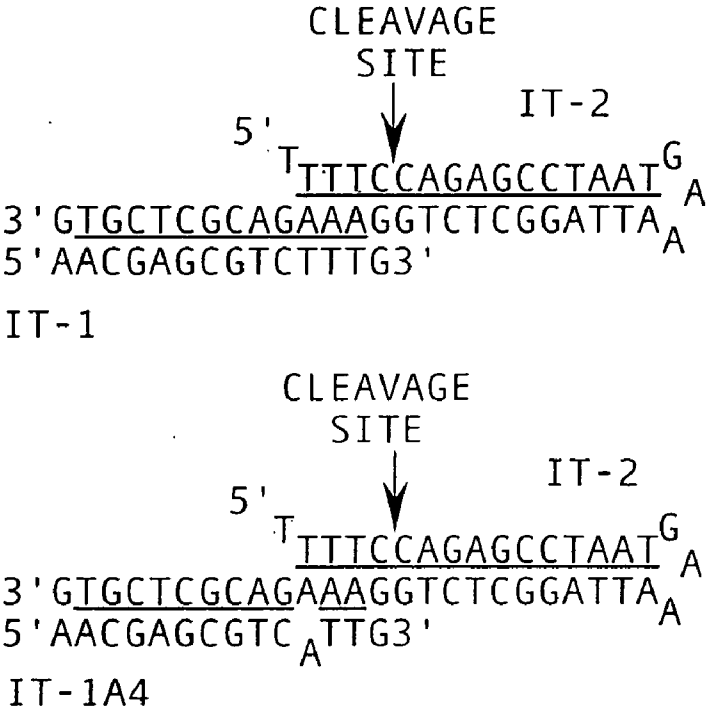

CLEAVAGE
SITE
IT-2
5'
TTTTCCAGAGCCTAATGA
3'GTGCTCGCAGAAAGGTCTCGGATTAA
5'AACGAGCGTCTTTG3'
IT-1
CLEAVAGE
SITE
IT-2
5'
TTTTCCAGAGCCTAATGA
3'GTGCTCGCAGAAAGGTCTCGGATTAA
5'AACGAGCGTCATTG3'
IT-1A4

FIG. 81

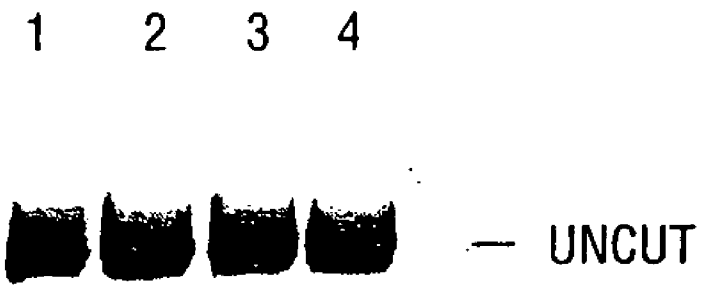


FIG. 82

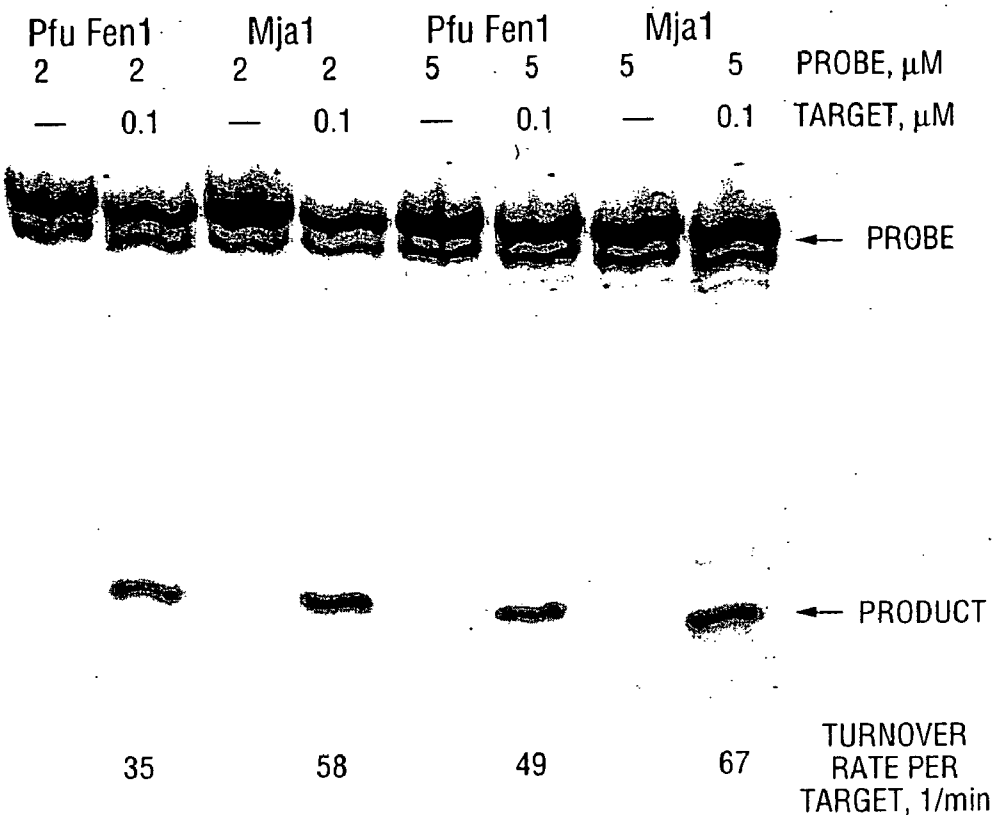

Pfu Fen1
Mja1
Pfu Fen1
Mja1
2 2 2 2 5 5 5 5 PROBE, μM
— 0.1 — 0.1 — 0.1 — 0.1 TARGET, μM
PROBE
PRODUCT
35 58 49 67
TURNOVER RATE PER TARGET, 1/min

FIG. 83

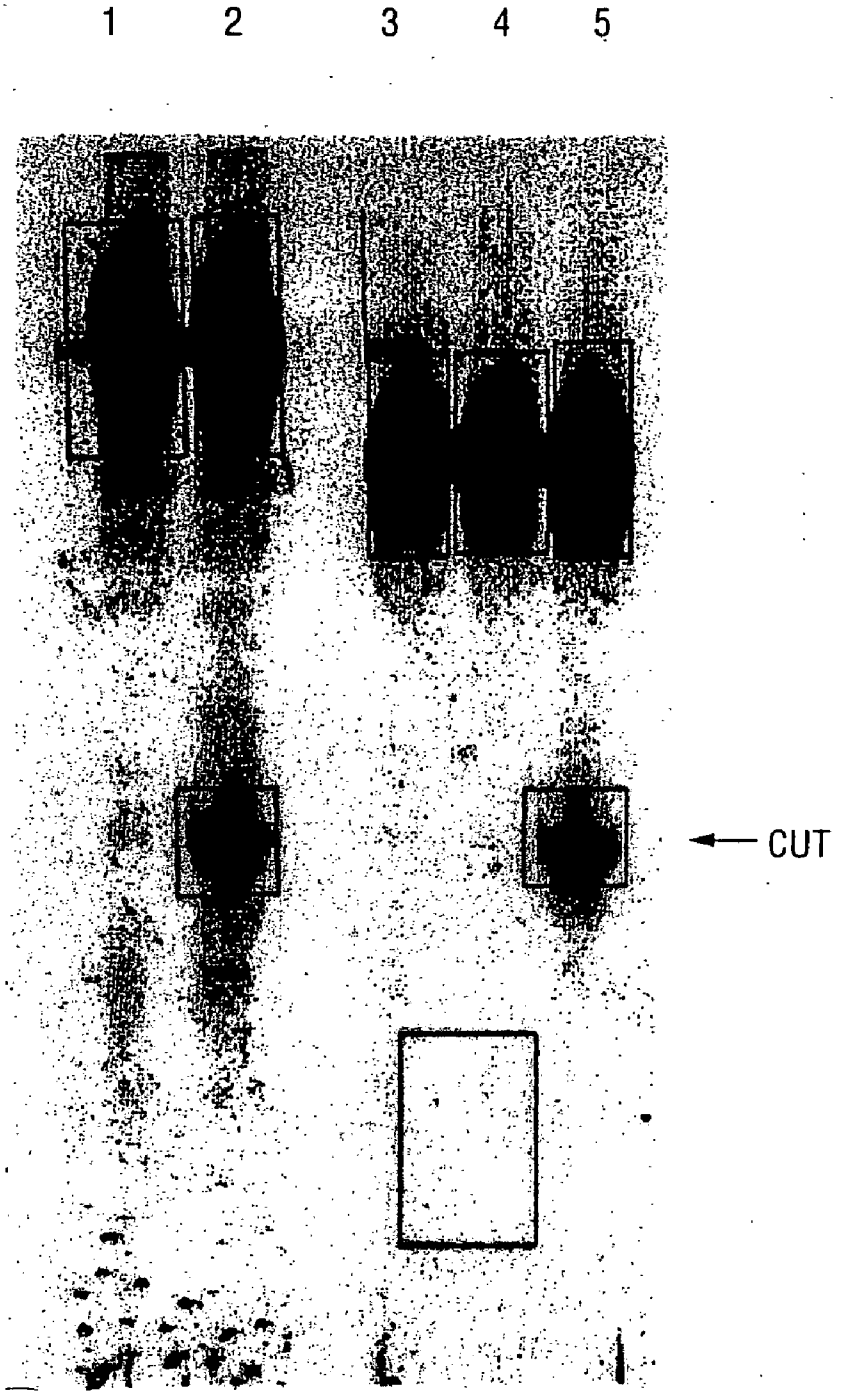


FIG. 84

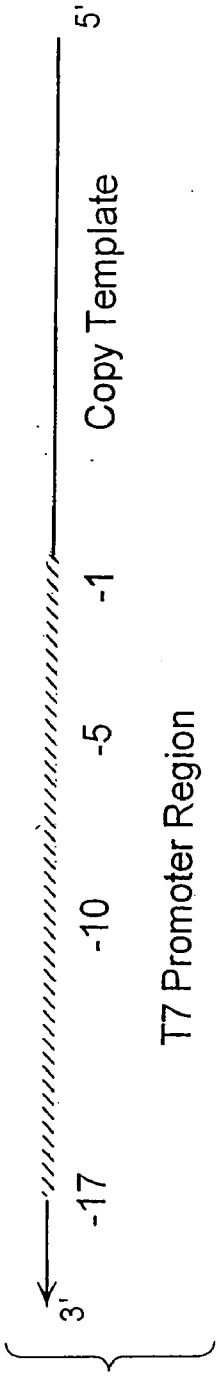


FIG. 85A

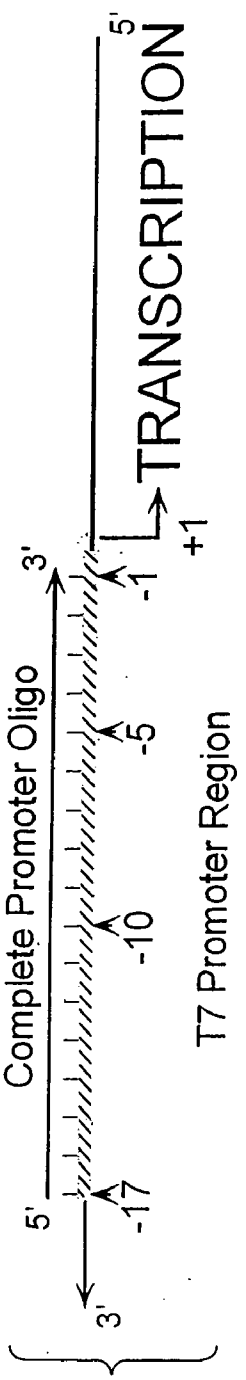


FIG. 85B

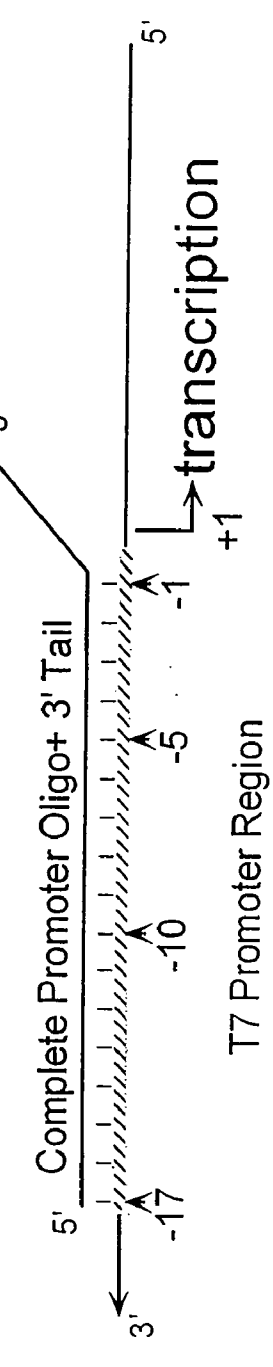


FIG. 85C

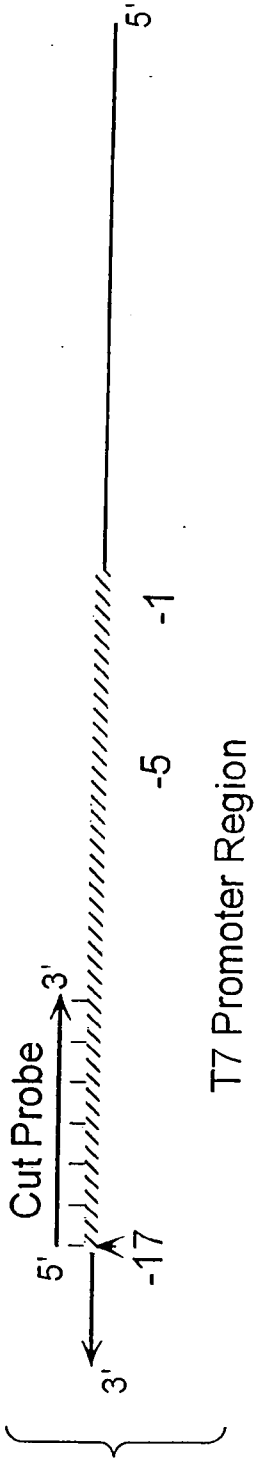


FIG. 86A

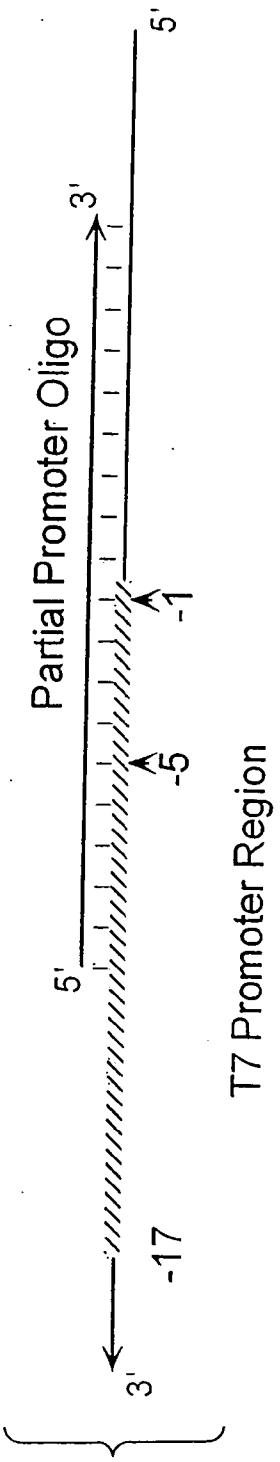


FIG. 86B

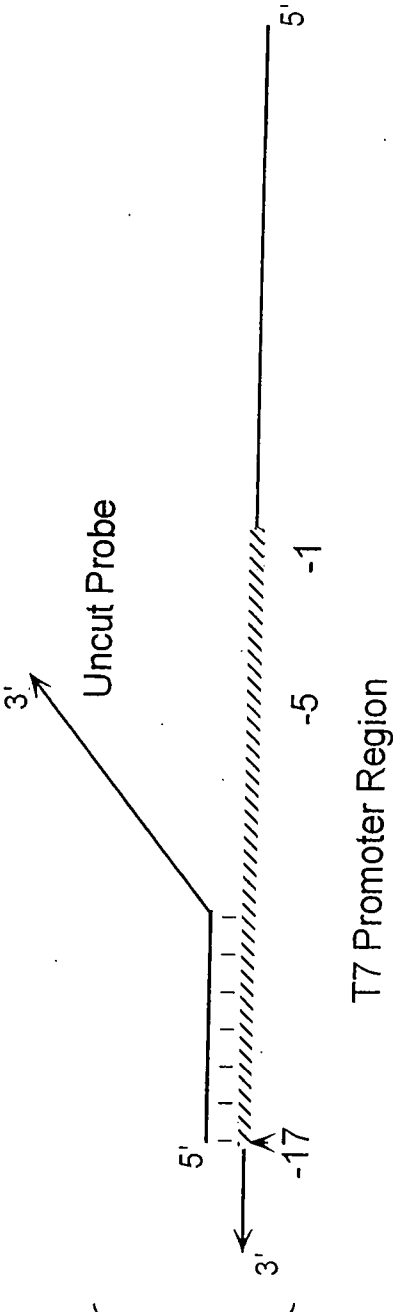


FIG. 86C

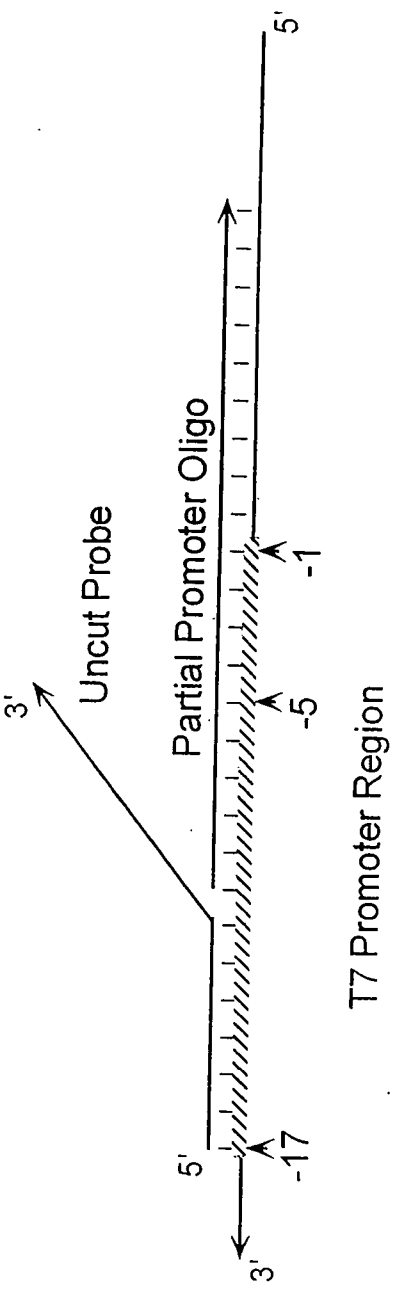


FIG. 86D

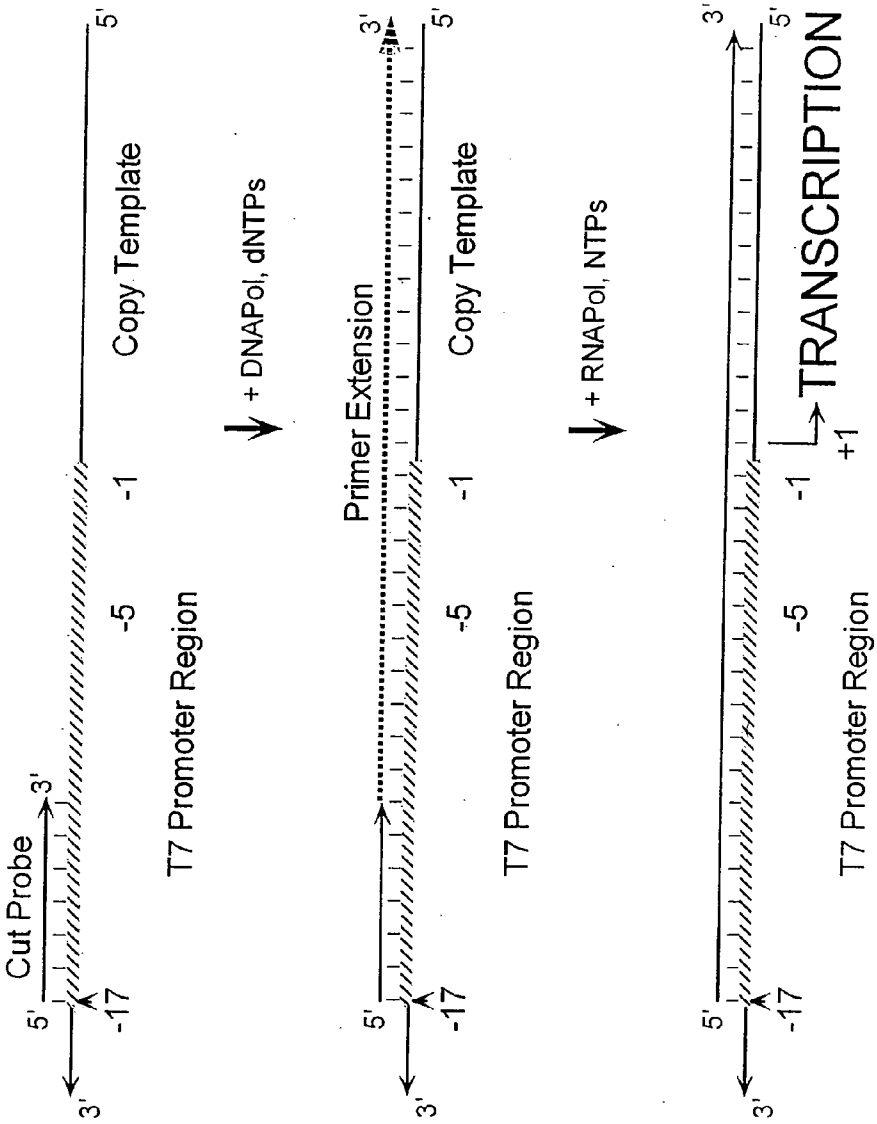

Cut Probe
5'
3'
-17
-5
-1
Copy Template
5'
T7 Promoter Region
+ DNAPol, dNTPs
Primer Extension
3'
5'
Copy Template
T7 Promoter Region
+ RNAPol, NTPs
TRANSCRIPTION
+1

FIG. 87

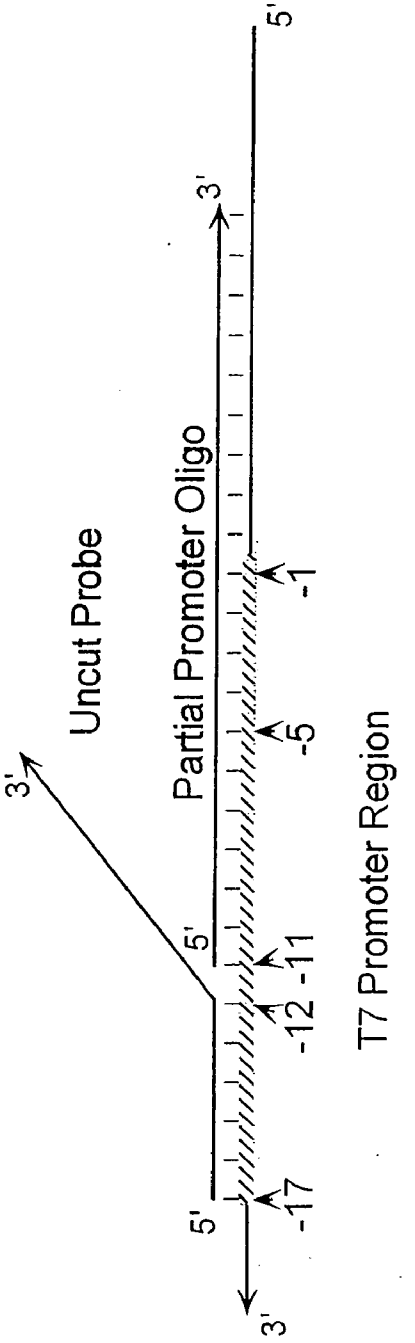


FIG. 88A

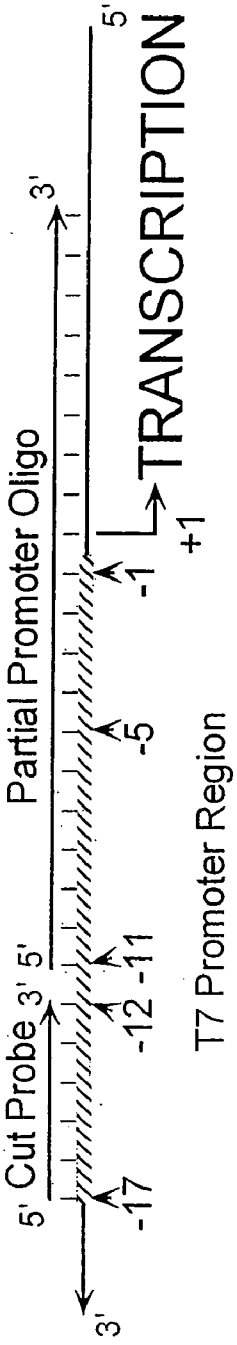


FIG. 88B

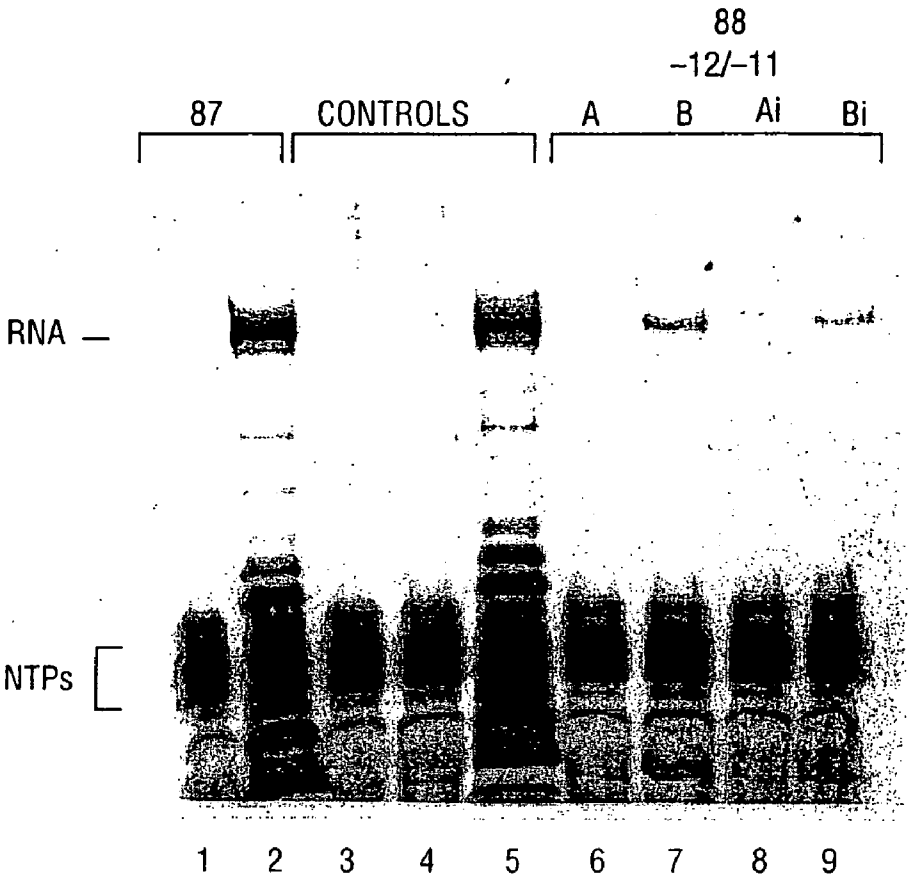


FIG. 89

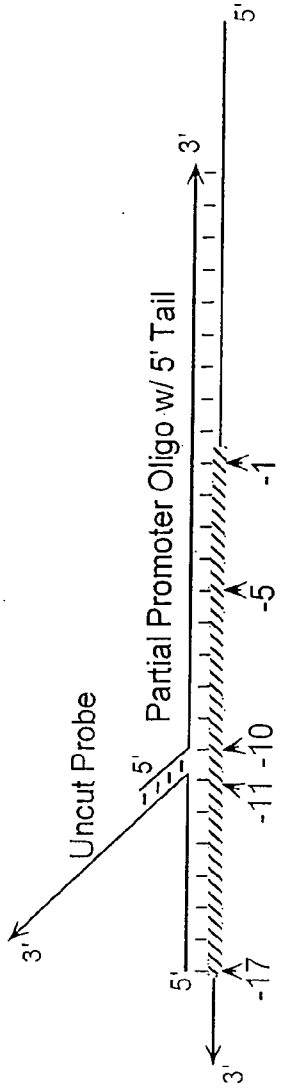


FIG. 90A

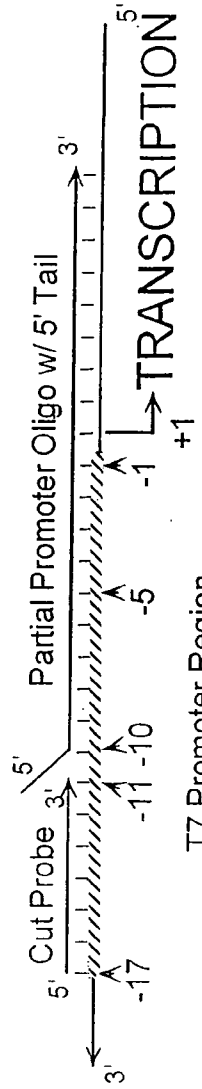


FIG. 90B

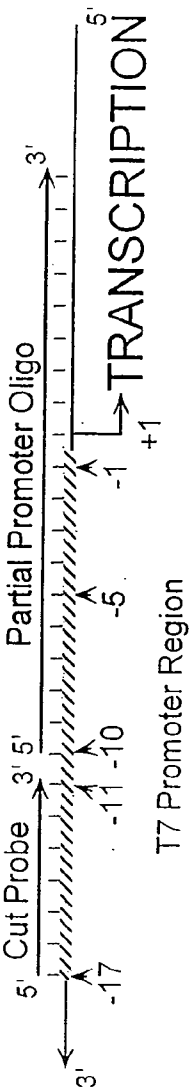


FIG. 90C

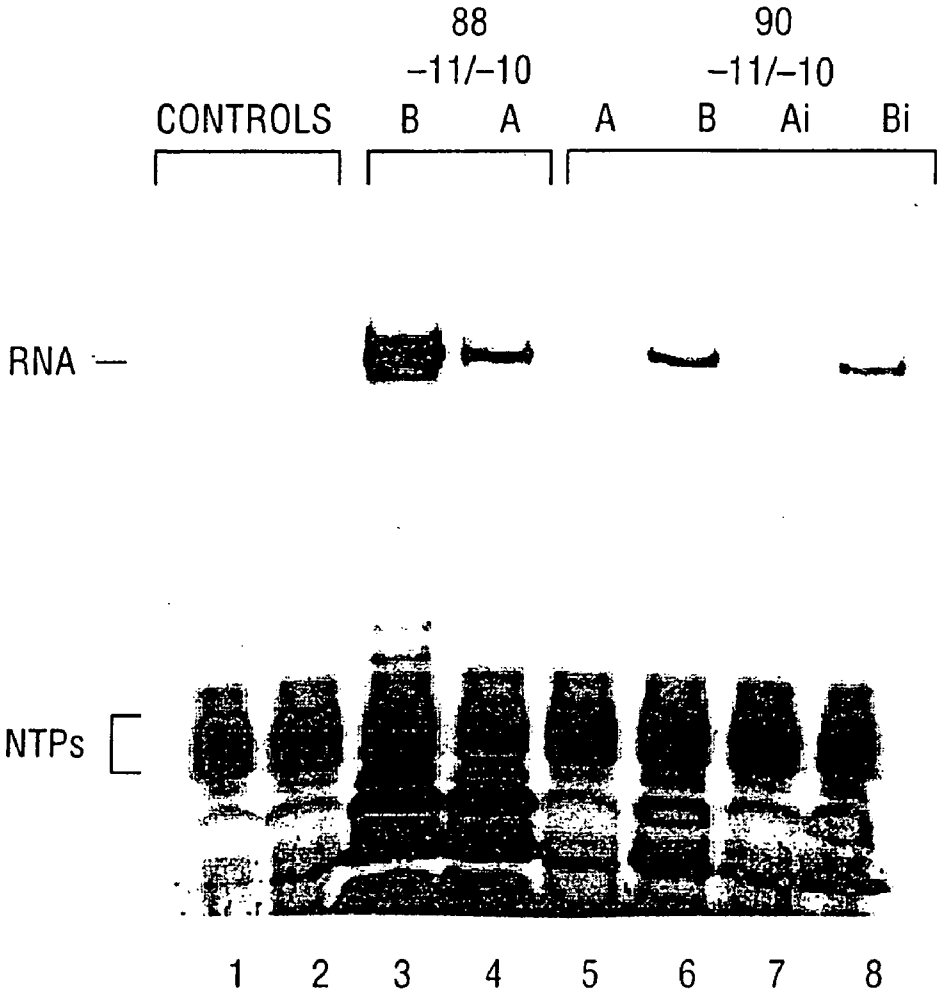


FIG. 91

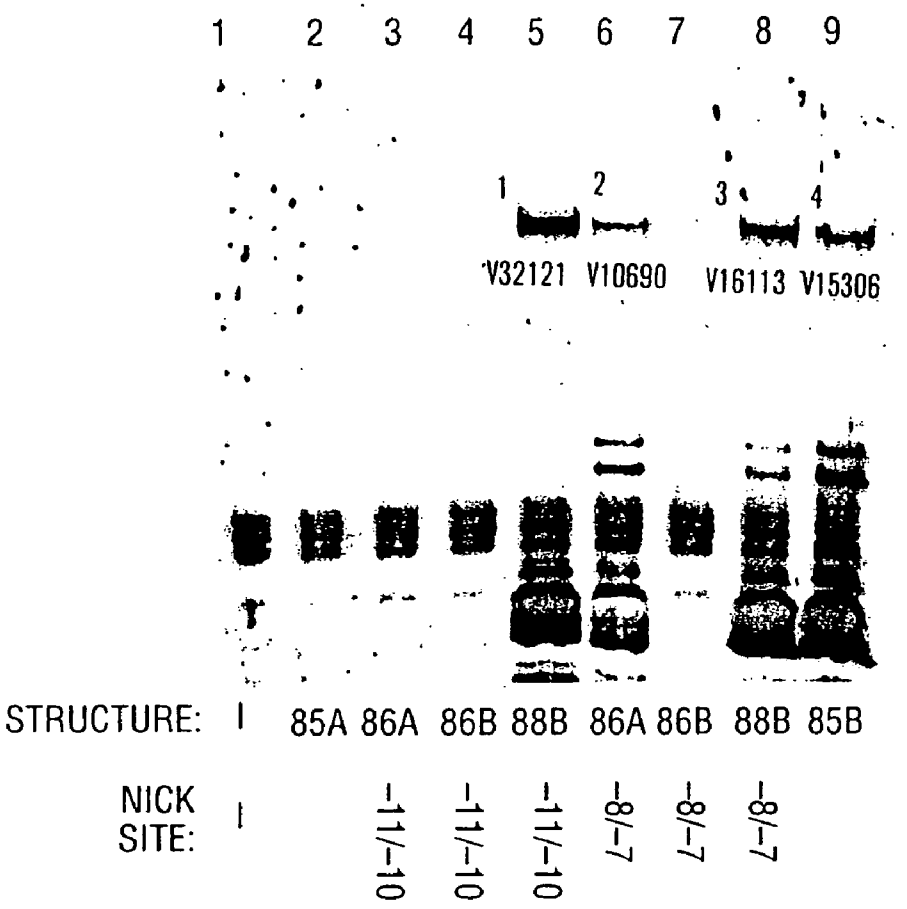
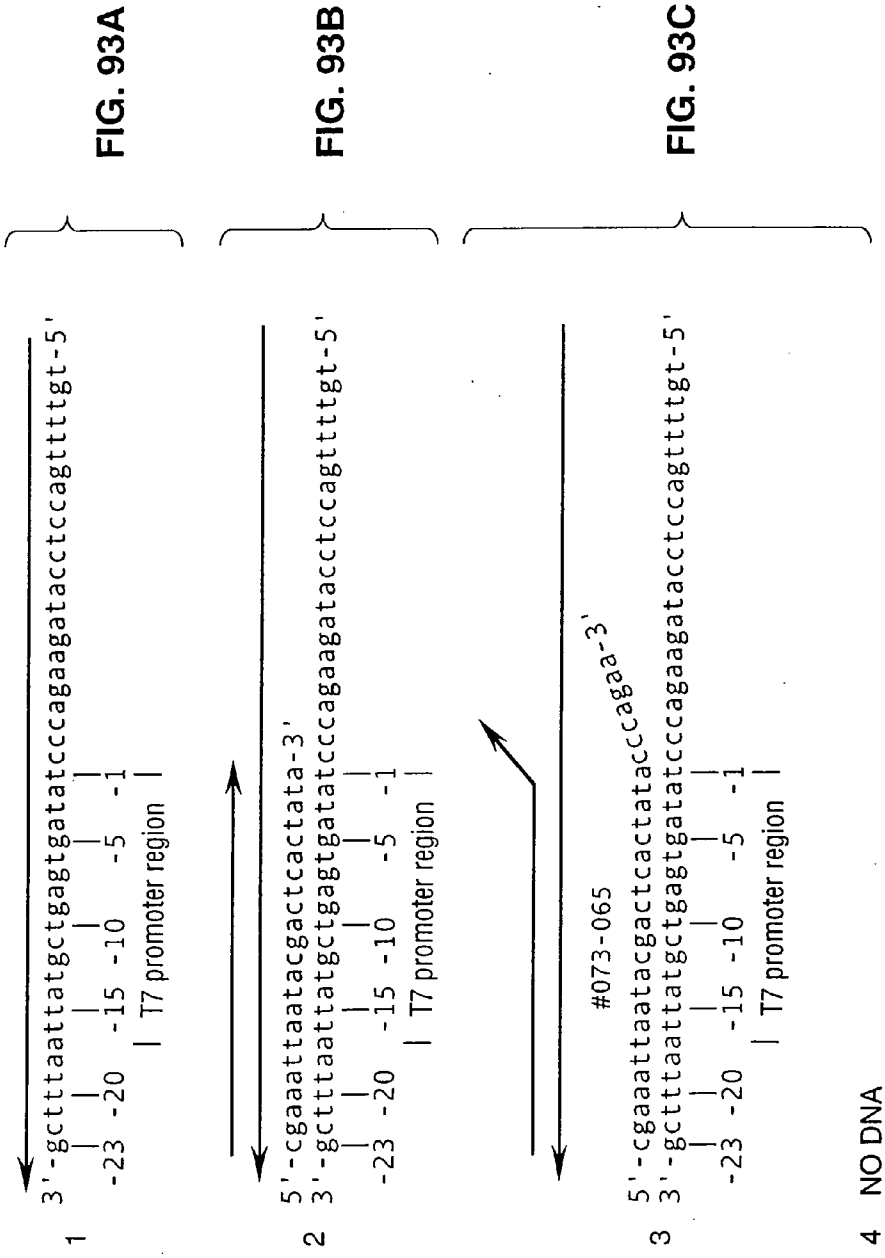

1 2 3 4 5 6 7 8 9
1 2 3 4
V32121 V10690 V16113 V15306
STRUCTURE: I 85A 86A 86B 88B 86A 86B 88B 85B
NICK SITE: I -11/-10 -11/-10 -11/-10 -8/-7 -8/-7 -8/-7

FIG. 92


FIG. 93A
FIG. 93B
FIG. 93C
1
3'-gctttaattatgctgagtgatatcccagaaagatacctccagttttgt-5'
-23 -20 -15 -10 -5 -1
T7 promoter region
2
5'-cgaaattaatacgactcactata-3'
3'-gctttaattatgctgagtgatatcccagaaagatacctccagttttgt-5'
-23 -20 -15 -10 -5 -1
T7 promoter region
3
#073-065
5'-cgaaattaatacgactcactatacccagaa-3'
3'-gctttaattatgctgagtgatatcccagaaagatacctccagttttgt-5'
-23 -20 -15 -10 -5 -1
T7 promoter region
4 NO DNA

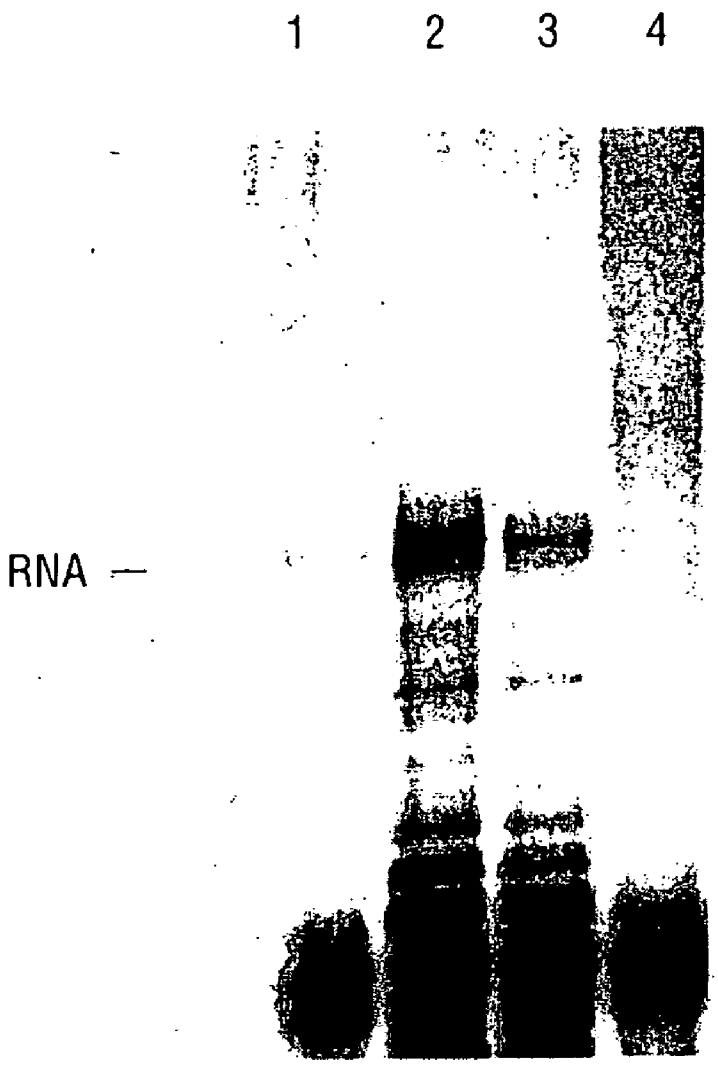


FIG. 93D

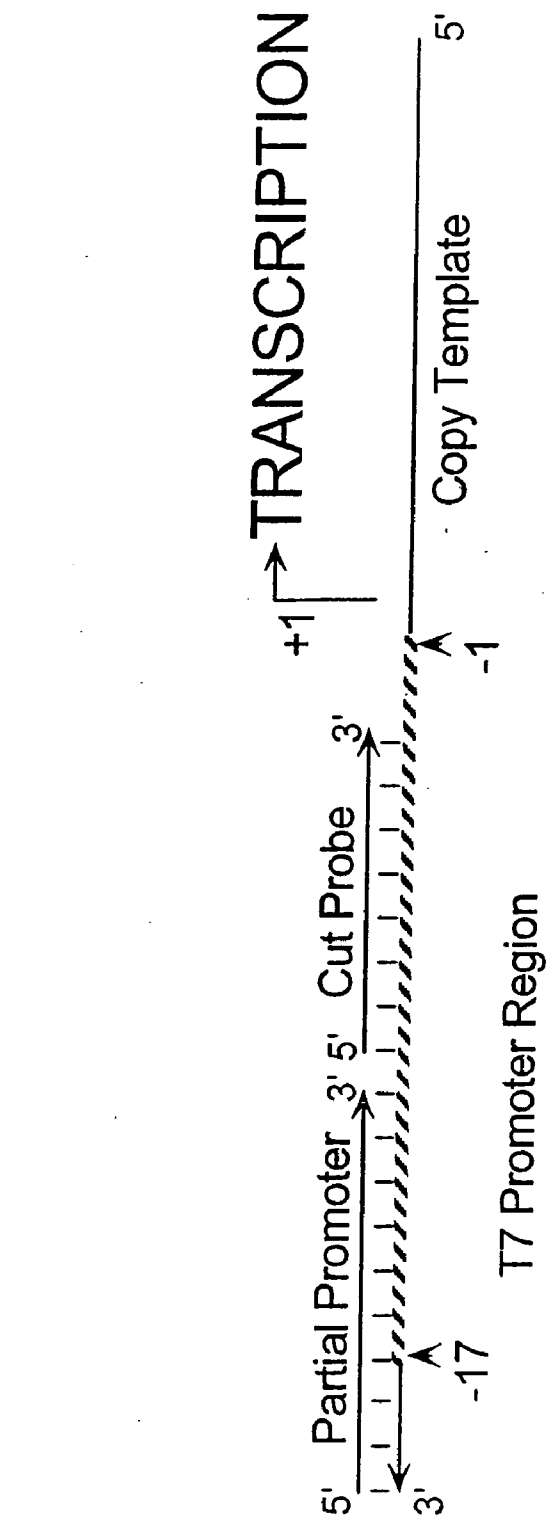

TRANSCRIPTION
+1
5'
Copy Template
-1
3'
Cut Probe
5'
3'
Partial Promoter
3'
5'
-17
T7 Promoter Region

FIG. 94

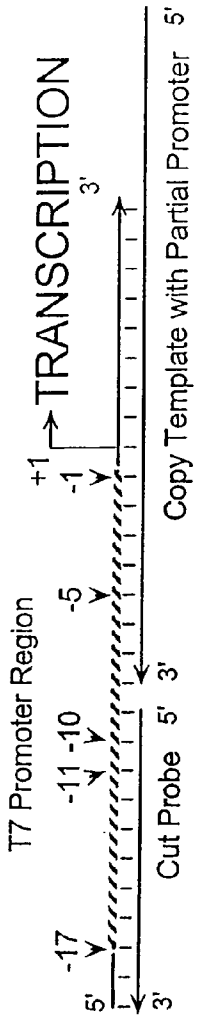


FIG. 95A

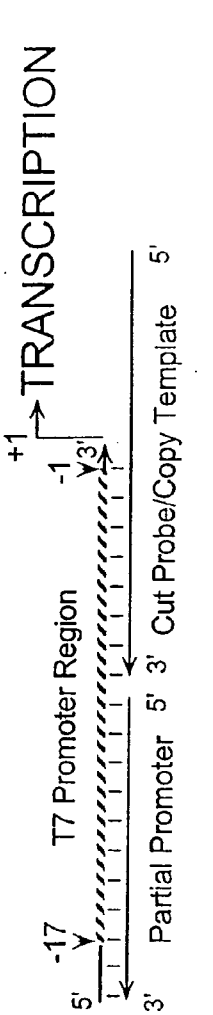


FIG. 95B

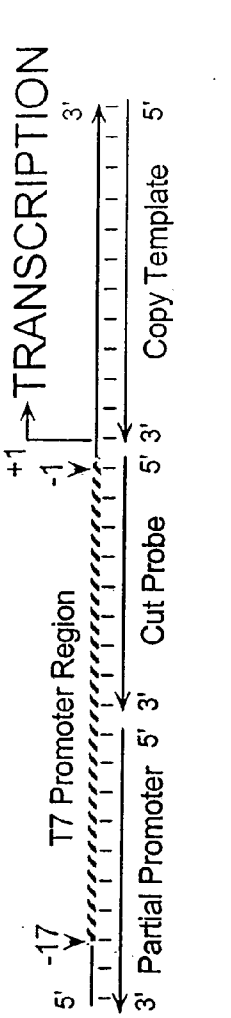


FIG. 95C

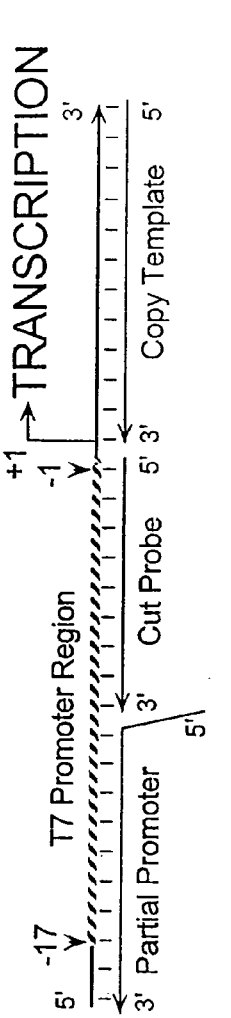


FIG. 95D

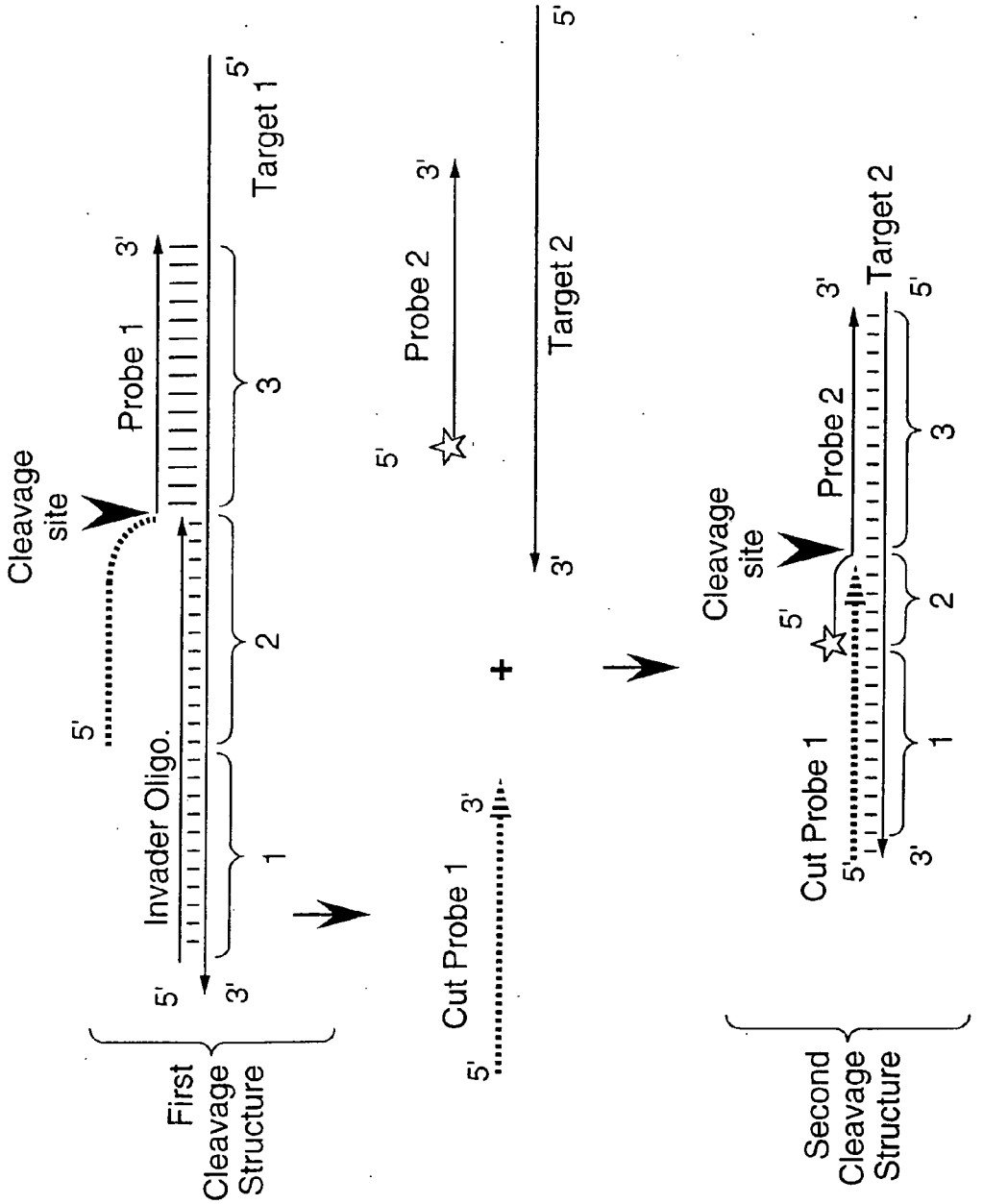

Cleavage site
Probe 1
3'
Target 1
5'
3
2
1
Invader Oligo.
5'
3'
First Cleavage Structure
Probe 2
3'
5'
Target 2
5'
3'
+
Cut Probe 1
3'
5'
Cleavage site
Probe 2
3'
Target 2
5'
5'
3
2
1
Cut Probe 1
5'
3'
Second Cleavage Structure

FIG. 96

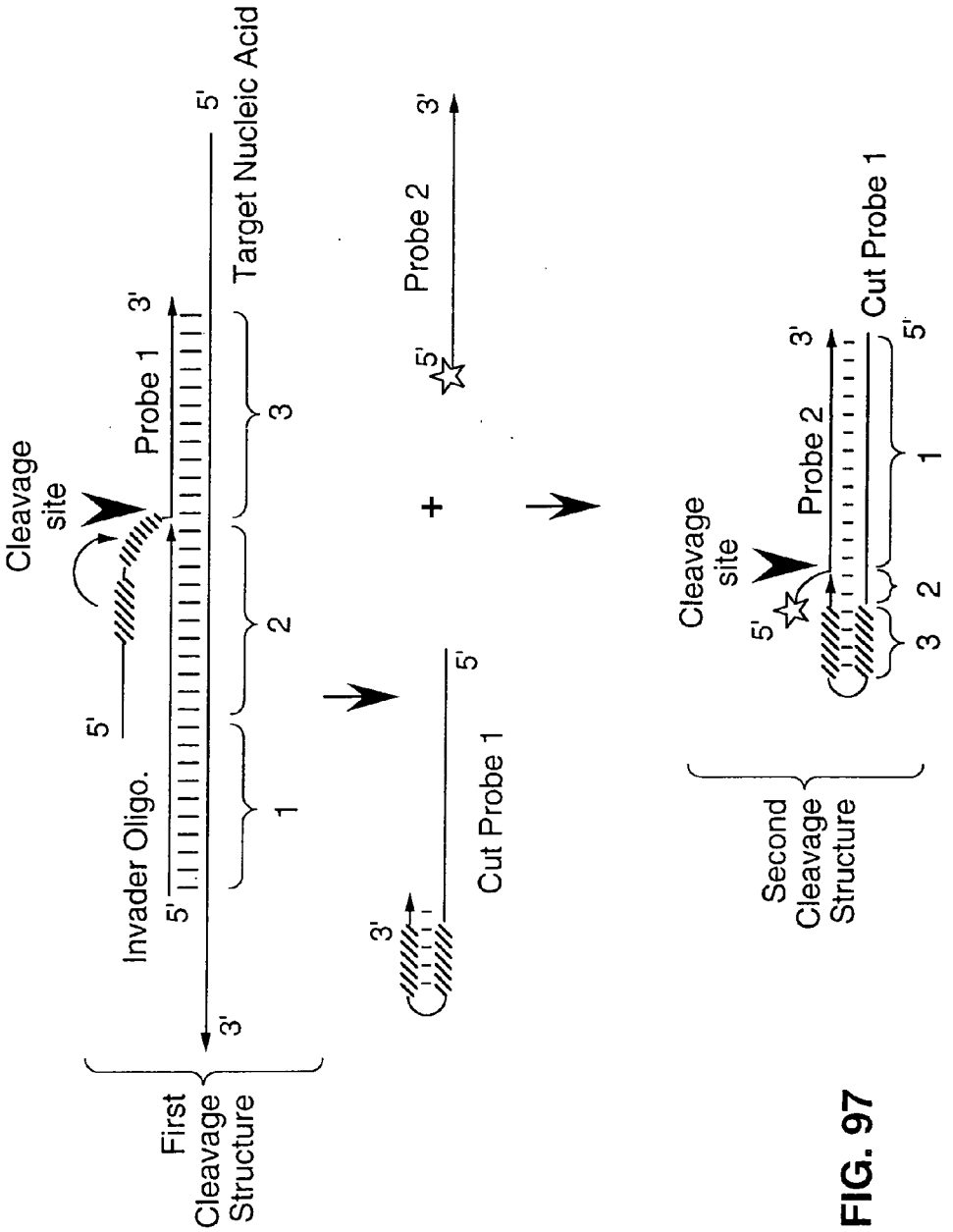

Cleavage site
Probe 1
Target Nucleic Acid
Invader Oligo.
First Cleavage Structure
Probe 2
Cut Probe 1
Second Cleavage Structure
Cut Probe 1

FIG. 97

PR1 probe

Cleavage site

5'FITTTTCCAGAGCCTAAT G3'

IT3 Invader-Target

A A ACGAGCGTCTTT G3'
G TGCTCGCAGAAAGGTCTCGGATTAATTTTTTTTT5'

IT3-8 Invader-Target

A A AGCGTCTT G3'
G TCGCAGAAGGTCTCGGATTAATTTTTTTTT5'

IT3-6 Invader-Target

A A CGTCTT G3'
G GCAGAAGGTCTCGGATTAATTTTTTTTT5'

IT3-4 Invader-Target

A A TCTT G3'
G AGAAGGTCTCGGATTAATTTTTTTTT5'

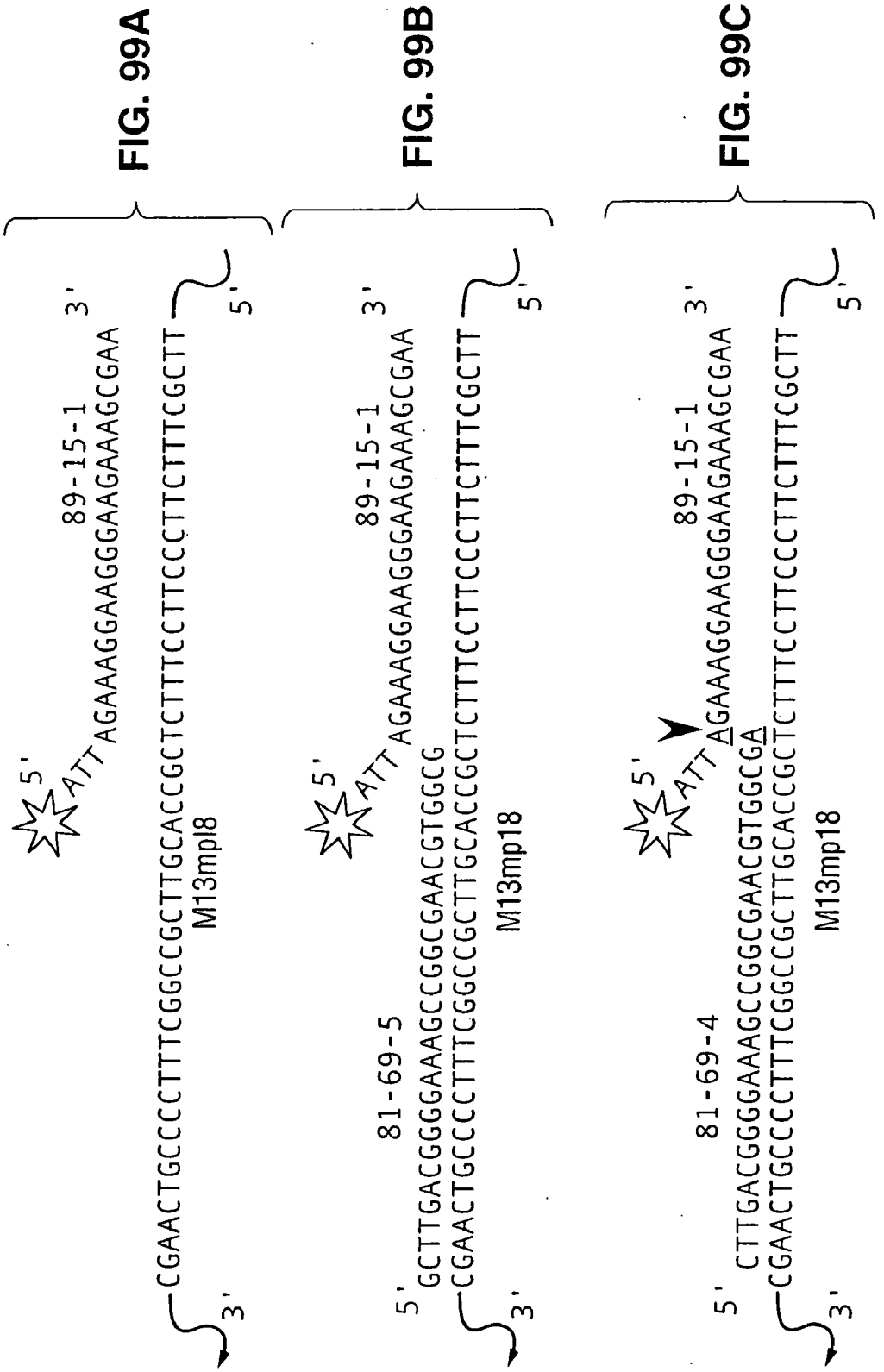
IT3-3 Invader-Target

A A CTT G3'
G GAAGGTCTCGGATTAATTTTTTTTT5'

IT3-0 Invader-Target

3'GAAGGTCTCGGATTAATTTTTTTTT5'

FIG. 98


FIG. 99A
5'
ATT
89-15-1
3'
AGAAAGGAAGGGAAGAAAGCGAA
CGAACTGCCCCTTTCGGCCGCTTGCACCGCTCTTTCCTTCCTTCTTTCGCTT
M13mp18
3'
5'
FIG. 99B
5'
ATT
89-15-1
3'
AGAAAGGAAGGGAAGAAAGCGAA
5'
81-69-5
GCTTGACGGGGAAAGCCGGCGAACGTGGCG
CGAACTGCCCCTTTCGGCCGCTTGCACCGCTCTTTCCTTCCTTCTTTCGCTT
M13mp18
3'
5'
FIG. 99C
5'
ATT
89-15-1
3'
AGAAAGGAAGGGAAGAAAGCGAA
5'
81-69-4
CTTGACGGGGAAAGCCGGCGAACGTGGCGA
CGAACTGCCCCTTTCGGCCGCTTGCACCGCTCTTTCCTTCCTTCTTTCGCTT
M13mp18
3'
5'

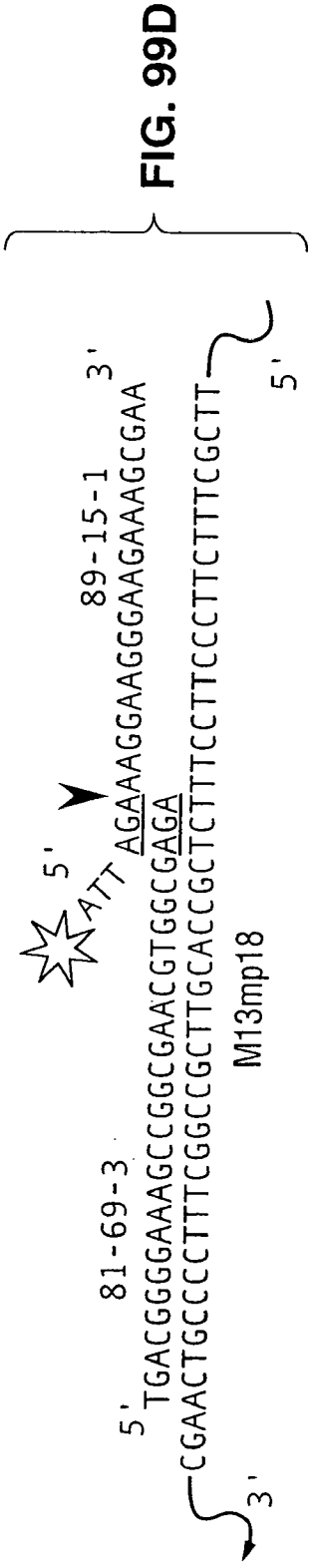


FIG. 99D

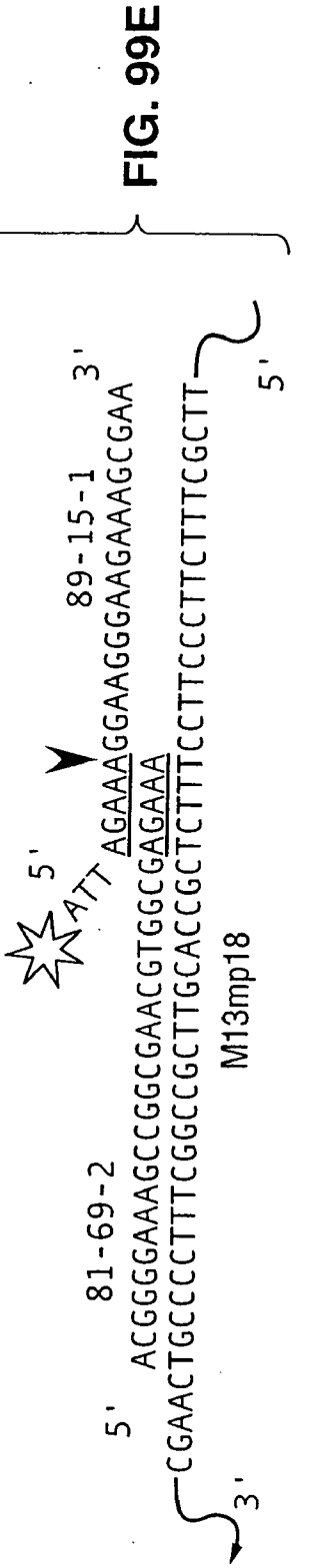


FIG. 99E

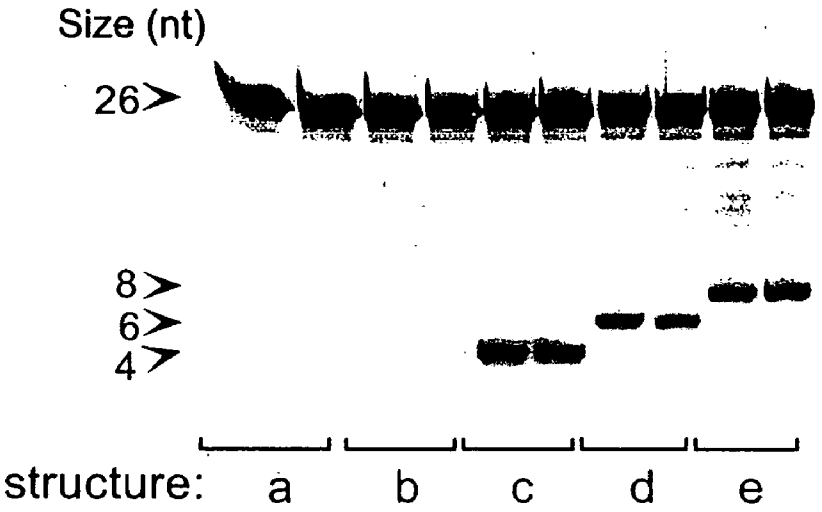


FIG. 100

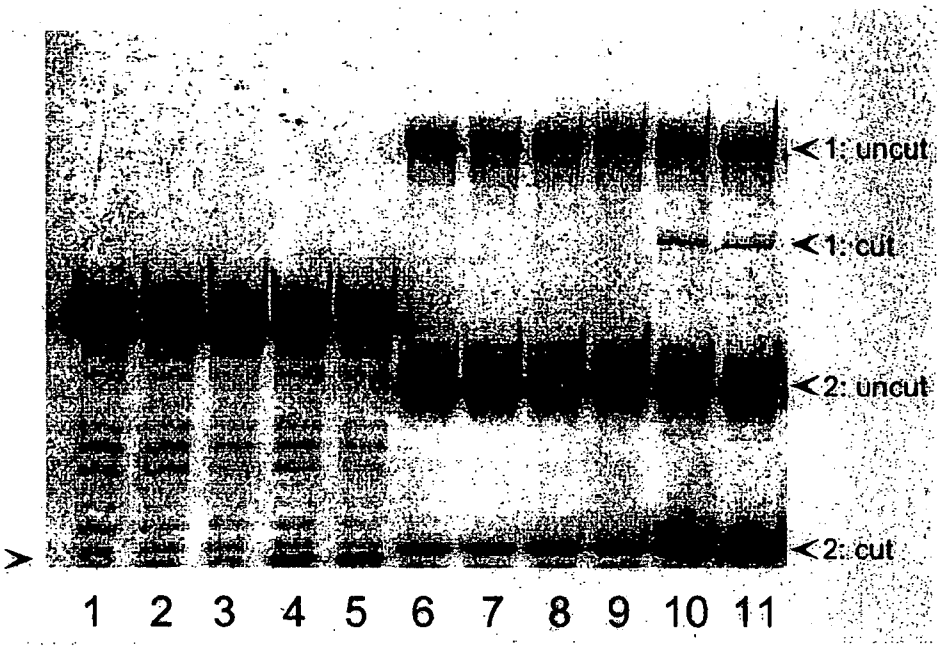
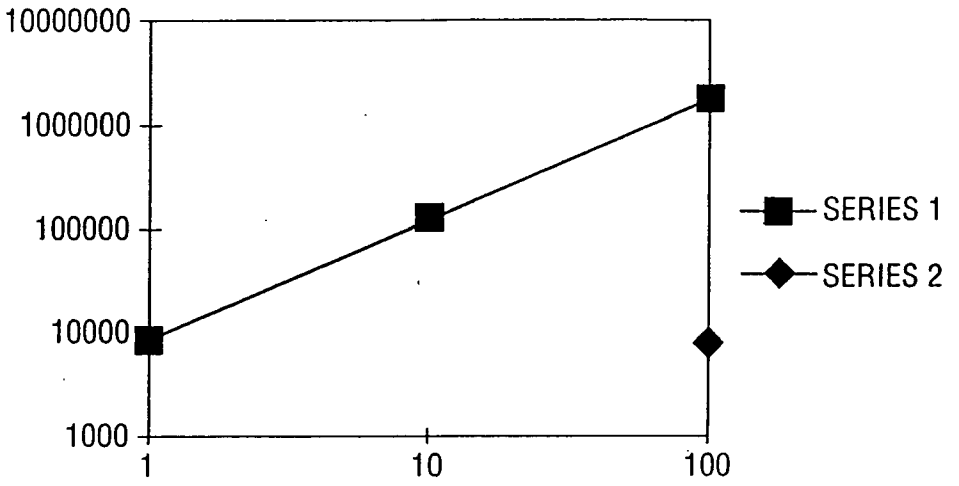


FIG. 101A



attomoles/target	basic invader	invader sqrd
1		8386
10		133185
100	8512	1862211

FIG. 101B

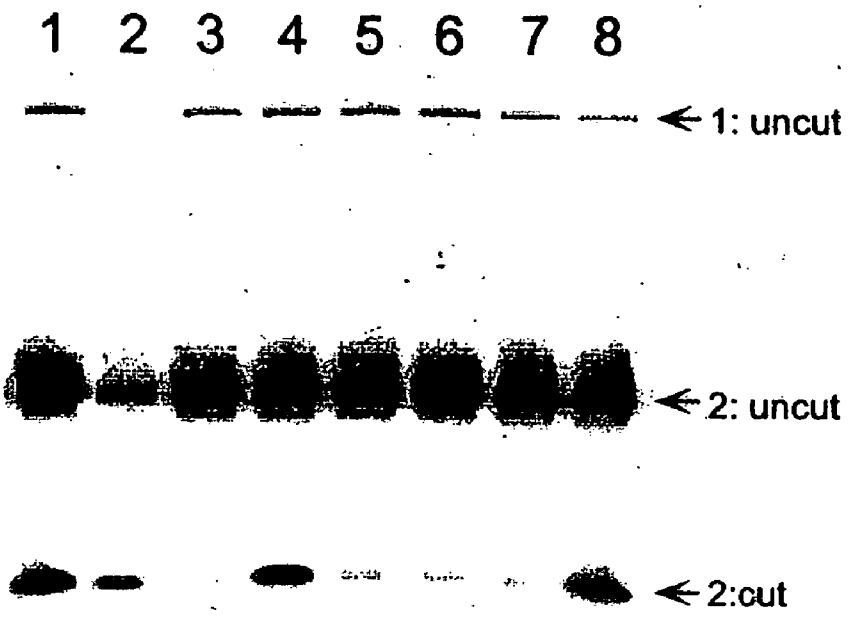


FIG. 102

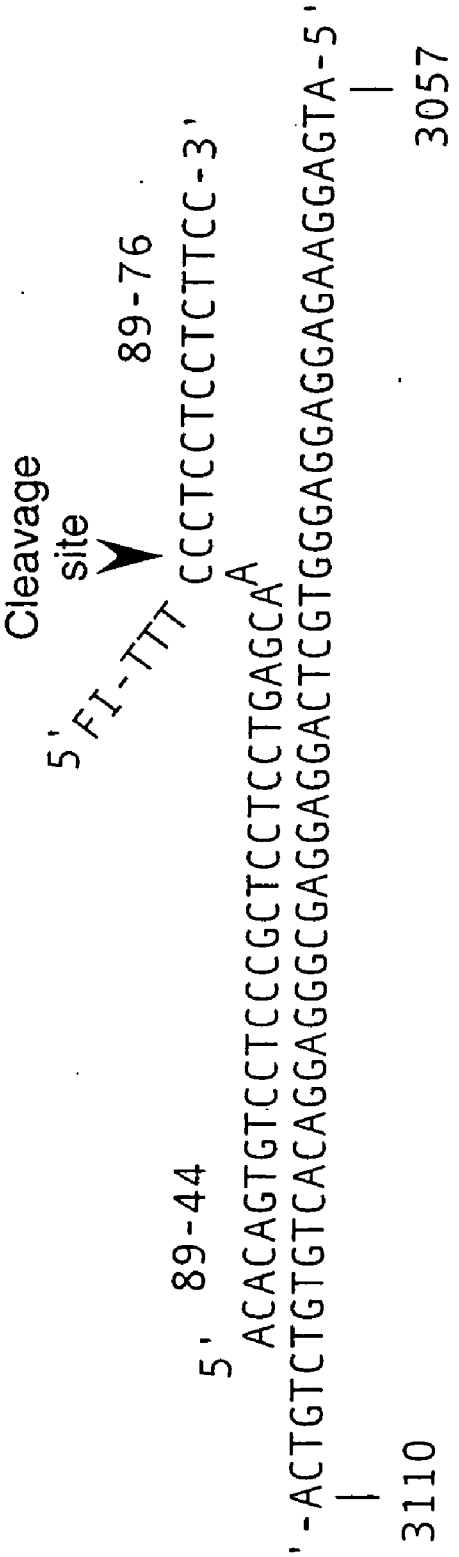

Cleavage site
5' FI-TTT CCCTCCTCCTCTTCC-3'
89-76
5' 89-44
ACACAGTGTCCTCCCGCTCCTCCTGAGCA A
3'-ACTGTCTGTGTCACAGGAGGGCGAGGAGGACTCGTGGGAGGAGAAGGAGTA-5'
3110
3057
HCMV Target Sequence

FIG. 103

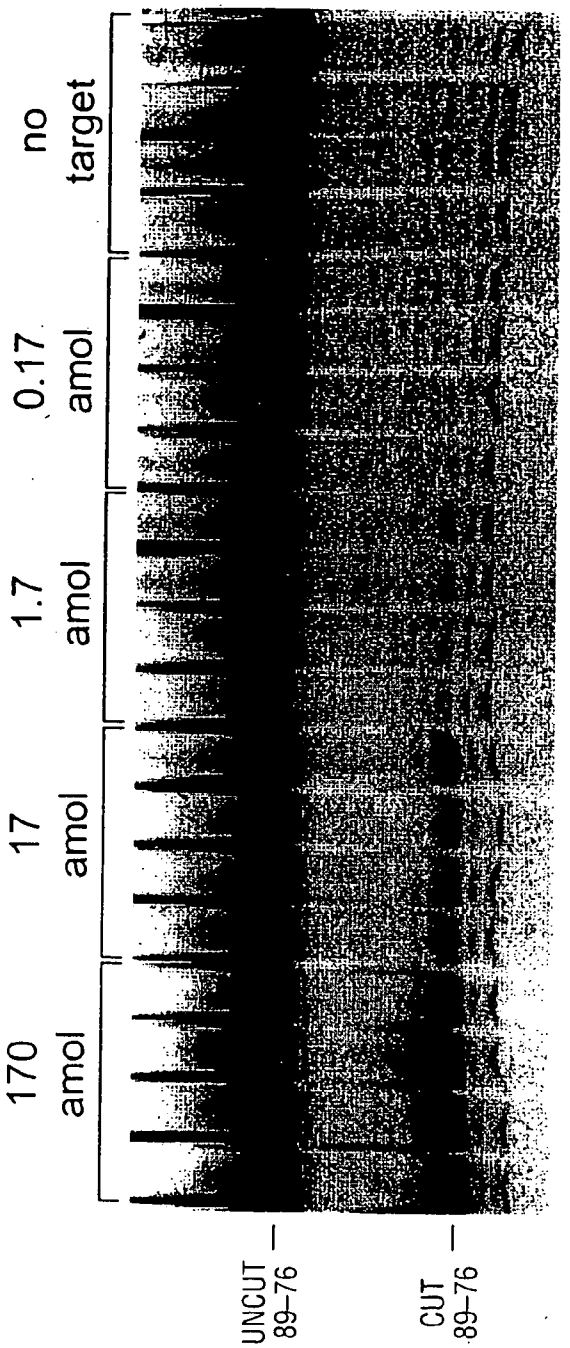

170 amol
17 amol
1.7 amol
0.17 amol
no target
UNCUT 89–76
CUT 89–76

FIG. 104

FIGURE 105

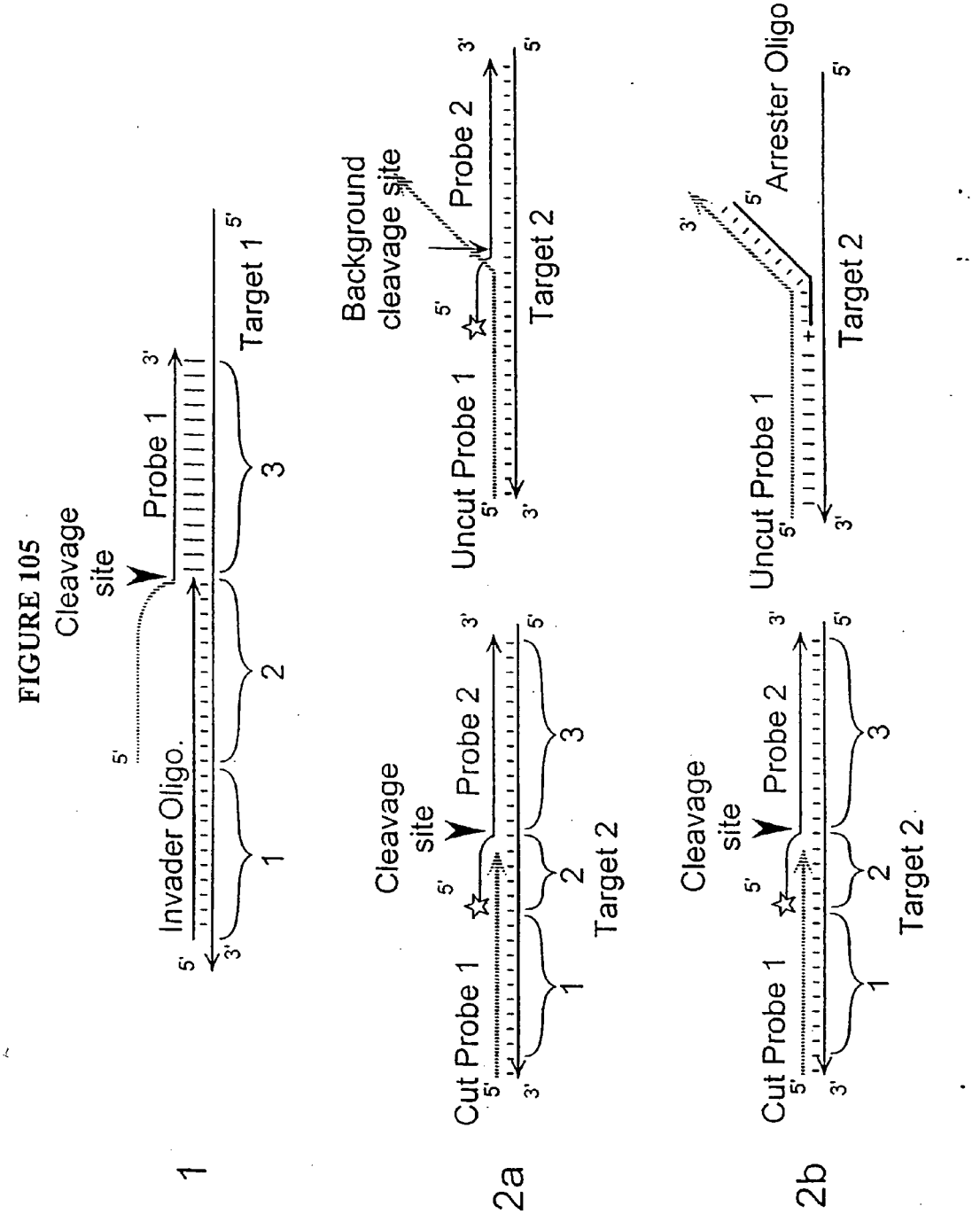

Cleavage site
Probe 1
Invader Oligo.
Target 1
1
2
3
5'
3'
Background cleavage site
Probe 2
Uncut Probe 1
Target 2
2a
Cut Probe 1
Arrester Oligo
2b

FIGURE 106

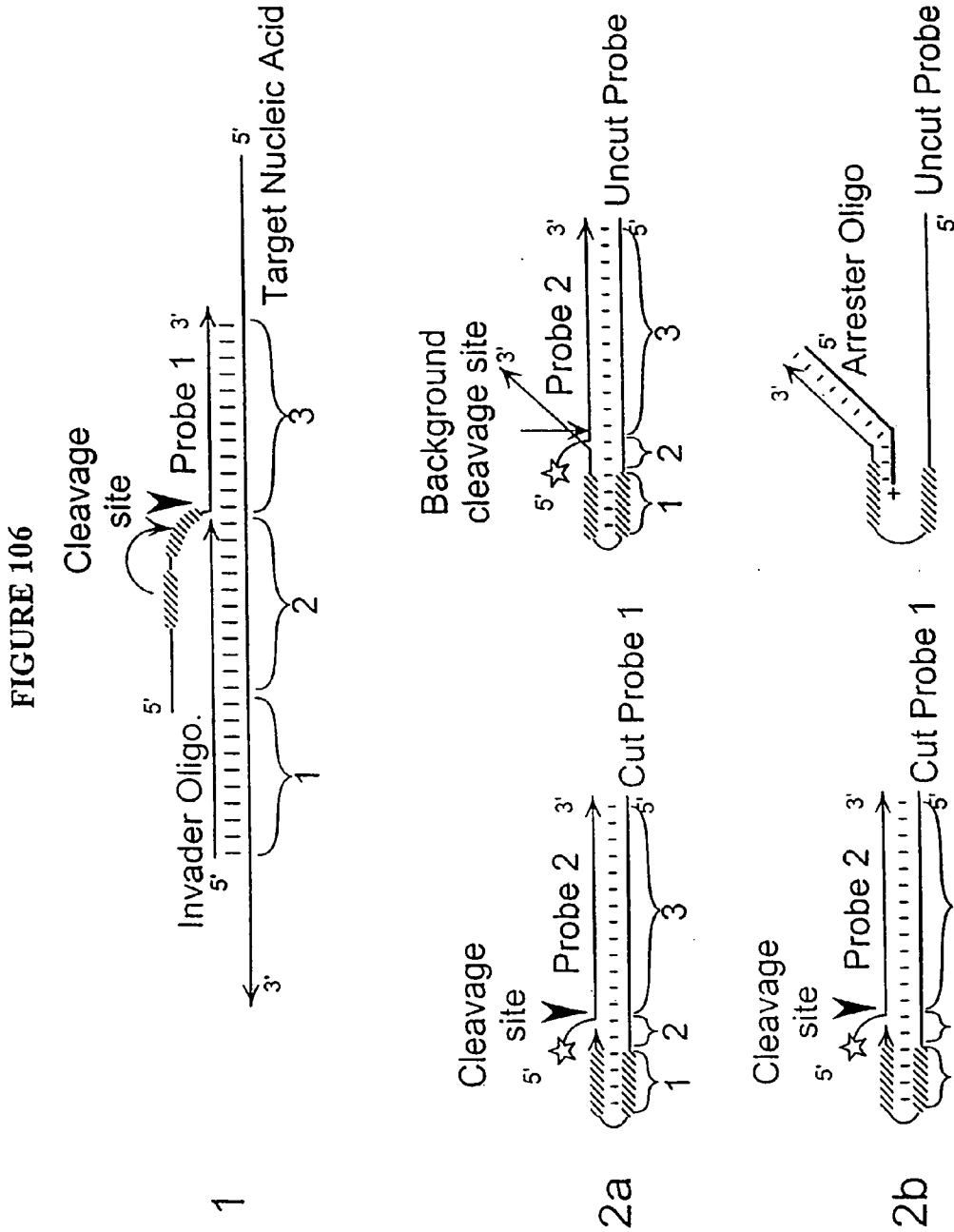

Cleavage site
Probe 1
Invader Oligo.
Target Nucleic Acid
1
Background cleavage site
Probe 2
Uncut Probe 1
Cleavage site
Probe 2
Cut Probe 1
2a
Arrester Oligo
Uncut Probe 1
Cleavage site
Probe 2
Cut Probe 1
2b

FIGURE 107

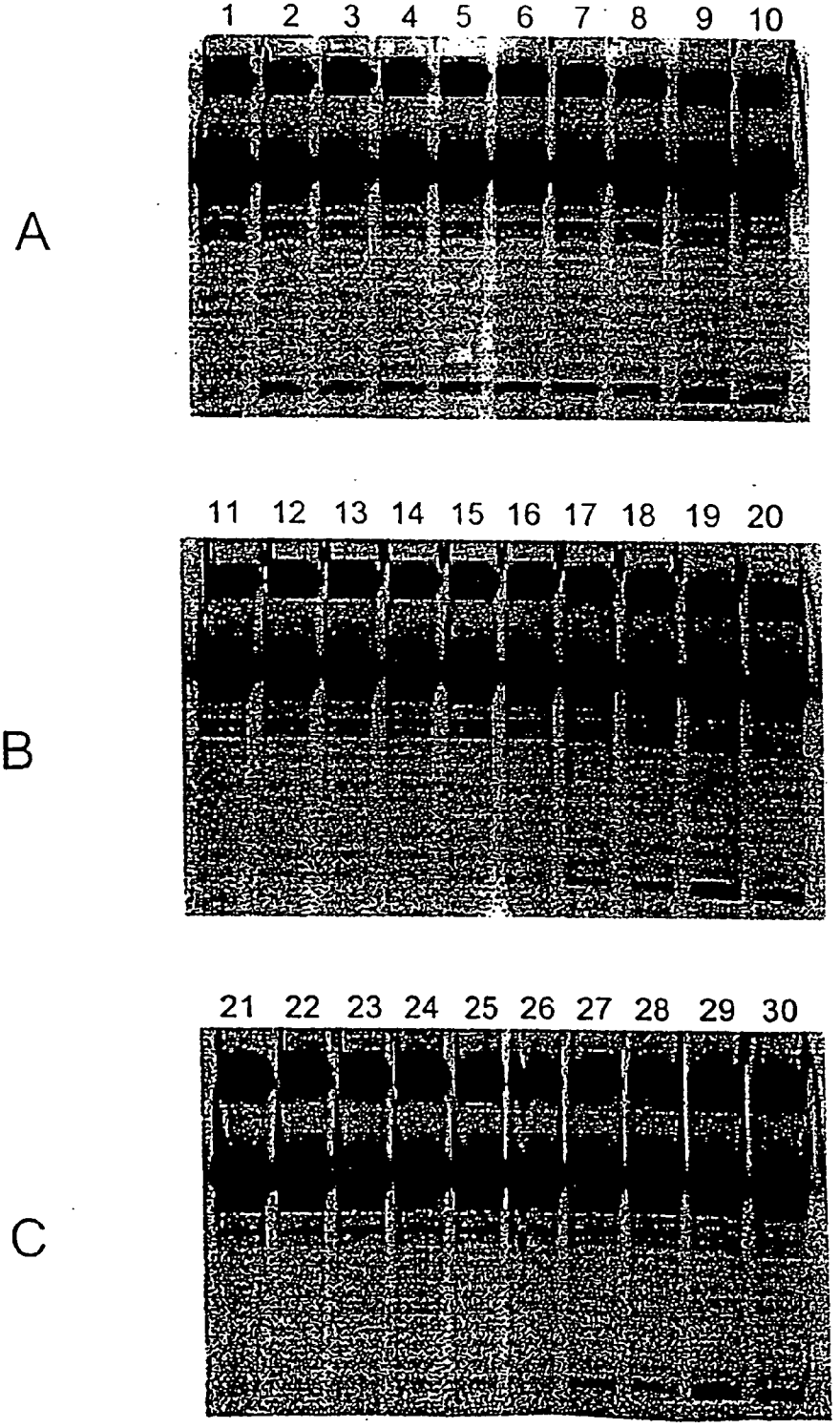
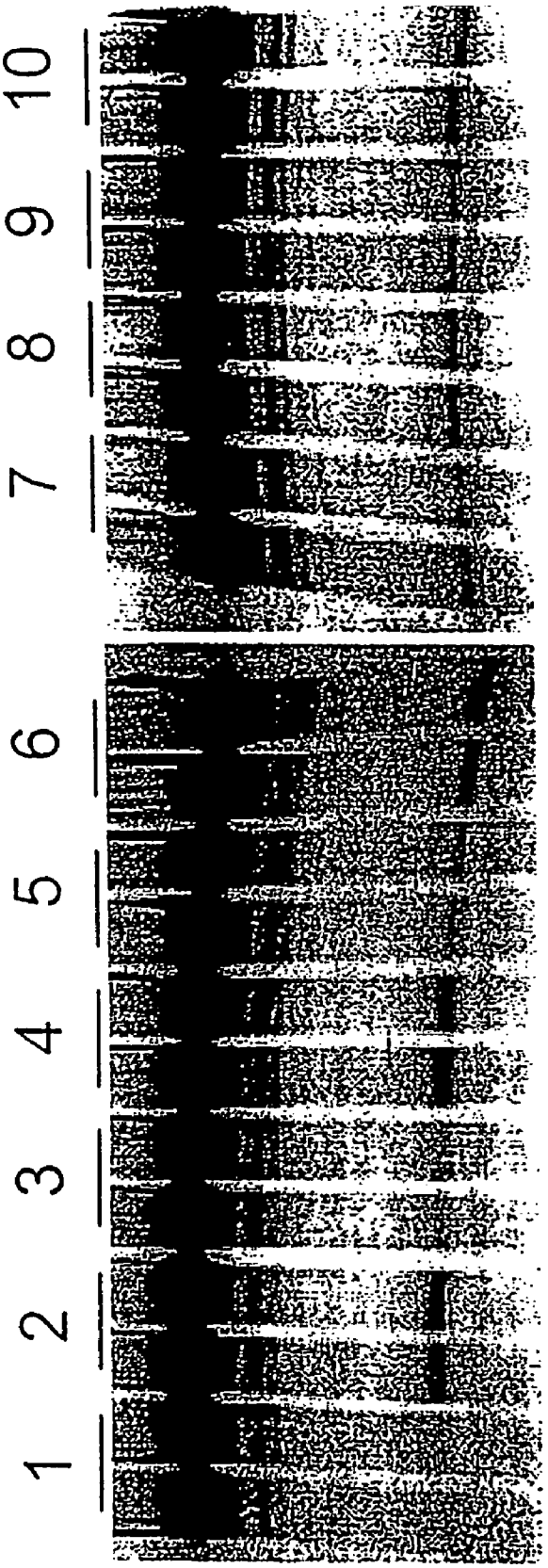

1 2 3 4 5 6 7 8 9 10
A
11 12 13 14 15 16 17 18 19 20
B
21 22 23 24 25 26 27 28 29 30
C

FIGURE 108A



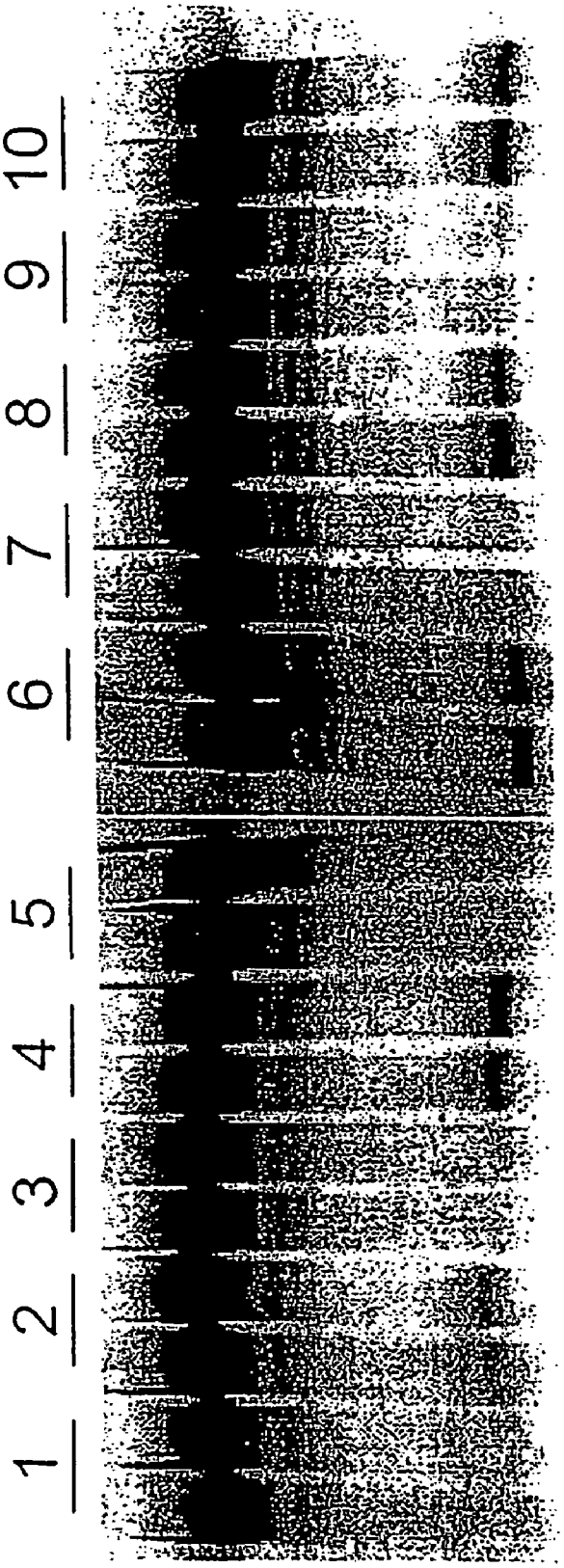


FIGURE 108B

FIGURE 108C

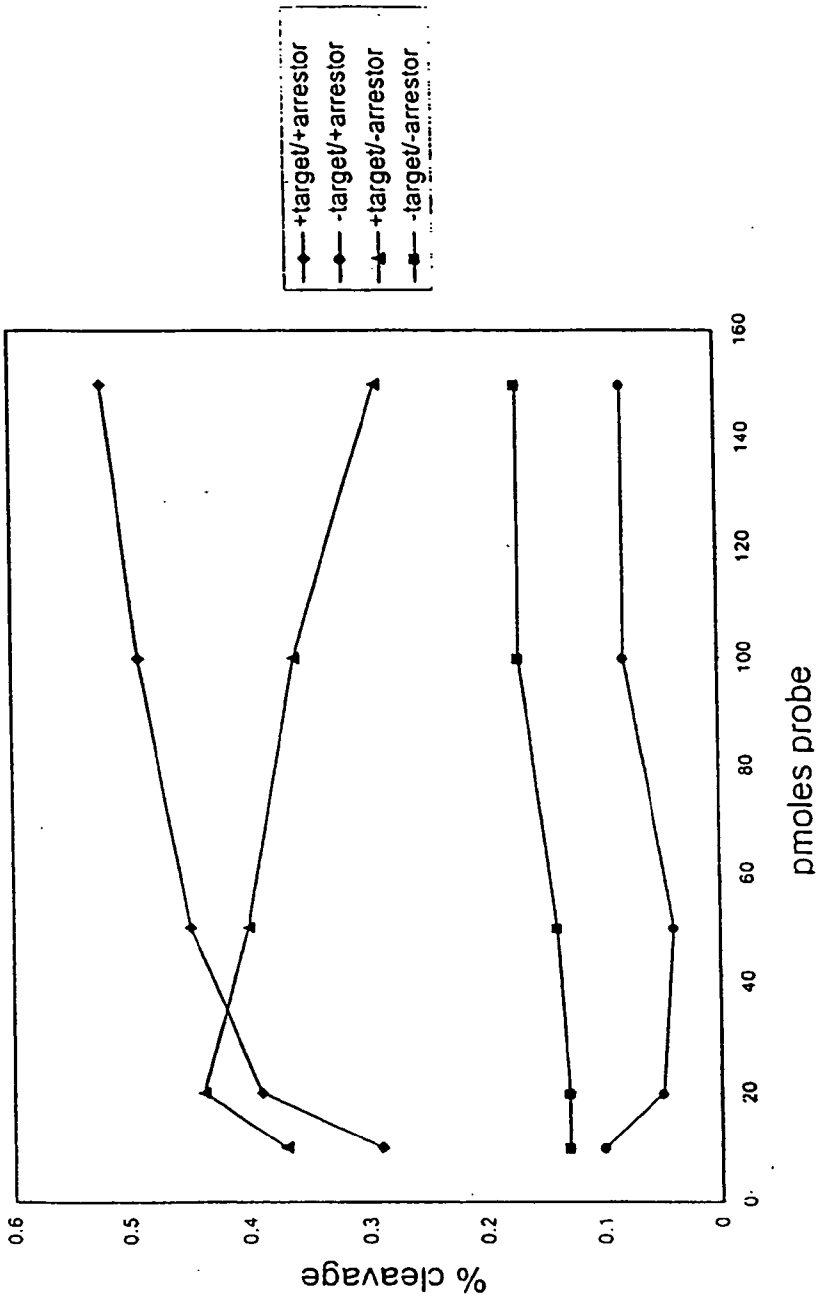

+target/+arrestor
-target/+arrestor
+target/-arrestor
-target/-arrestor
% cleavage
0.6
0.5
0.4
0.3
0.2
0.1
0
pmoles probe
0
20
40
60
80
100
120
140
160

FIGURE 109A

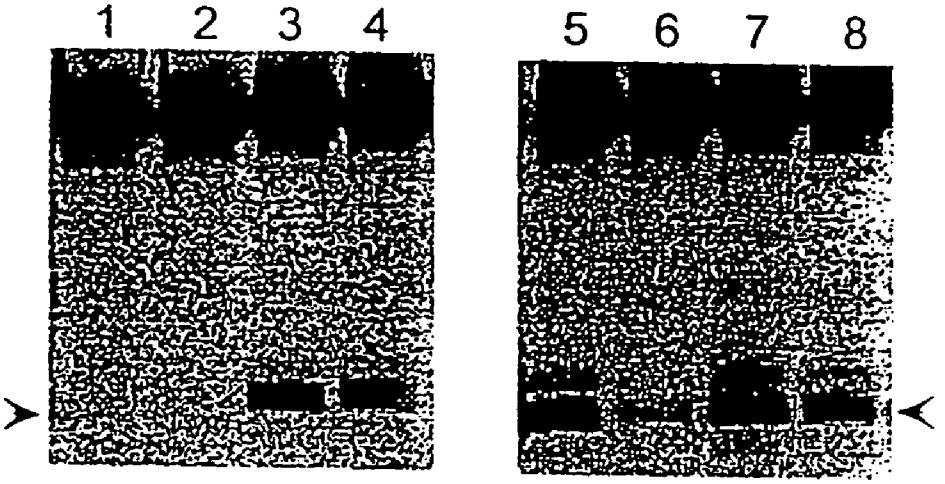


FIGURE 109B

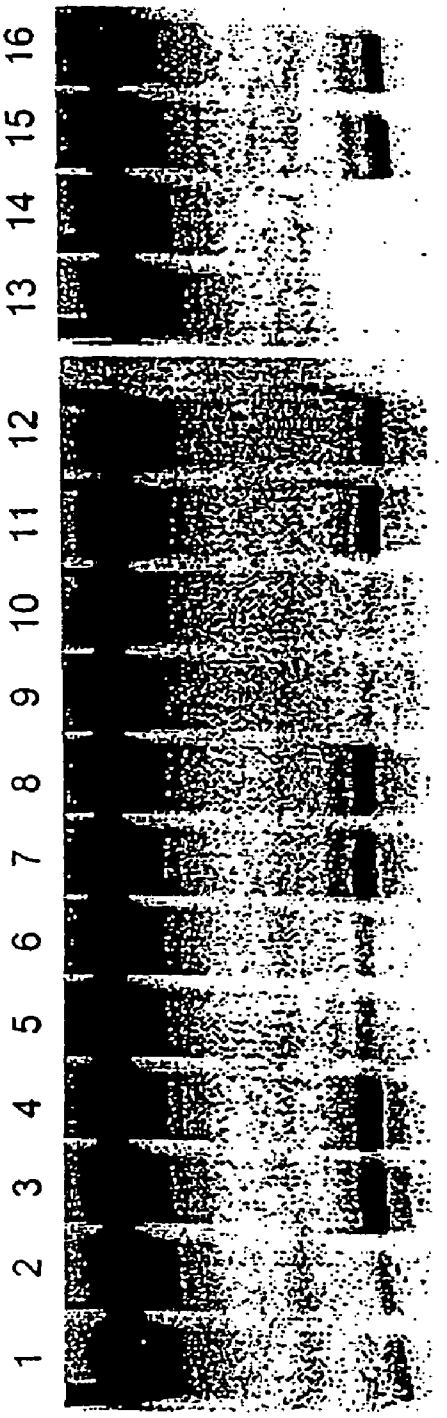


FIGURE 110A

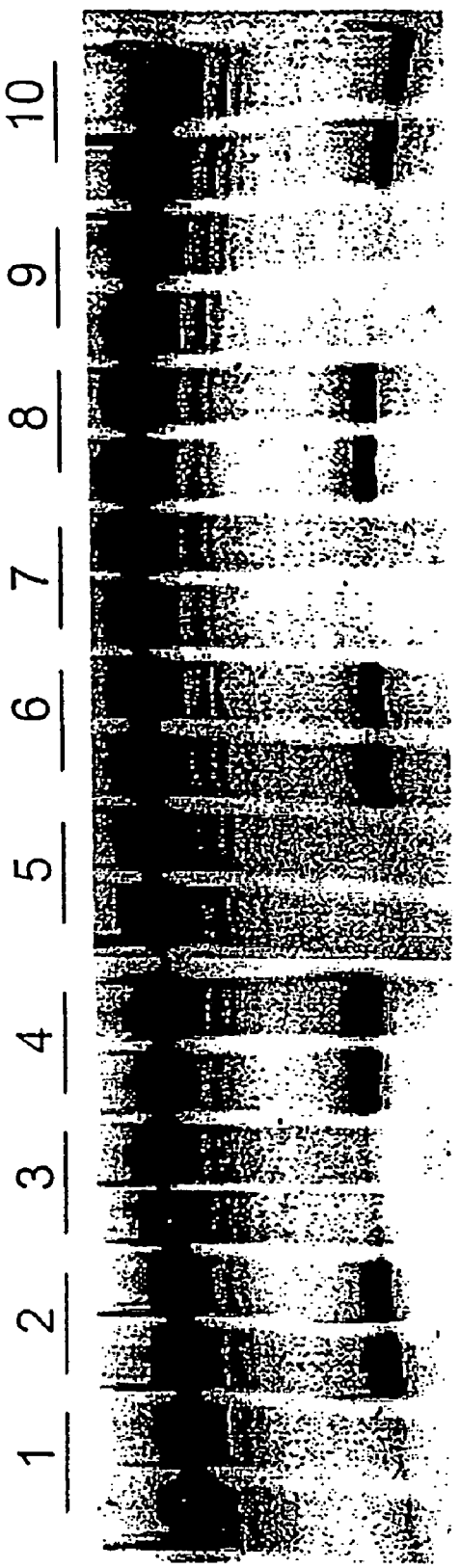
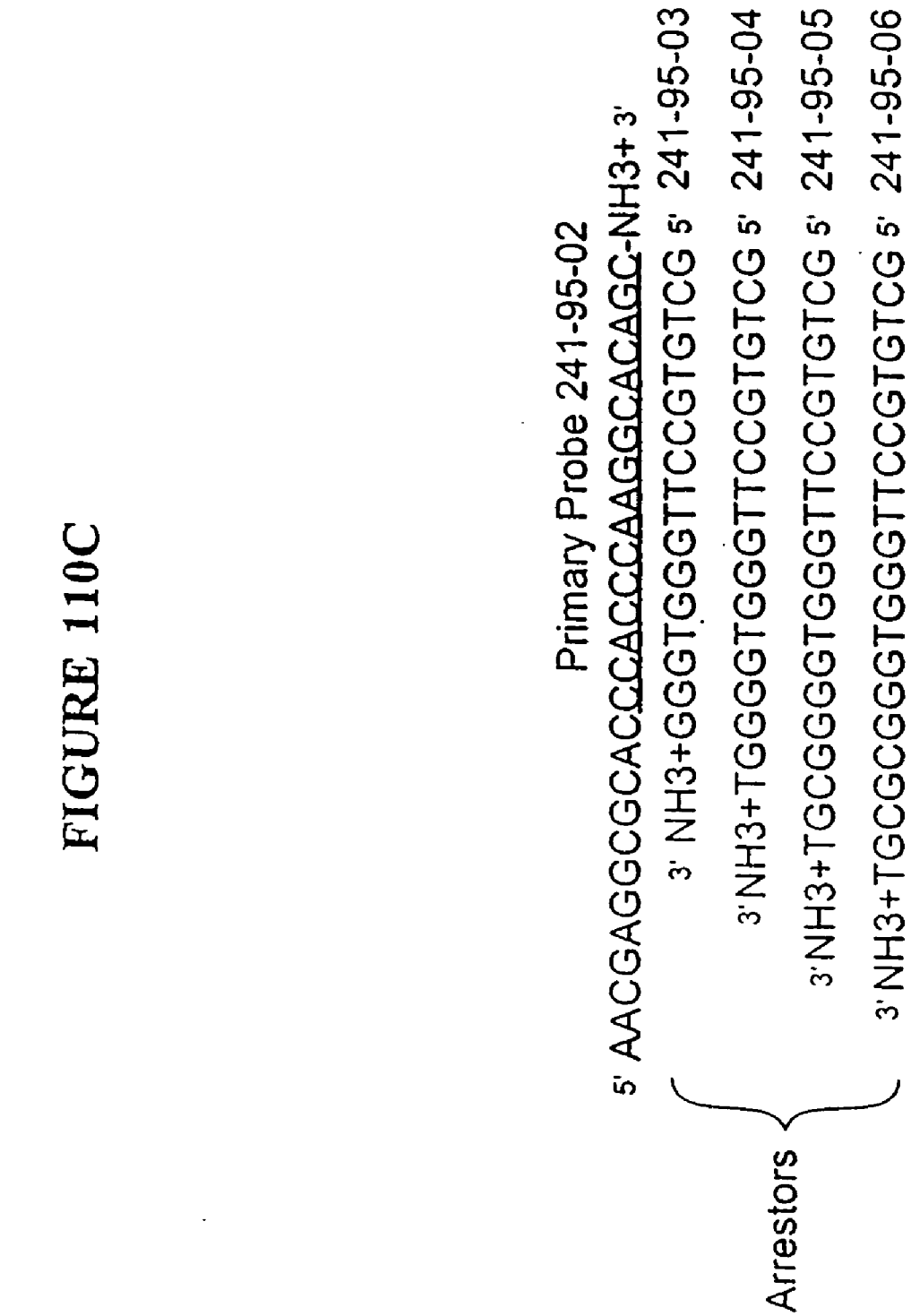


FIGURE 110B



FIGURE 110C


Primary Probe 241-95-02
5' AACGAGGCGCACCCACCCAAGGCACAGC-NH3+ 3'
Arrestors
3' NH3+GGGTGGGTTCCGTGTCG 5' 241-95-03
3'NH3+TGGGGTGGGTTCCGTGTCG 5' 241-95-04
3'NH3+TGCGGGGTGGGTTCCGTGTCG 5' 241-95-05
3'NH3+TGCGCGGGGTGGGTTCCGTGTCG 5' 241-95-06

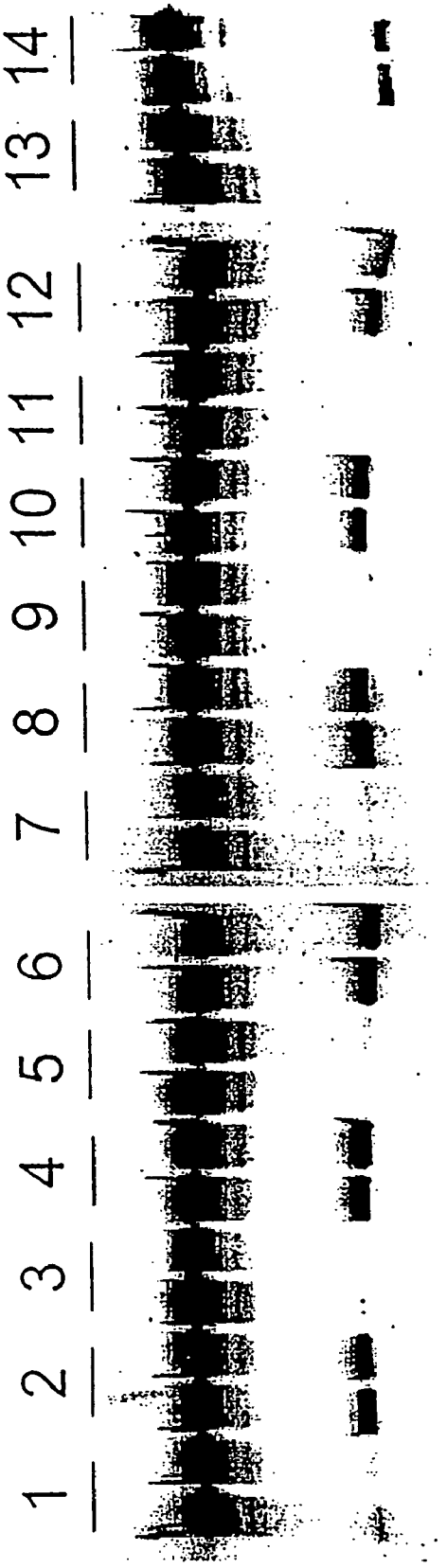
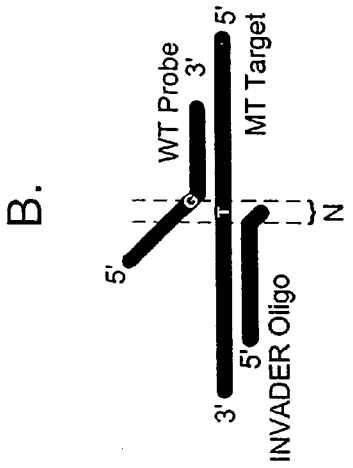


FIGURE 111

FIGURE 112


B.
WT Probe
3'
5'
MT Target
5'
G
T
N
5'
3'
5'
INVADER Oligo

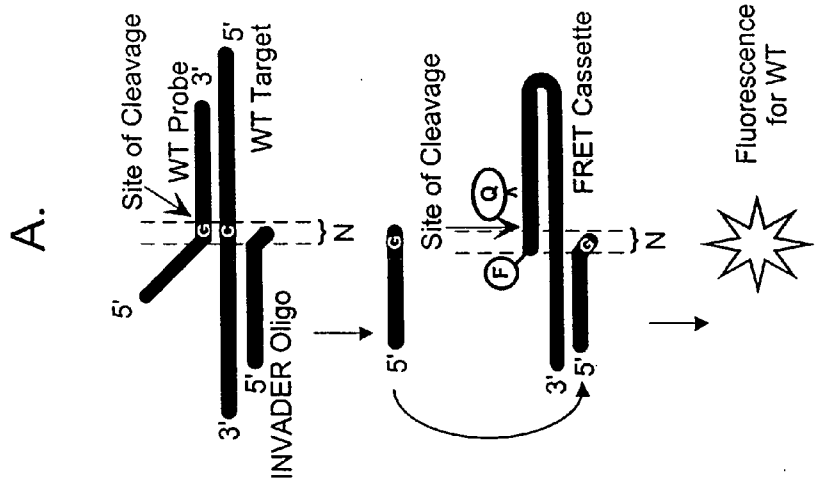

A.
Site of Cleavage
WT Probe
3'
5'
WT Target
G
C
C
N
5'
3'
5'
INVADER Oligo
5'
G
Site of Cleavage
Q
X
F
FRET Cassette
G
N
3'
5'
Fluorescence
for WT

FIGURE 113A

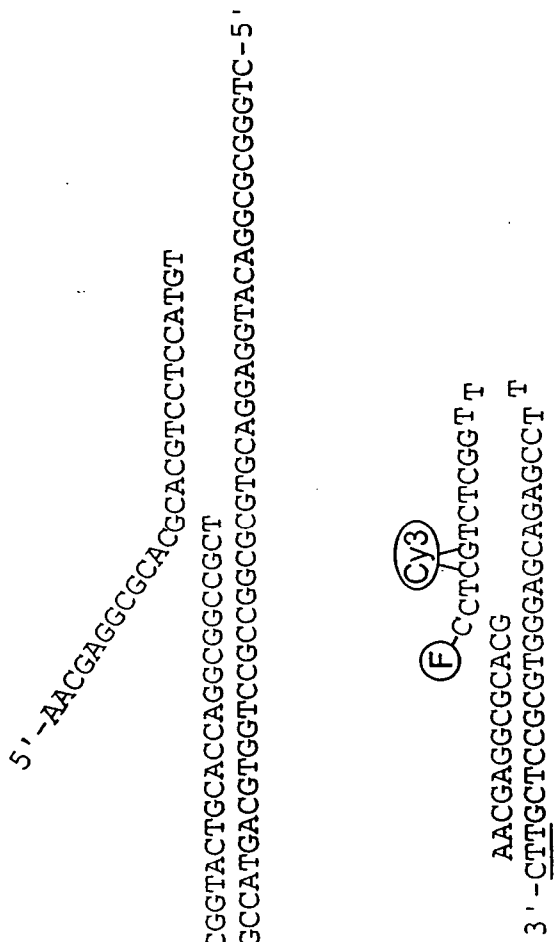

5'-AACGAGGCGCACGCACGTCCTCCATGT
5'-CGGTACTGCACCAGGCGGCCGCT
3'-GAGCGGCGCCATGACGTGGTCCGCCGGCGCGTGCAGGAGGTACAGGCGCGGGTC-5'
F
Cy3
CCTCGTCTCGGTT
AACGAGGCGCACG
3'-CTTGCTCCGCGTGGGAGCAGAGCCTT

FIGURE 113B

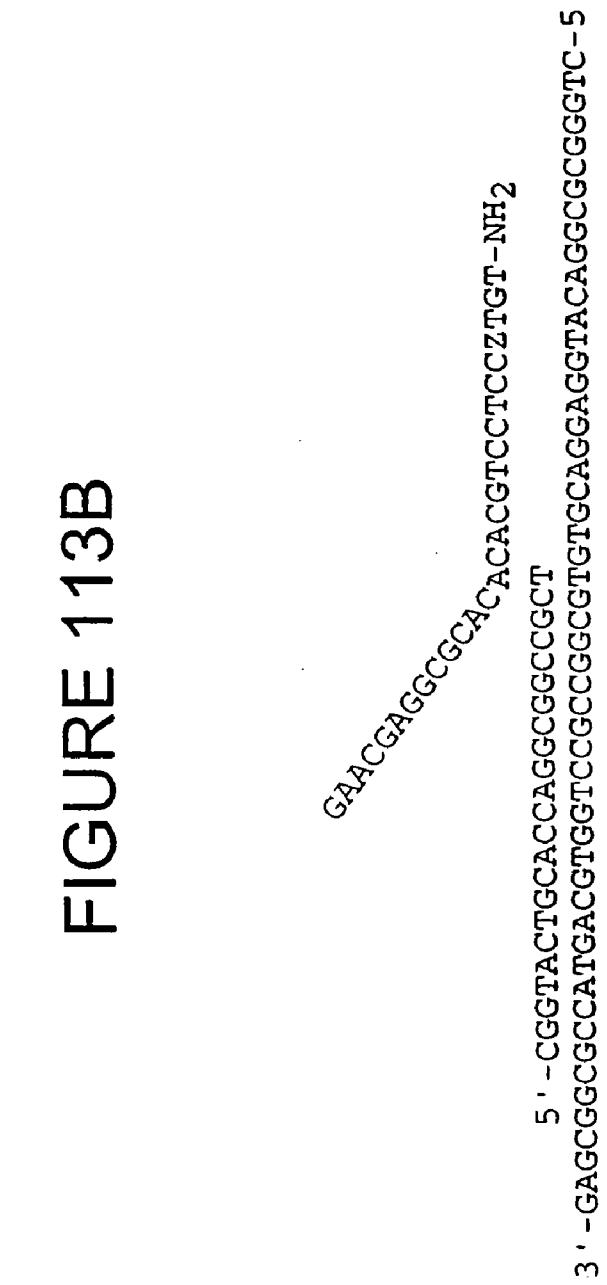

GAACGAGGCGCAC
ACACGTCCTCCTCCZTGT-NH2
5'-CGGTACTGCACCAGGCGGCCGCT
3'-GAGCGGCGCCATGACGTGGTCCGCCGGCGTGTGCAGGAGGTACAGGCGCGGGTC-5'
Cy3
F
CCTCGTCTCGGTT
AACGAGGCGCACA
3'-CTTGCTCCGCGTGGGAGCAGAGCCT T

FIGURE 113C

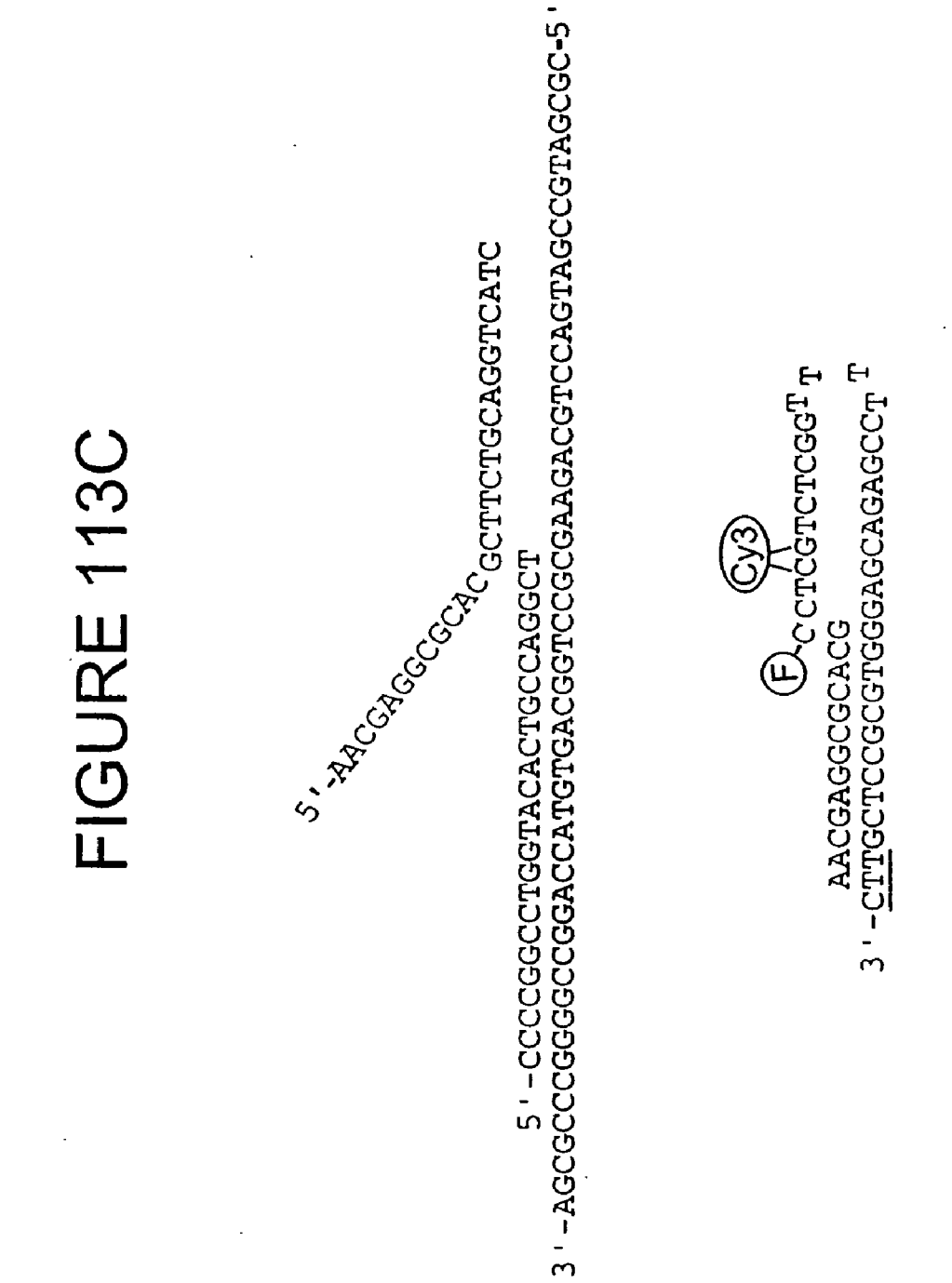

5'-AACGAGGCGCACGCTTCTGCAGGTCATC
5'-CCCCGGCCTGGTACACTGCCAGGCT
3'-AGCGCCCGGGGCCGGACCATGTGACGGTCCGCGAAGACGTCCAGTAGCCGTAGCGC-5'
Cy3
F
CCTCGTCTCGGT T
AACGAGGCGCACG
3'-CTTGCTCCGCGTGGGAGCAGAGCCT T

FIGURE 113D

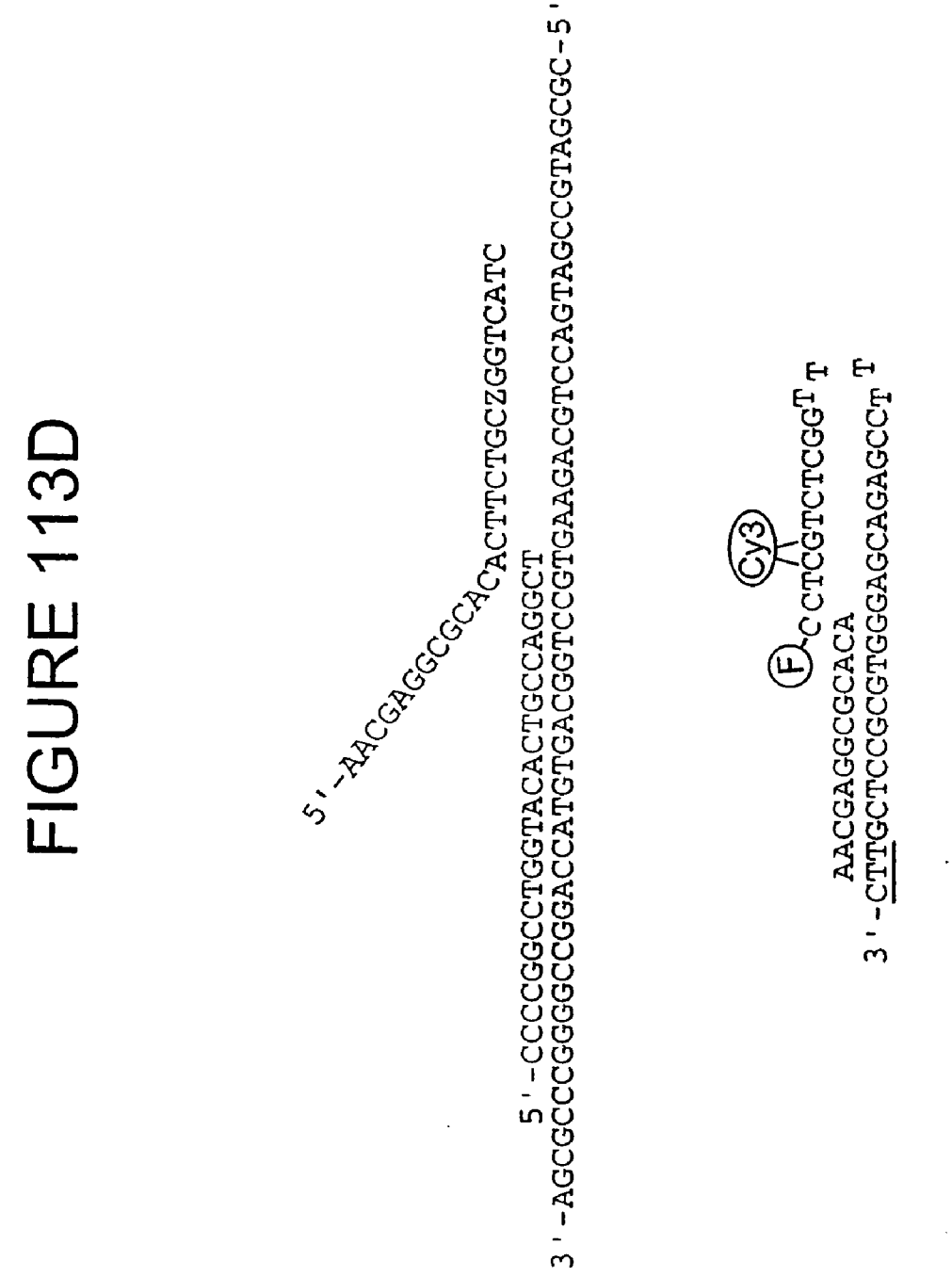
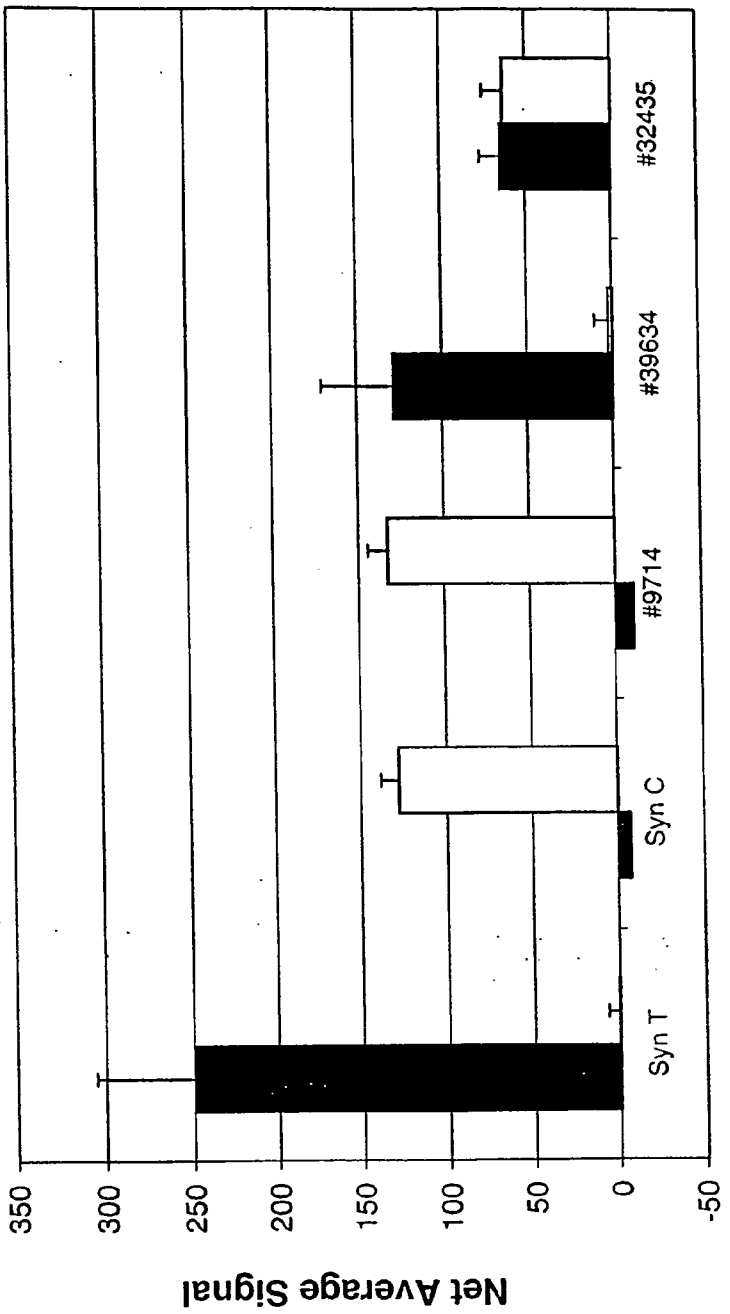

5'-AACGAGGCGCACACTTCTGCZGGTCATC
5'-CCCCGGCCTGGTACACTGCCAGGCT
3'-AGCGCCCGGGGCCGGACCATGTGACGGTCCGTGAAGACGTCCAGTAGCCGTAGCGC-5'
Cy3
F
C CTCGTCTCGGT T
AACGAGGCGCACA
3'-CTTGCTCCGCGTGGGAGCAGAGCC T T

FIGURE 114A


Net Average Signal
350
300
250
200
150
100
50
0
-50
Syn T
Syn C
#9714
#39634
#32435

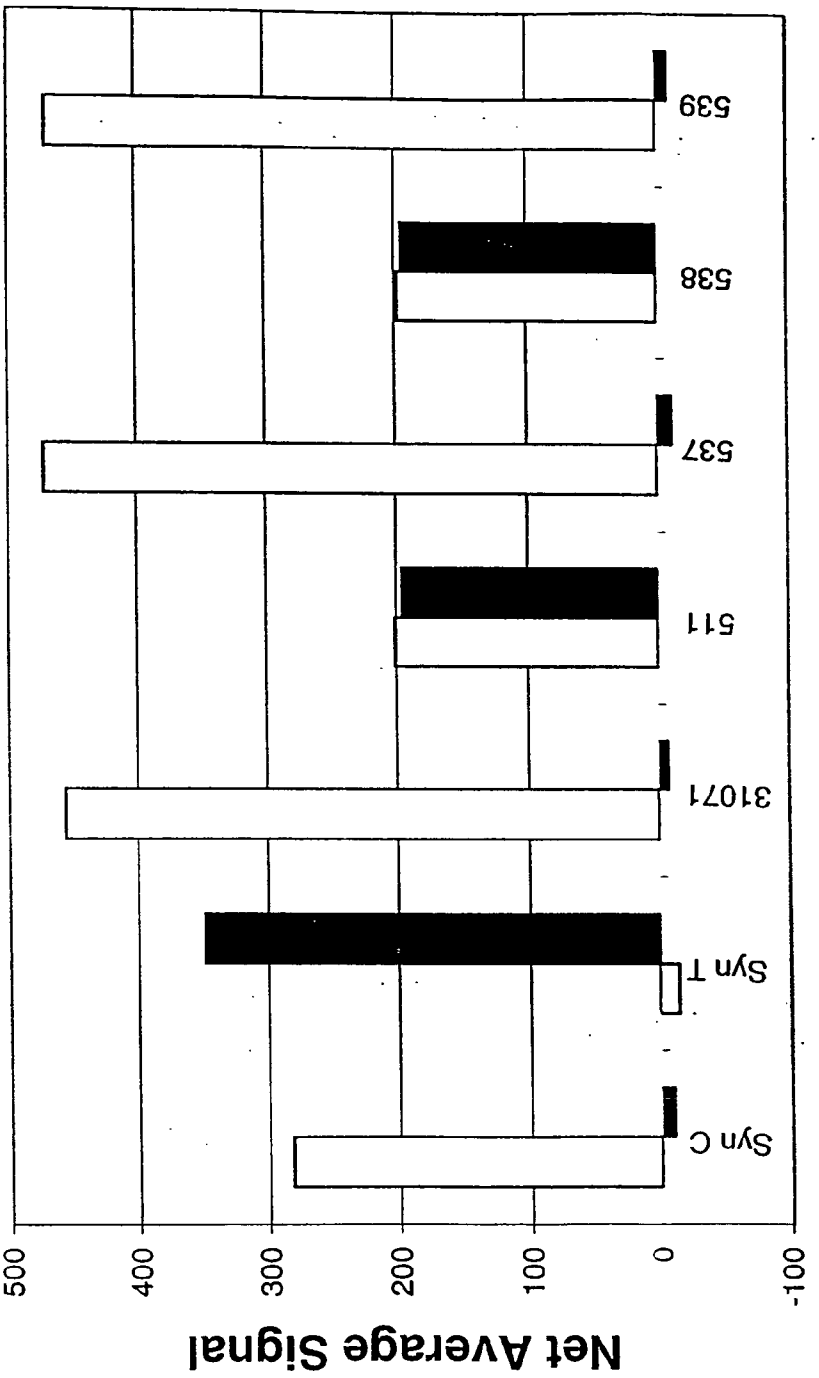

Net Average Signal
500
400
300
200
100
0
-100
Syn C
Syn T
31071
511
537
538
539

FIGURE 114B

FIGURE 115A

5'-AACGAACGCGCAGGCCAGGTGGAGCATTT-3'
5'-CCCCTGGGGAAGAGCAGAGATATACGTC
3'-GACCCCTTCTCGTCTCTATATGCACGGTCCACCTCGTGG-5'
F
CY3
CTCC GTCTCGGT T
AACGAACGCGCAGG

FIGURE 115B

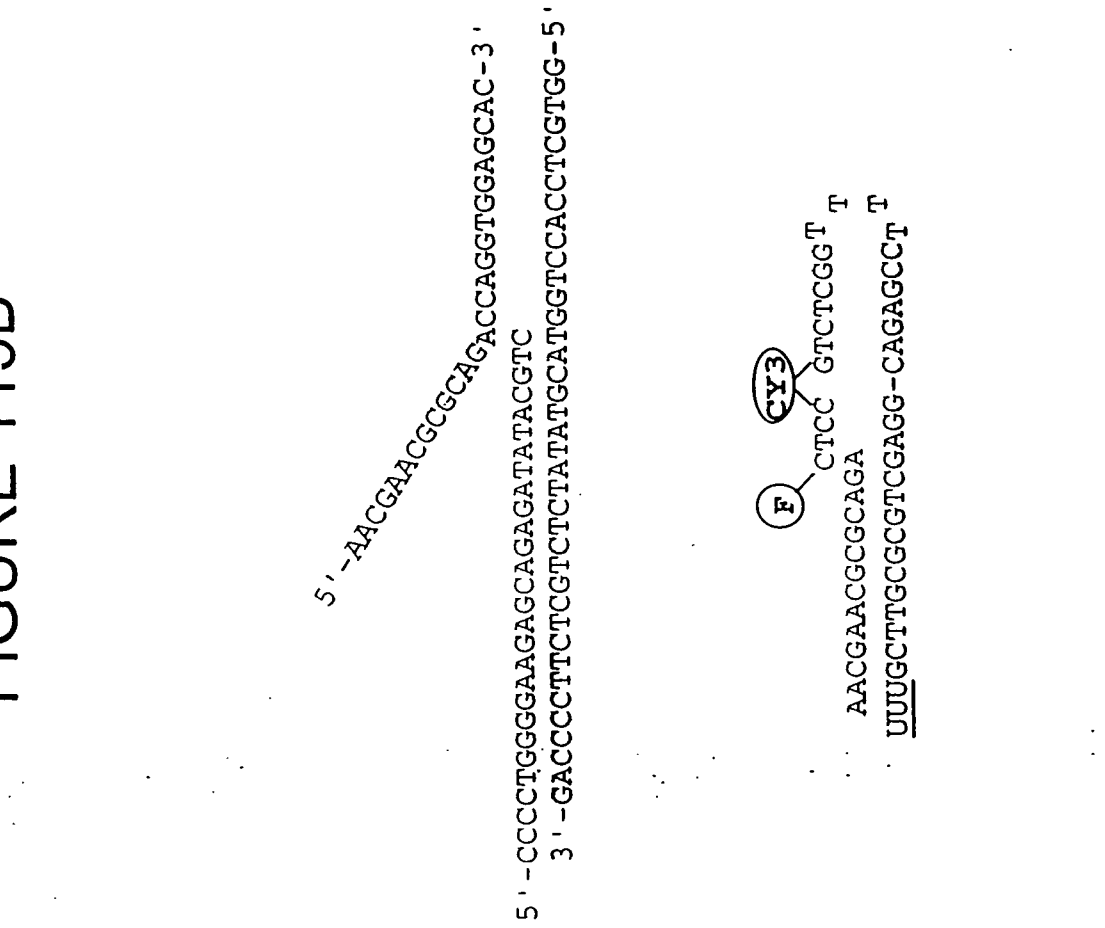

5'-AACGAACGCGCAGACCAGGTGGAGCAC-3'
5'-CCCCTGGGGAAGAGCAGAGATATACGTC
3'-GACCCCTTCTCGTCTCTATATGCATGGTCCACCTCGTGG-5'
F
CY3
CTCC GTCTCGG T T
AACGAACGCGCAGA
UUUGCTTGCGCGTCGAGG-CAGAGCCT T

FIGURE 115C

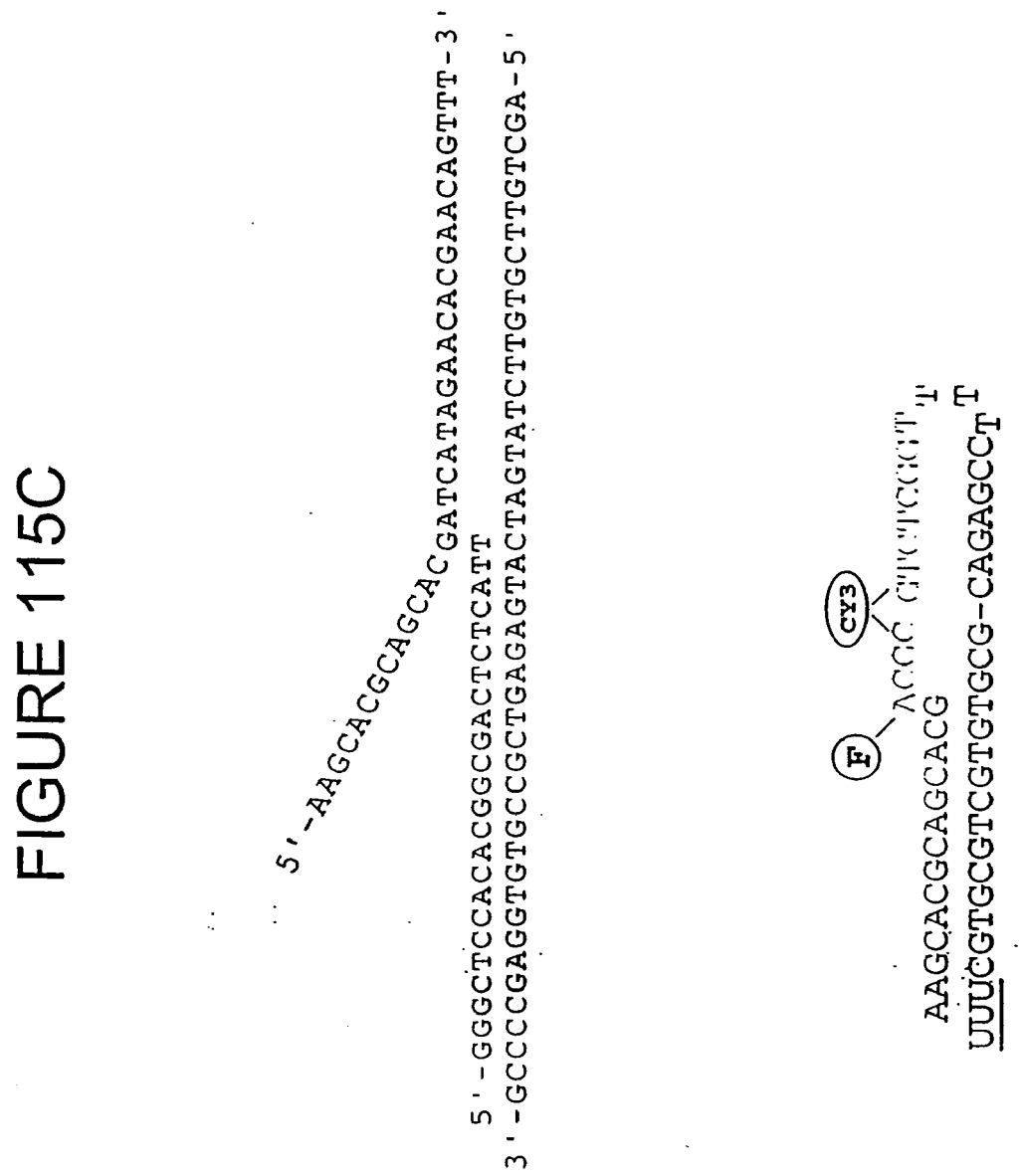

5'-AAGCACGCAGCACGATCATAGAACACGAACAGTTT-3'
5'-GGGCTCCACACGGCGACTCTCATT
3'-GCCCCGAGGTGTGCCGCTGAGAGTACTAGTATCTTGTGCTTGTCGA-5'
F
CY3
AAGCACGCAGCACG
UUUCGTGCGTCGTGTGCG-CAGAGCCT

FIGURE 115D

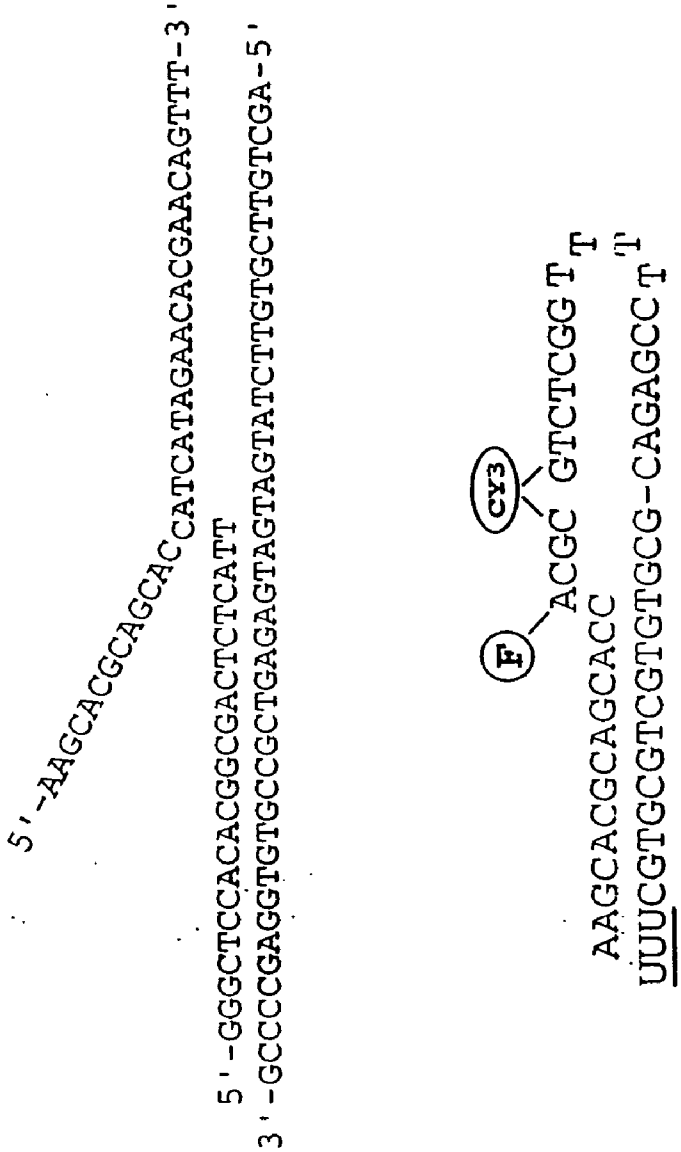

5'-AAGCACGCAGCACCATCATAGAACACGAACAGTTT-3'
5'-GGGCTCCACACGGCGACTCTCATT
3'-GCCCCGAGGTGTGCCGCTGAGAGTAGTAGTATCTTGTGCTTGTCGA-5'
F
CY3
ACGC GTCTCGG T T
AAGCACGCAGCACC
UUUCGTGCGTCGTGTGCG-CAGAGCC T T

FIGURE 116

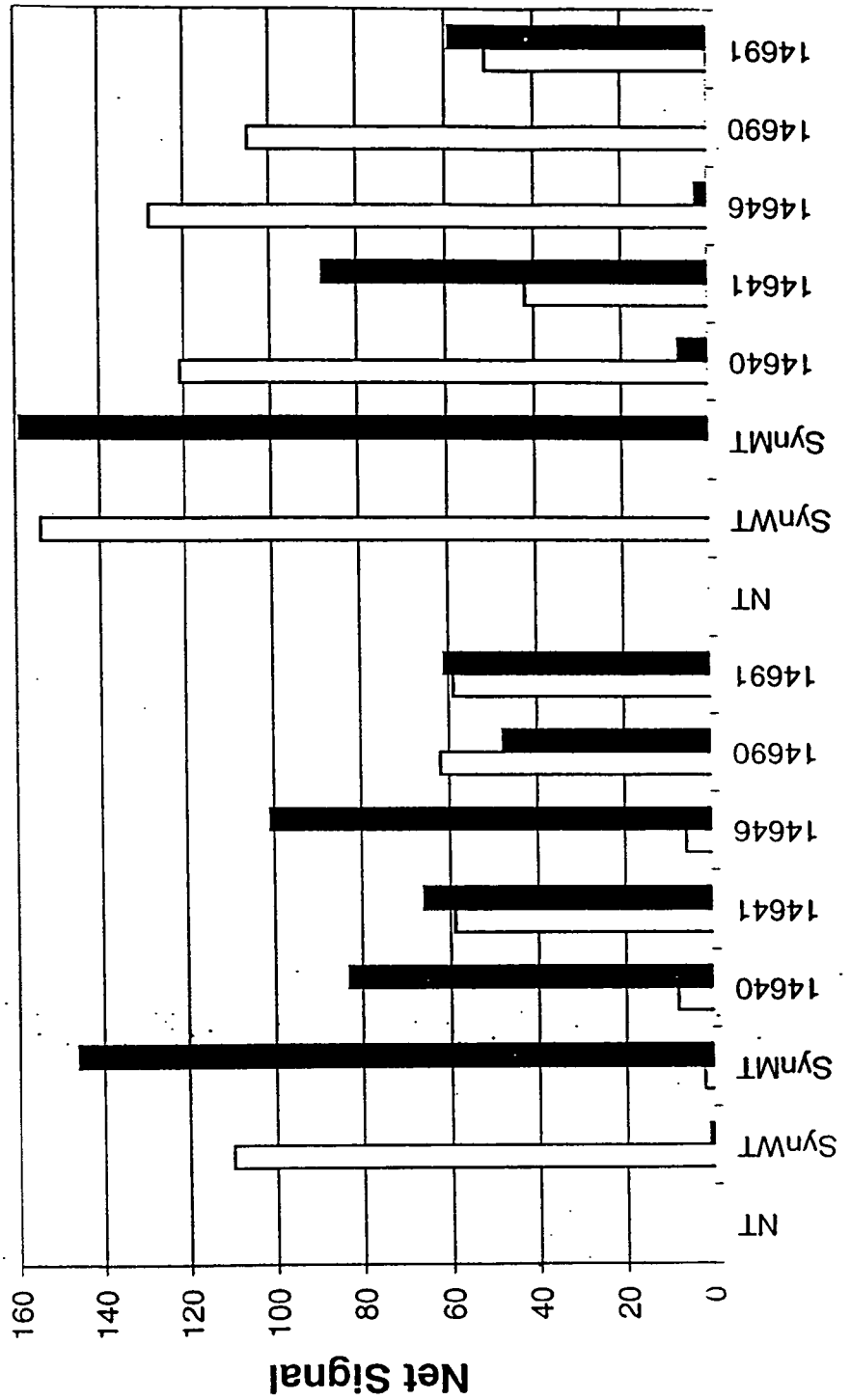

14691
14690
14646
14641
14640
SynMT
SynWT
NT
14691
14690
14646
14641
14640
SynMT
SynWT
NT
160
140
120
100
80
60
40
20
0
Net Signal

FIGURE 117A

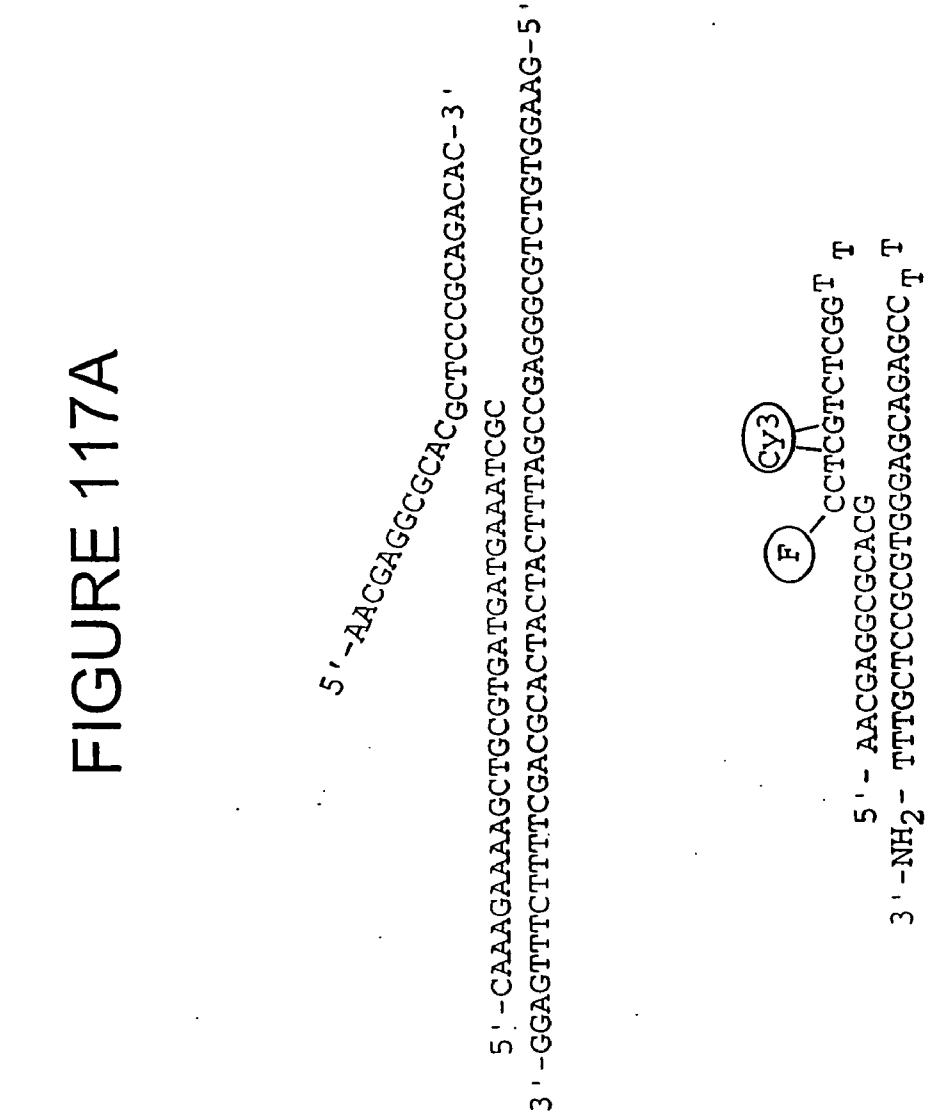

5'-AACGAGGCGCACGCTCCCGCAGACAC-3'
5'-CAAAGAAAAGCTGCGTGATGATGAAATCGC
3'-GGAGTTTCTTTTCGACGCACTACTACTTTAGCCGAGGGCGTCTGTGGAAG-5'
Cy3
F
CCTCGTCTCGGT T
5'- AACGAGGCGCACG
3'-NH2- TTTGCTCCGCGTGGGAGCAGAGCC T T

FIGURE 117B

5'-AACGAGGCGCACACTCCCGCAGACACC-3'
5'-CAAAGAAAAGCTGCGTGATGATGAAATCGC
3'-GGAGTTTCTTTTCGACGCACTACTACTTTAGCTGAGGGCGTCTGTGGAAG-5'
Cy3
F
5'-AACGAGGCGCACA
3'-NH2-TTTGCTCCGCGTGGGAGCAGAGCC T

FIGURE 118

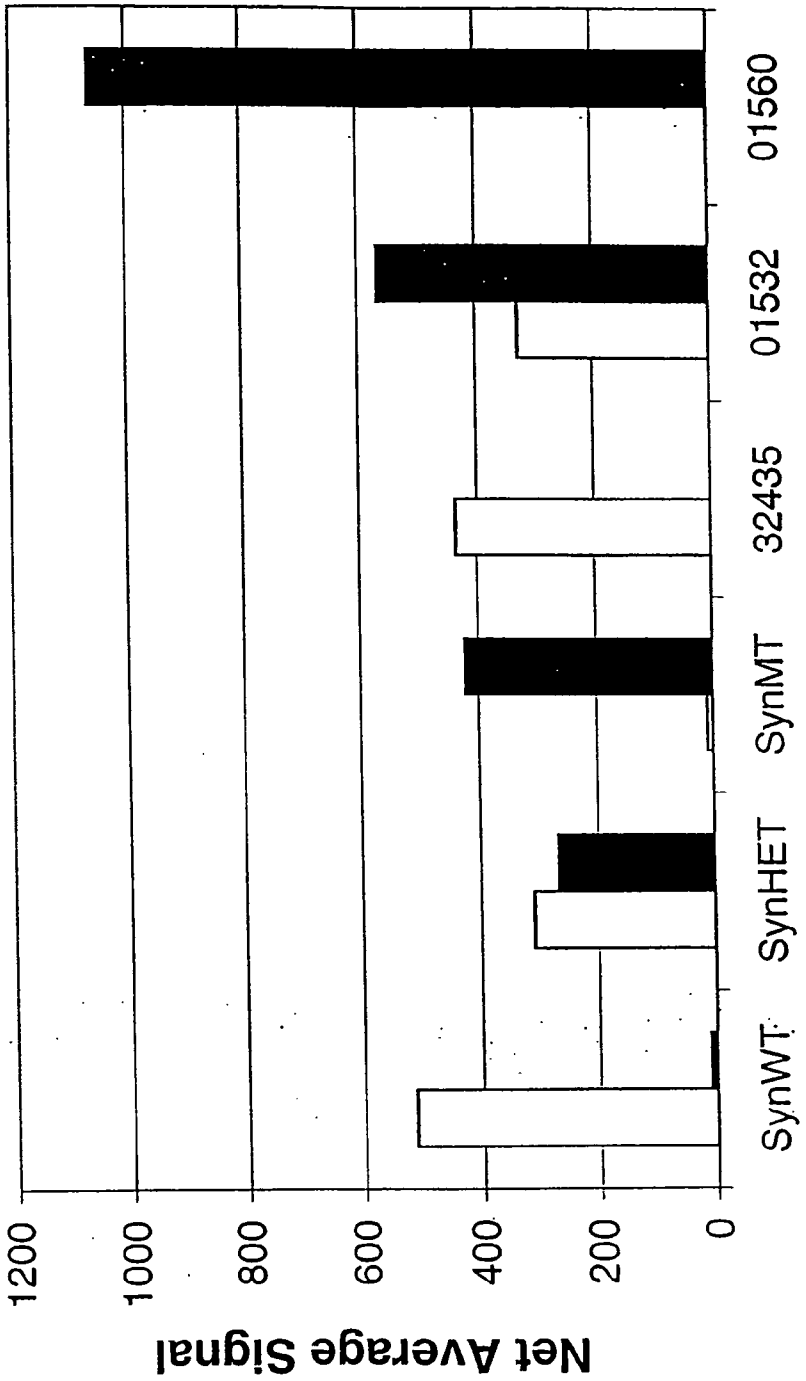

Net Average Signal
1200
1000
800
600
400
200
0
SynWT
SynHET
SynMT
32435
01532
01560

FIGURE 119A

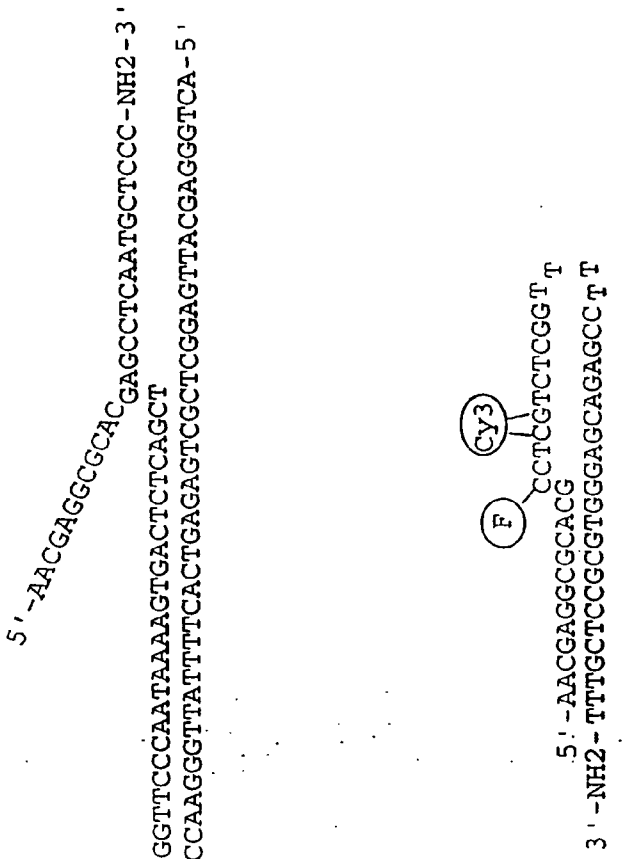

5'-AACGAGGCGCAC
GAGCCTCAATGCTCCC-NH2-3'
5'-TATGGTTCCCAATAAAGTGACTCTCAGCT
3'-TTGATACCAAGGGTTATTTTCACTGAGAGTCGCTCGGAGTTACGAGGGTCA-5'
Cy3
F
CCTCGTCTCGGT
T
5'-AACGAGGCGCACG
3'-NH2-TTTGCTCCGCGTGGGAGCAGAGCC
T
T

FIGURE 119B

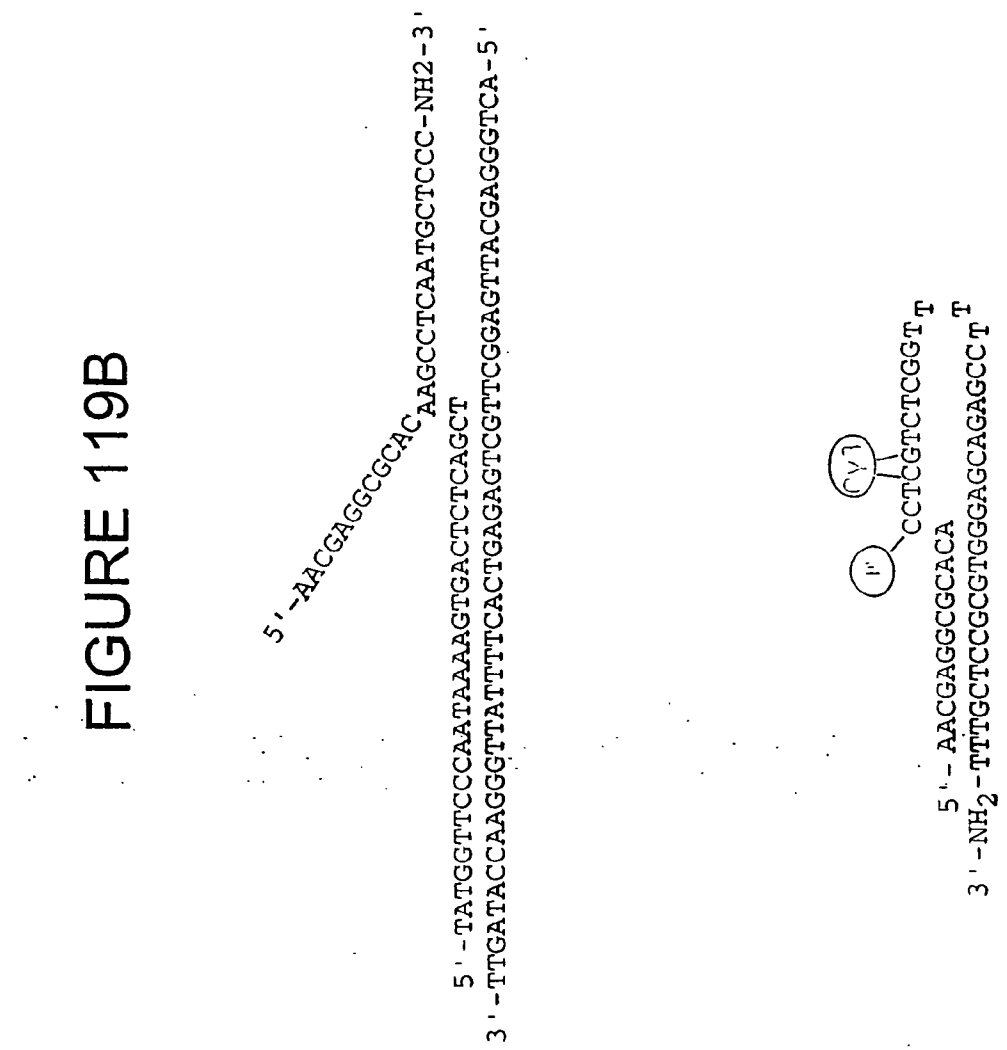

5'-AACGAGGCGCAC
AAGCCTCAATGCTCCC-NH2-3'
5'-TATGGTTCCCAATAAAAGTGACTCTCAGCT
3'-TTGATACCAAGGGTTATTTTCACTGAGAGTCGTTCGGAGTTACGAGGGTCA-5'
CCTCGTCTCGGTT
5'- AACGAGGCGCACA
3'-NH2-TTTGCTCCGCGTGGGAGCAGAGCCTT

FIGURE 120

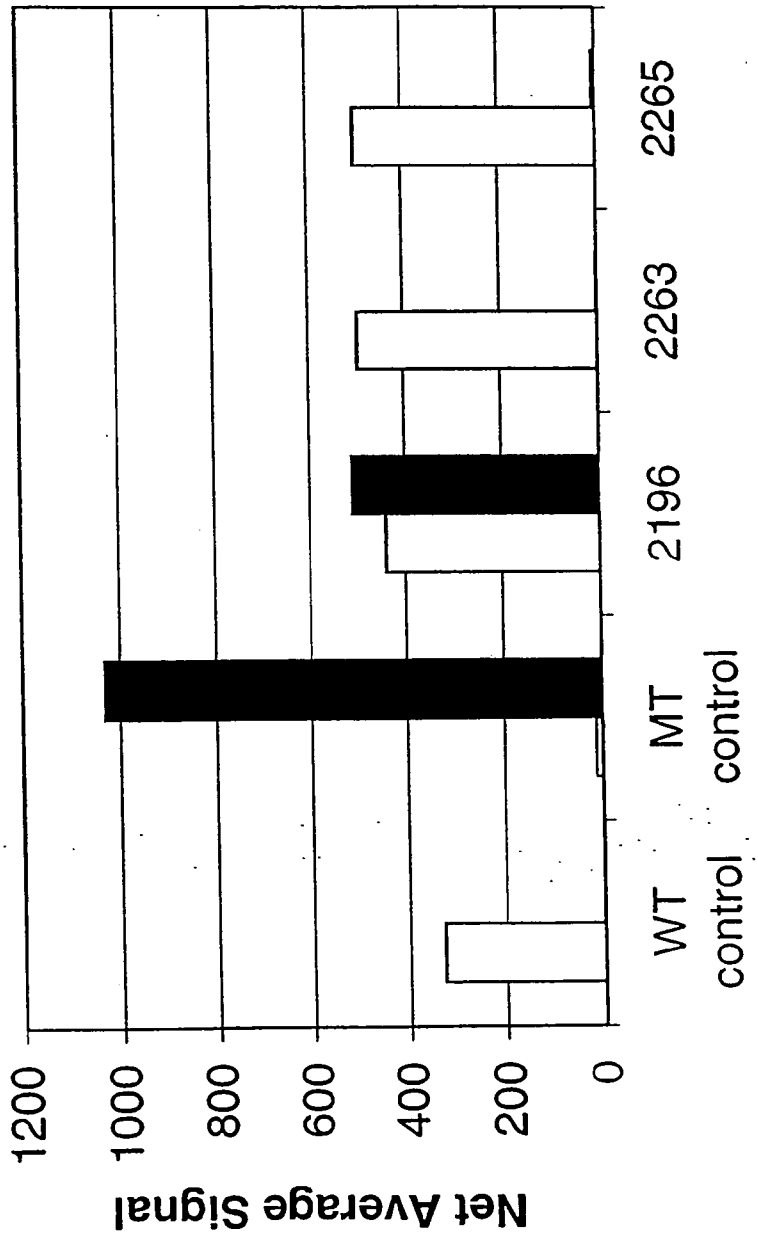

Net Average Signal
0
200
400
600
800
1000
1200
WT control
MT control
2196
2263
2265

FIGURE 121A

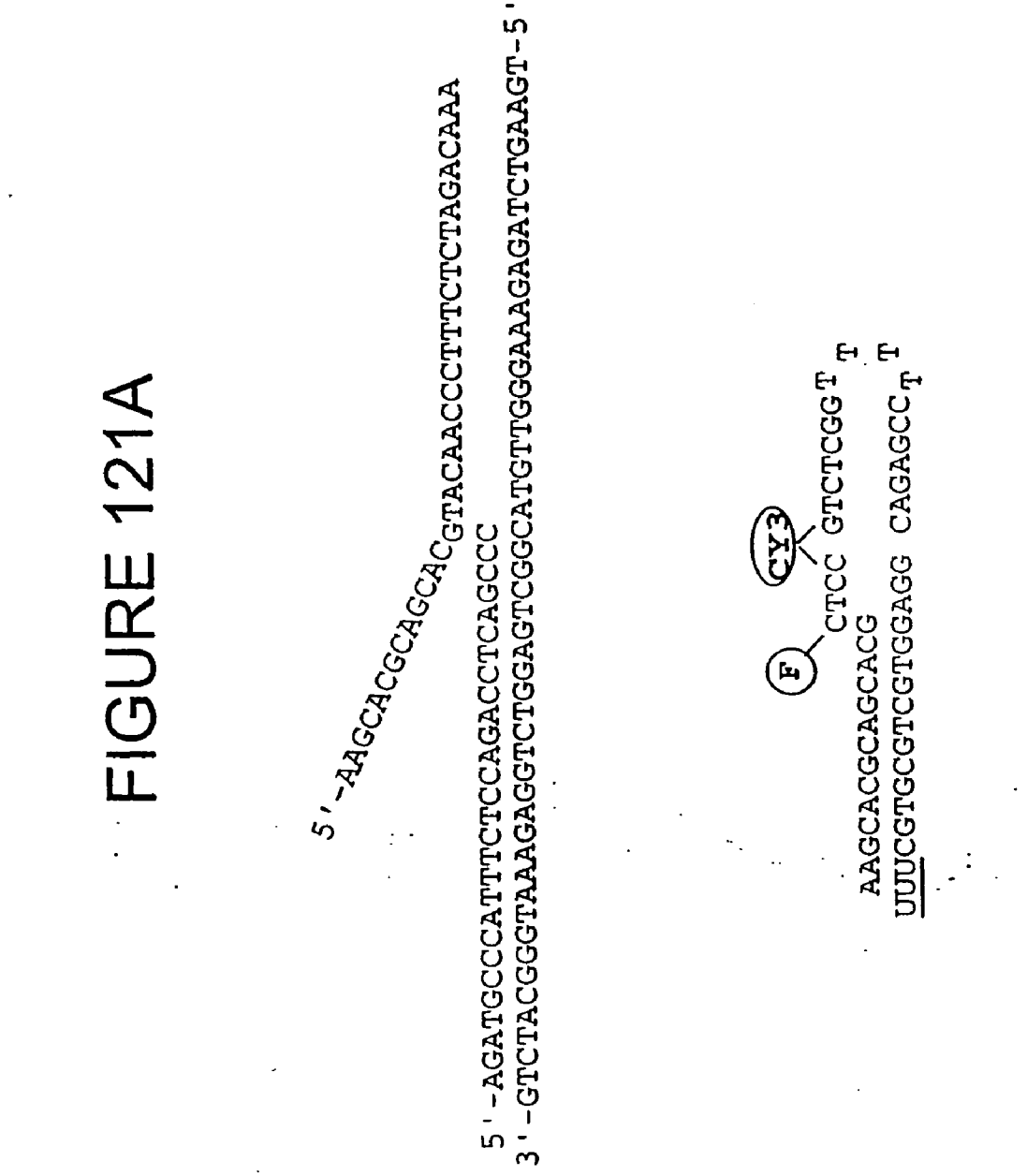

5'-AAGCACGCAGCACGTACAACCCTTTCTCTAGACAAA
5'-AGATGCCCATTTCTCCAGACCTCAGCCC
3'-GTCTACGGGTAAAGAGGTCTGGAGTCGGCATGTTGGGAAGAGATCTGAAGT-5'
F
CY3
CTCC GTCTCGGT T
T
AAGCACGCAGCACG
UUUCGTGCGTCGTGGAGG CAGAGCC T
T

FIGURE 121B

5'-AAGCACGCAGCACAGGAACCCTGTGACAT-3'
5'-CCATCCAGGGAAGAGTGGCCTGTTT
3'-GGGTAGGTCCCTTCTCACCGGACAATCCTTGGGACACTGTAAAGTTT-5'
F
CY3
AAGCACGCAGCACA
UUUCGTGCGTCGTGGAGG-CAGAGCC

FIGURE 122

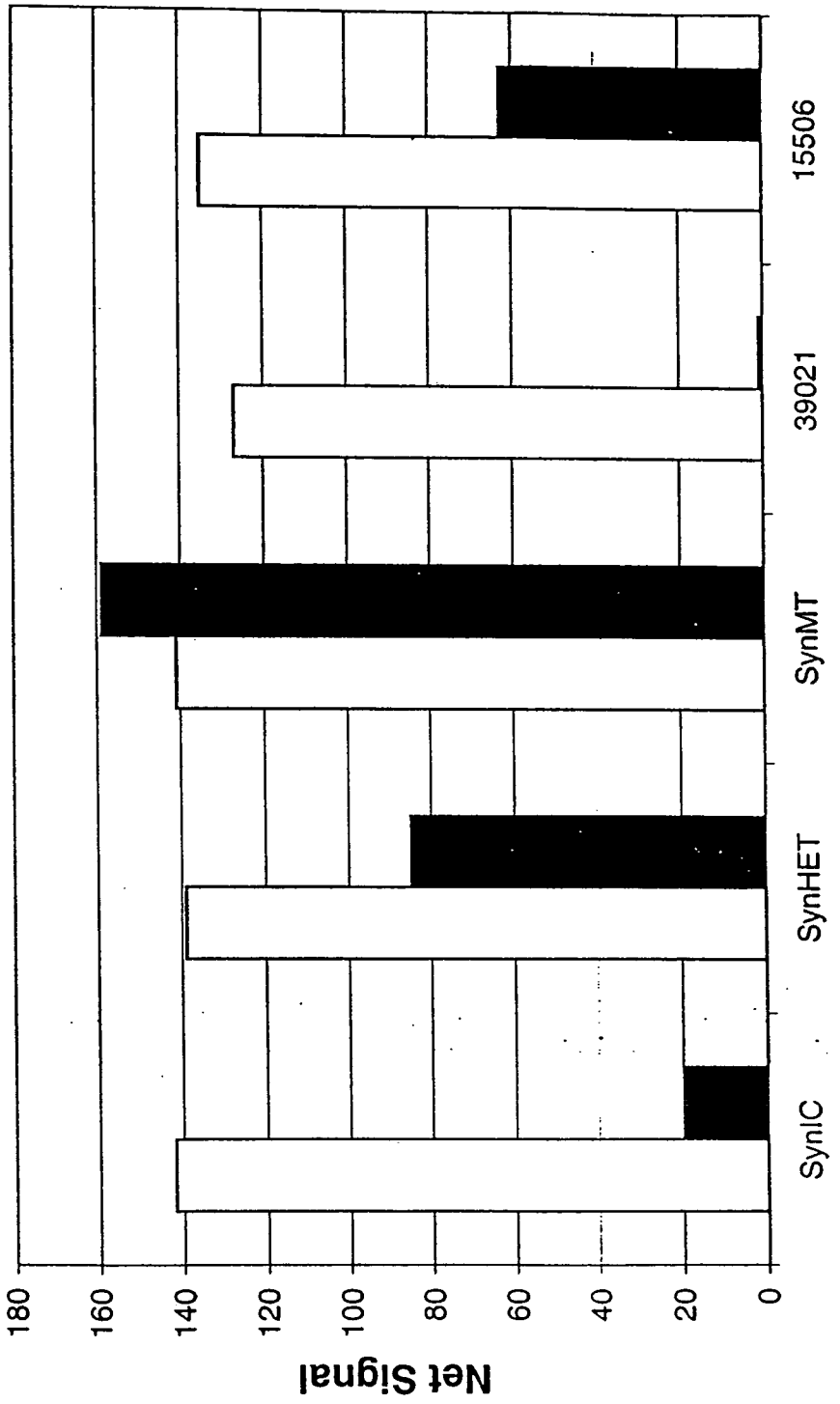

Net Signal
180
160
140
120
100
80
60
40
20
0
SynIC
SynHET
SynMT
39021
15506

FIGURE 123A

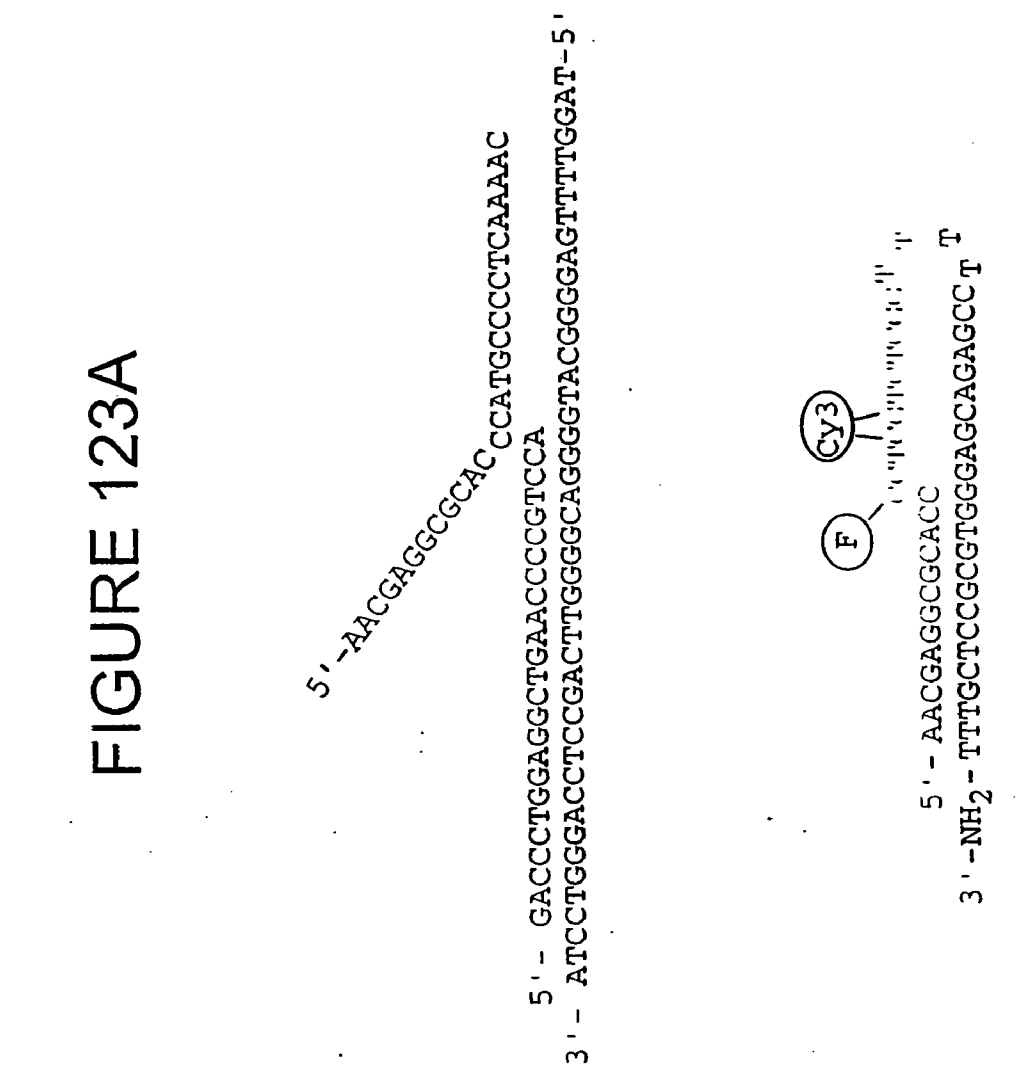

5'-AACGAGGCGCAC
CCATGCCCCTCAAAAC
5'- GACCCTGGAGGCTGAACCCCGTCCA
3'- ATCCTGGGACCTCCGACTTGGGGCAGGGGTACGGGGAGTTTTGGAT-5'
F
Cy3
5'- AACGAGGCGCACC
3'-NH2- TTTGCTCCGCGTGGGAGCAGAGCC T T

FIGURE 123B

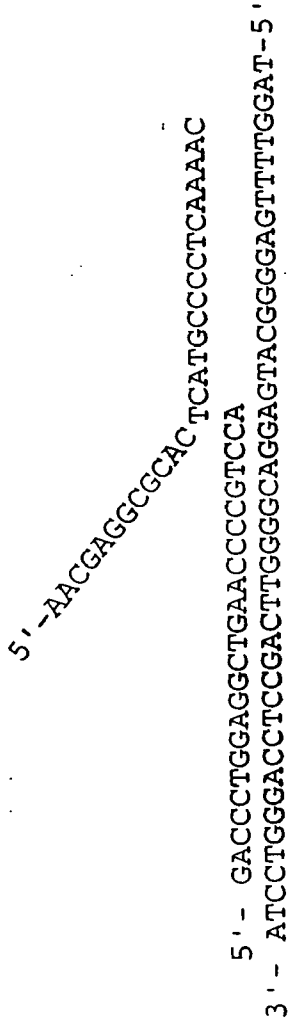

5'-AACGAGGCGCAC TCATGCCCCTCAAAAC
5'- GACCCTGGAGGCTGAACCCCGTCCA
3'- ATCCTGGGACCTCCGACTTGGGCAGGAGTACGGGGAGTTTTGGAT-5'
Cy3
F
CCTCGTCTCGGT T
5'- AACGAGGCGCACT
3'-NH2- TTTGCTCCGCGTGGGAGCAGAGCC T T

FIGURE 124

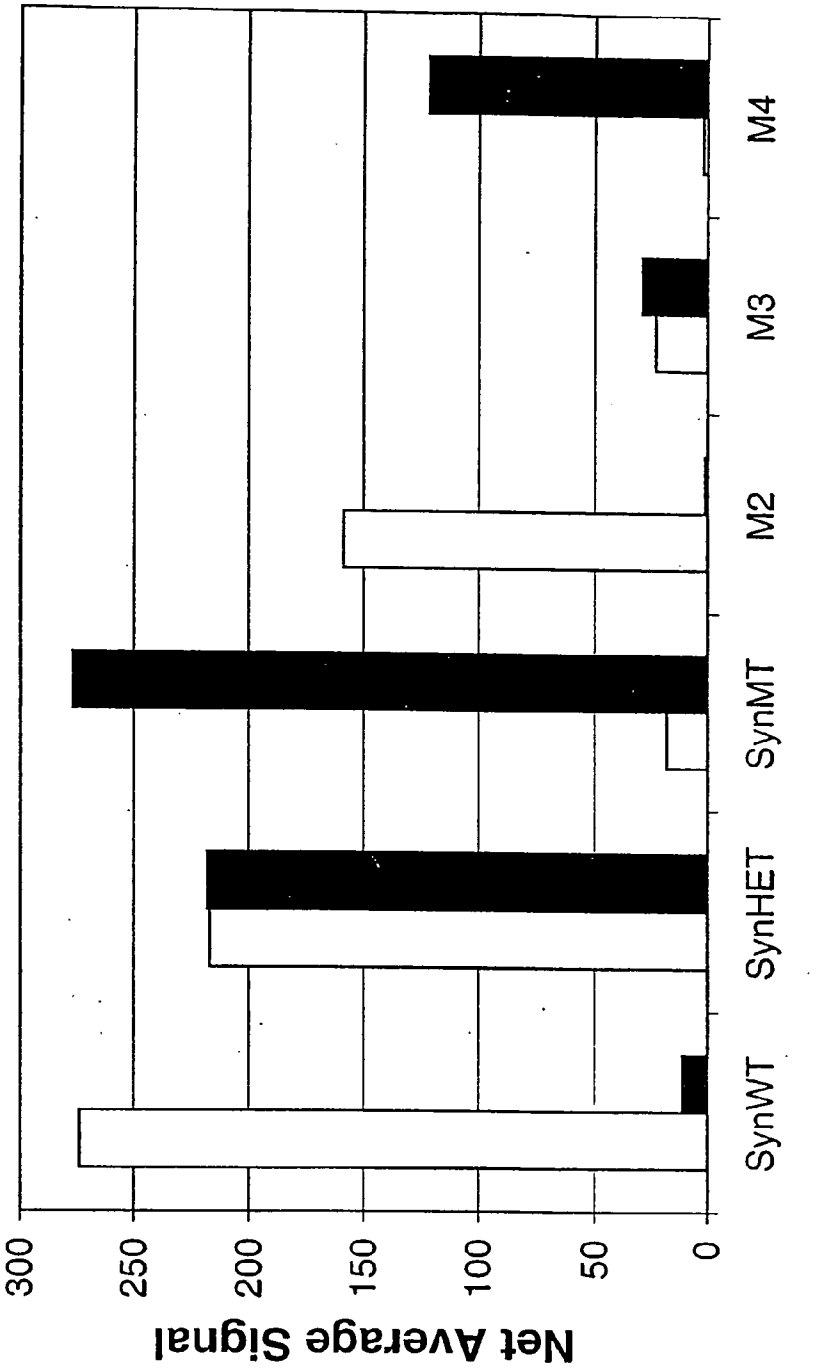

Net Average Signal
300
250
200
150
100
50
0
SynWT
SynHET
SynMT
M2
M3
M4

FIGURE 125A

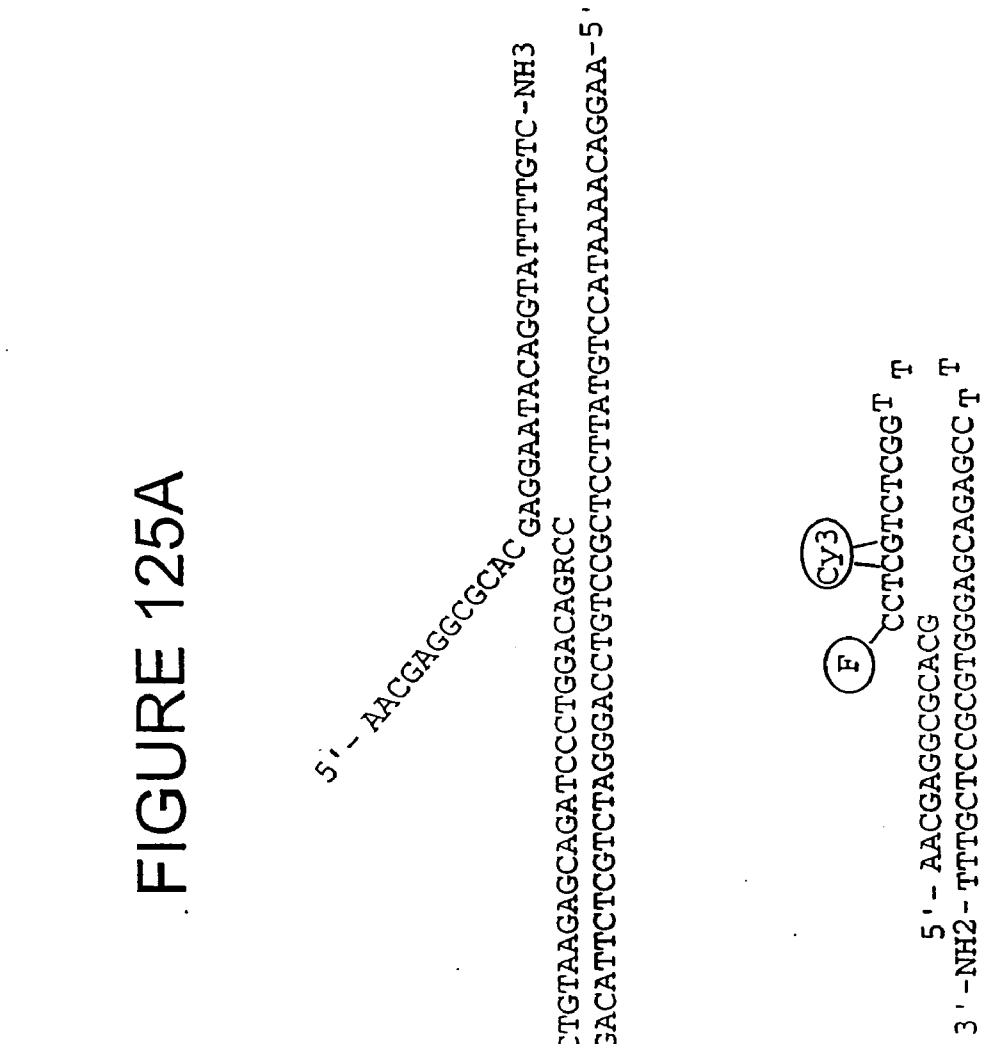

5'- AACGAGGCGCAC GAGGAATACAGGTATTTTGTC-NH3
5'- TAATCTGTAAGAGCAGATCCCTGGACAGRCC
3'- AGATTAGACATTCTCGTCTAGGGACCTGTCCGCTCCTTATGTCCATAAACAGGAA-5'
Cy3
F
CCTCGTCTCGGT T
T
5'- AACGAGGCGCACG
3'-NH2- TTTGCTCCGCGTGGGAGCAGAGCC T
T

FIGURE 125B

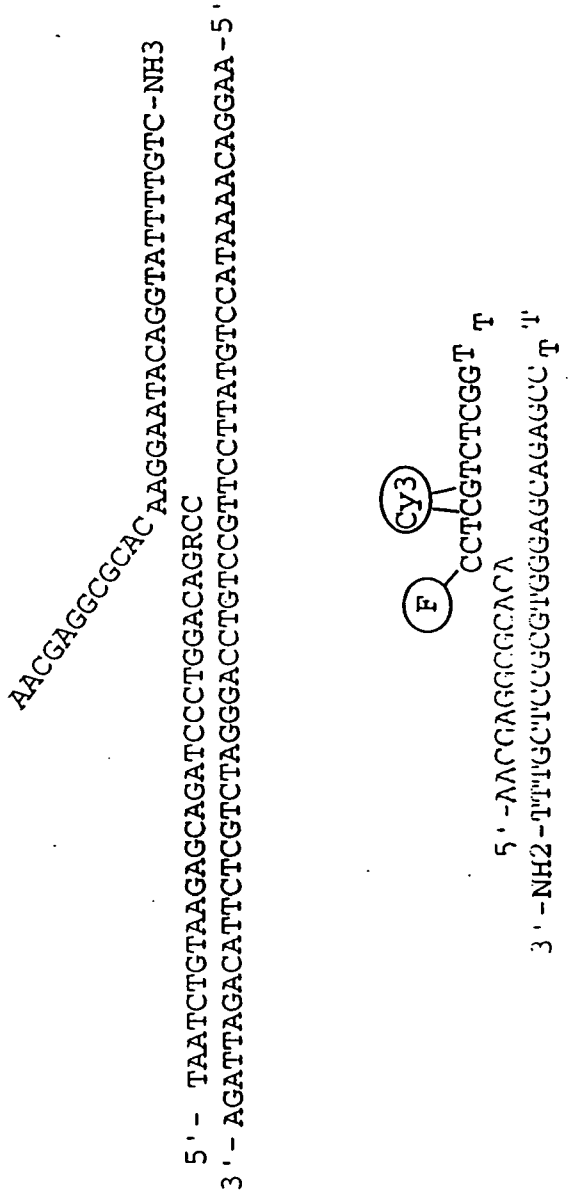

AACGAGGCGCAC
AAGGAATACAGGTATTTTGTC-NH3
5'- TAATCTGTAAGAGCAGATCCCTGGACAGRCC
3'- AGATTAGACATTCTCGTCTAGGGACCTGTCCGTTCCTTATGTCCATAAAACAGGAA-5'
F
Cy3
CCTCGTCTCGGT
T
5'-AACGAGGCGCAC
3'-NH2-TTTGCTCCGCGTGGGAGCAGAGCC
T
T

FIGURE 126

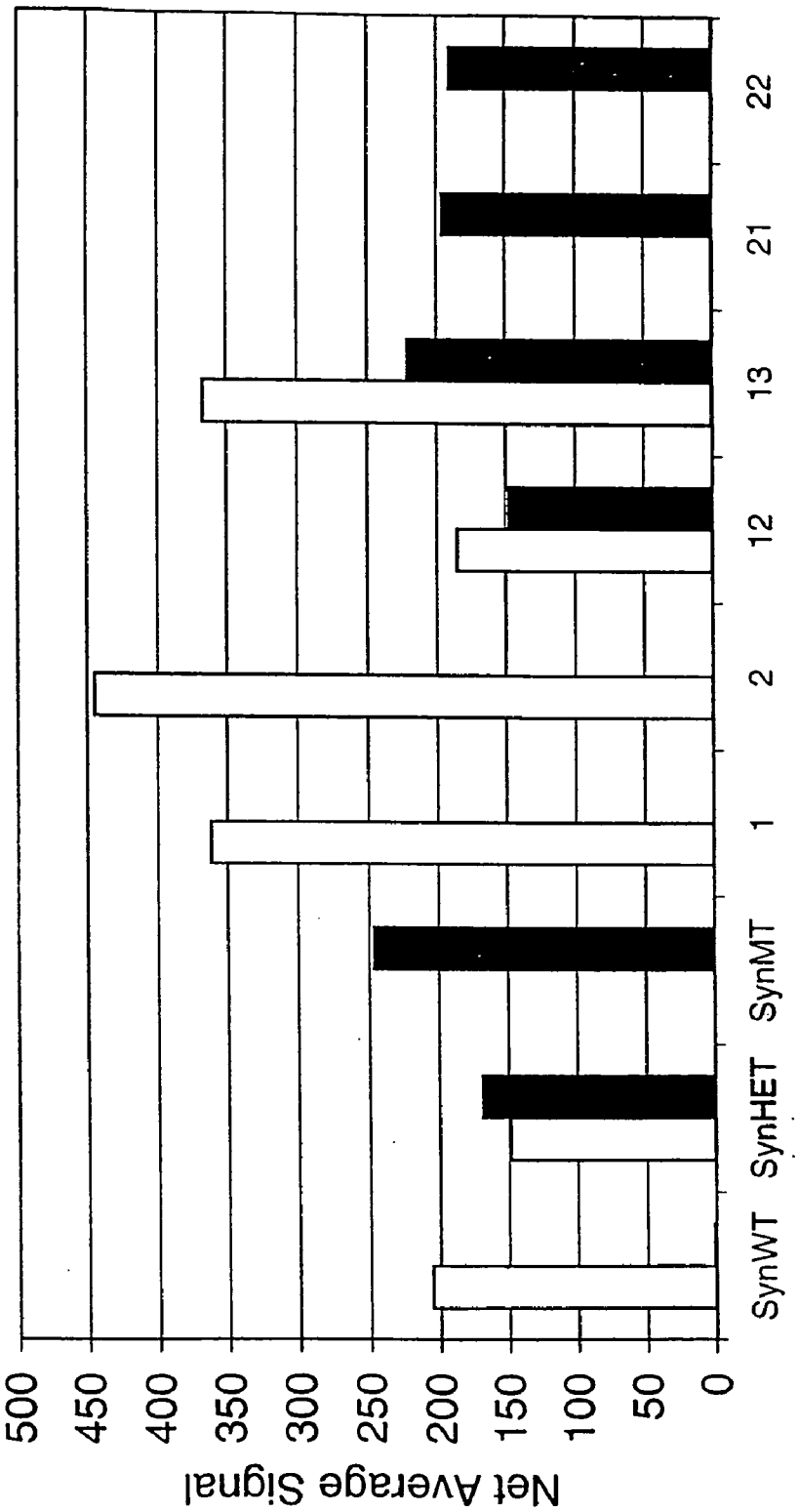

Net Average Signal
500
450
400
350
300
250
200
150
100
50
0
SynWT
SynHET
SynMT
1
2
12
13
21
22

FIGURE 127A

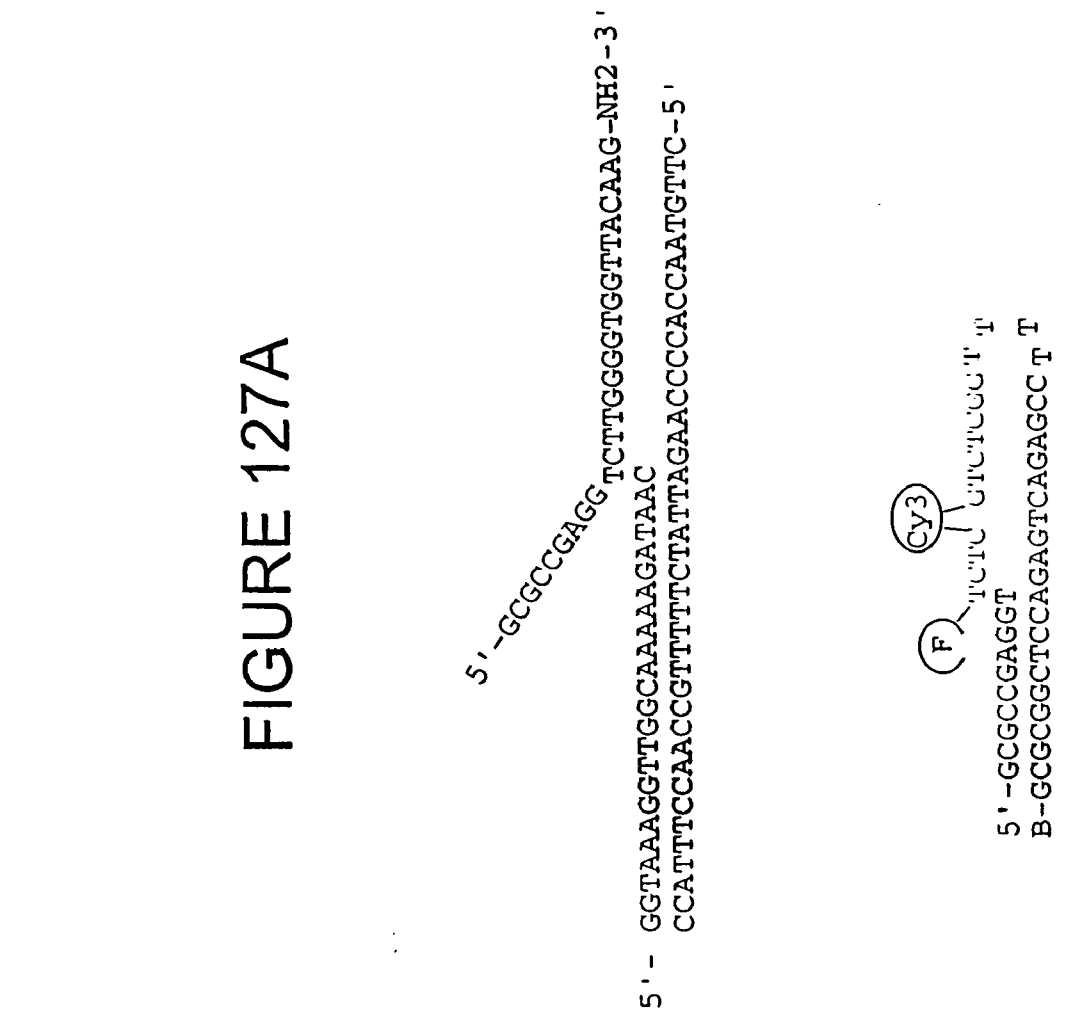

5'-GCGCCGAGG TCTTGGGGTGGTTACAAG-NH2-3'
5' - GGTAAAGGTTGGCAAAAAGATAAC
CCATTTCCAACCGTTTTTCTATTAGAACCCCACCAATGTTC-5'
Cy3
F
5'-GCGCCGAGGT
B-GCGCGGCTCCAGAGTCAGAGCC T T

FIGURE 127B

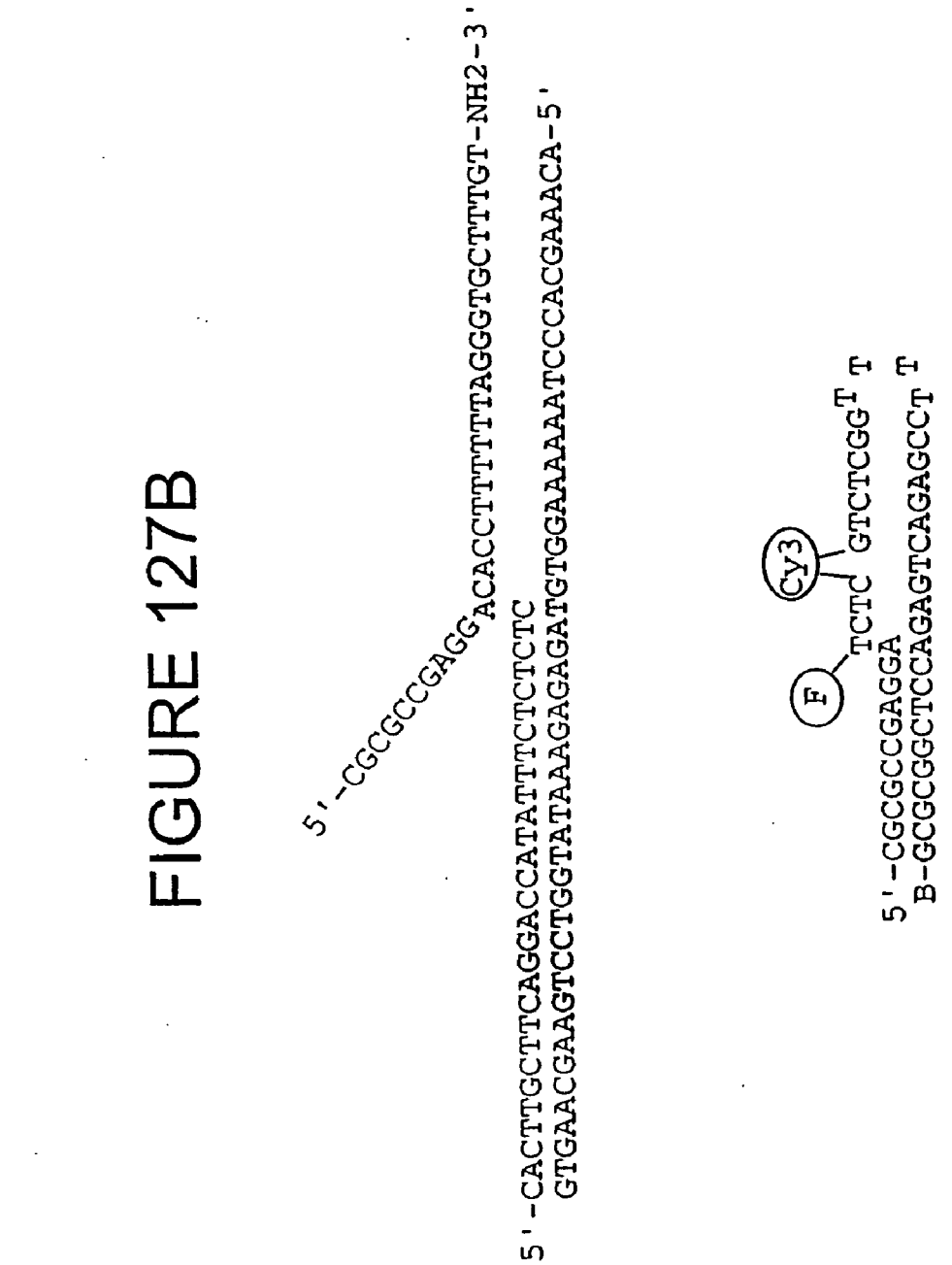

5'-CGCGCCGAGG
ACACCTTTTTTAGGGTGCTTTGT-NH2-3'
5'-CACTTGCTTCAGGACCATATTTCTCTCTC
GTGAACGAAGTCCTGGTATAAAGAGAGATGTGGAAAAAATCCCACGAAACA-5'
Cy3
F
TCTC GTCTCGG T T
5'-CGCGCCGAGGA
B-GCGCGGCTCCAGAGTCAGAGCC T T

FIGURE 128

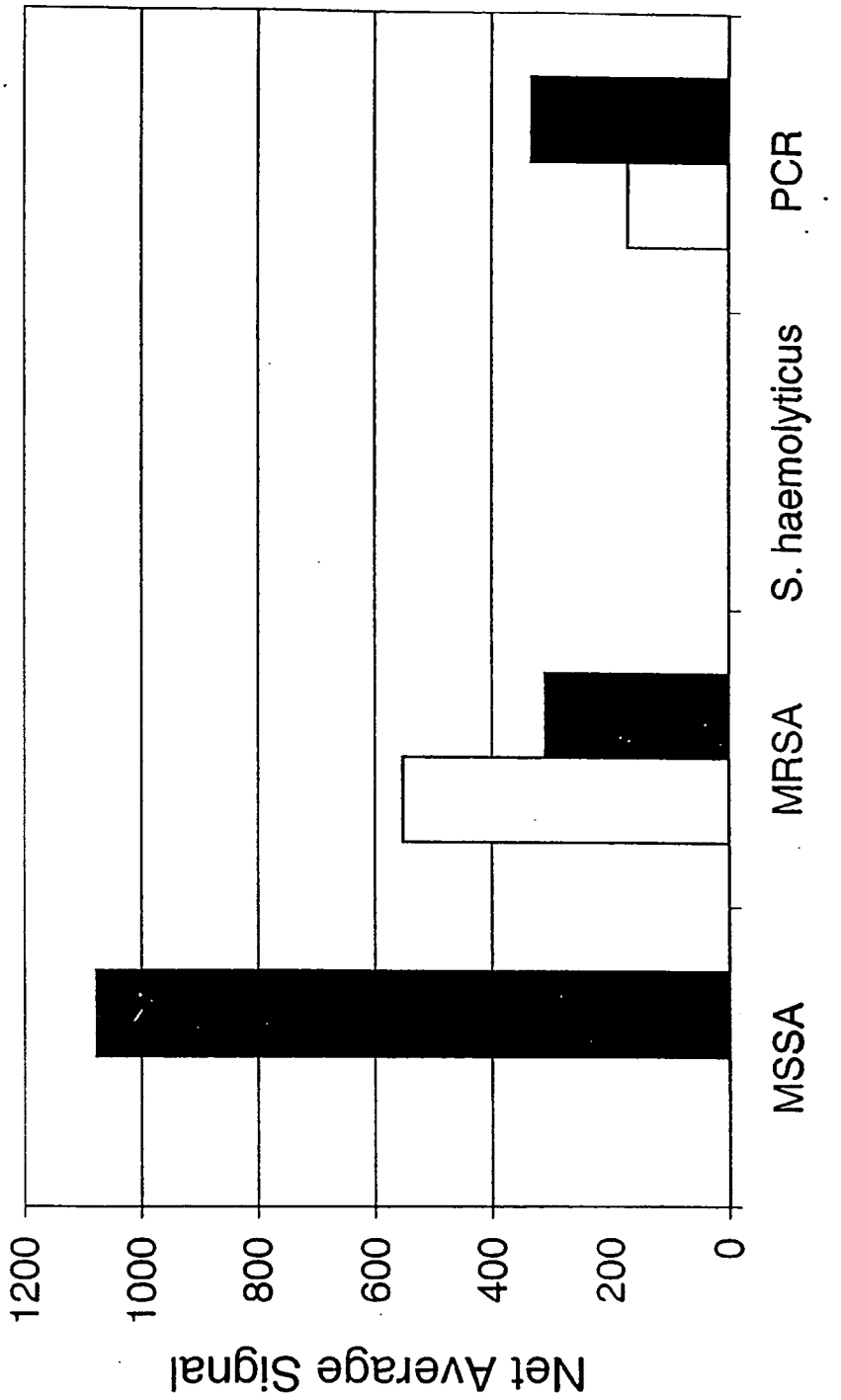

Net Average Signal
1200
1000
800
600
400
200
0
MSSA
MRSA
S. haemolyticus
PCR

FIGURE 129

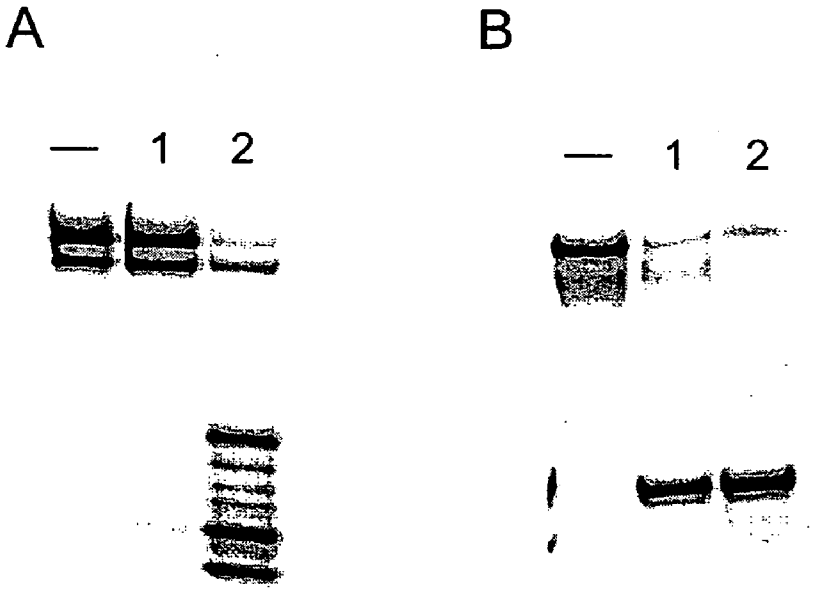


FIGURE 130

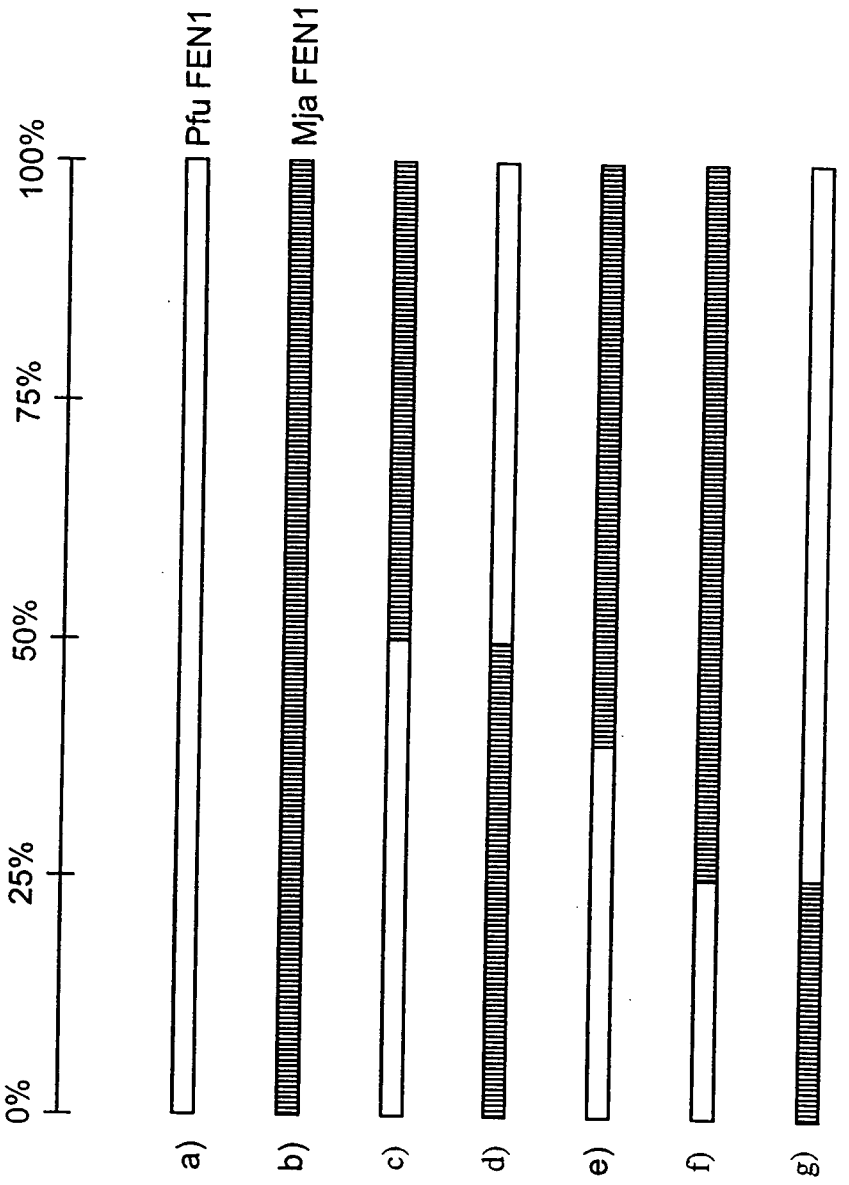


FIGURE 131A

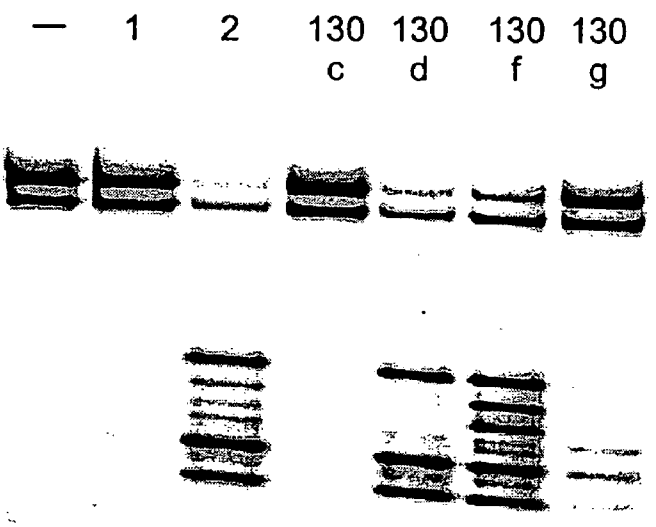


FIGURE 131B

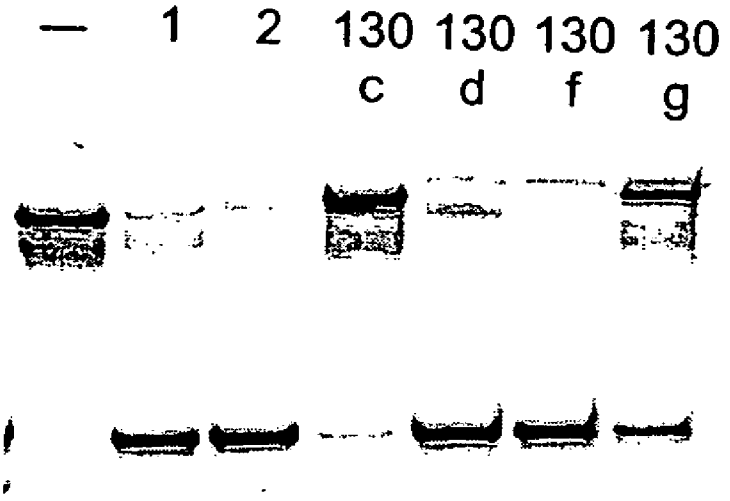


FIGURE 132

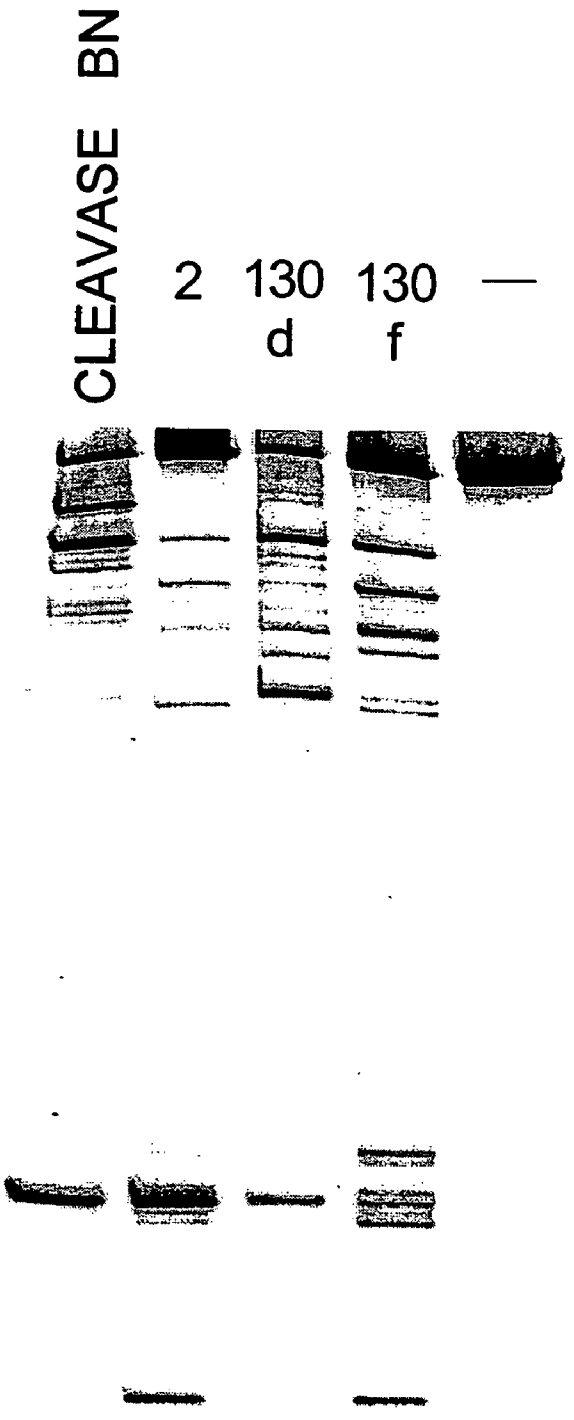


FIGURE 133A

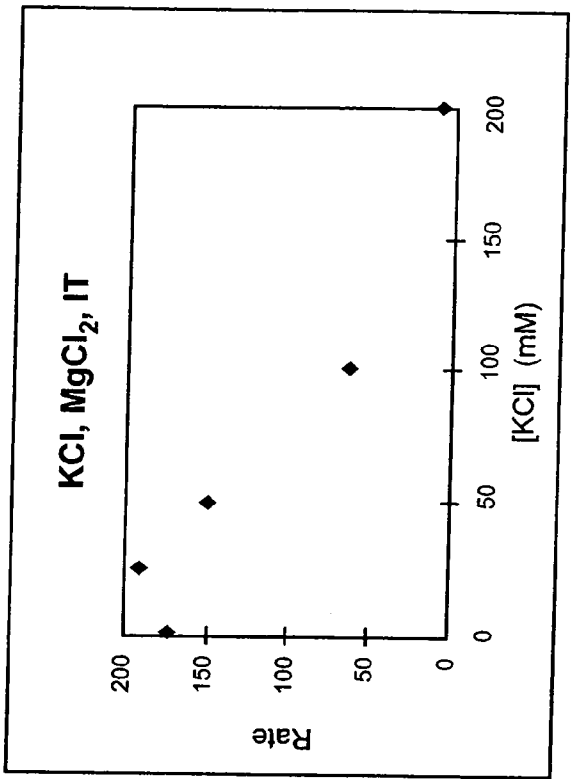


FIGURE 133B

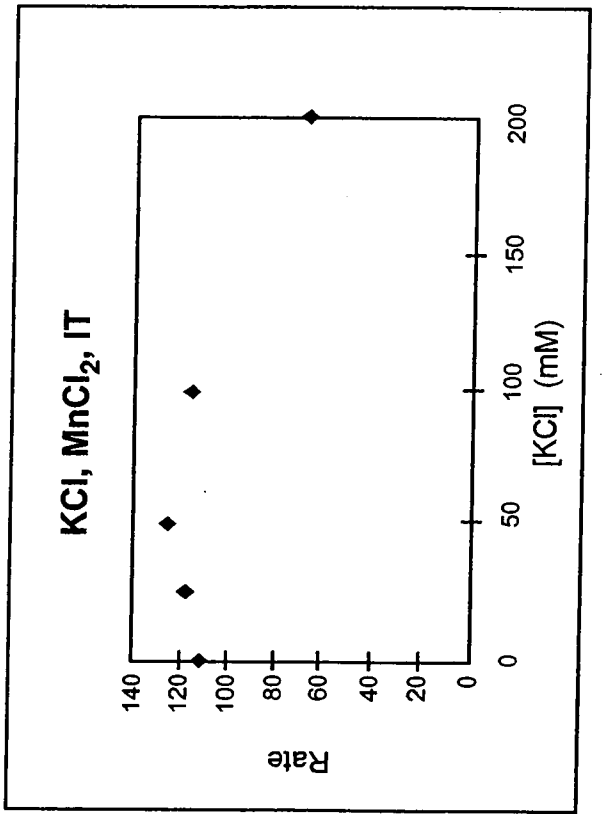


FIGURE 133C

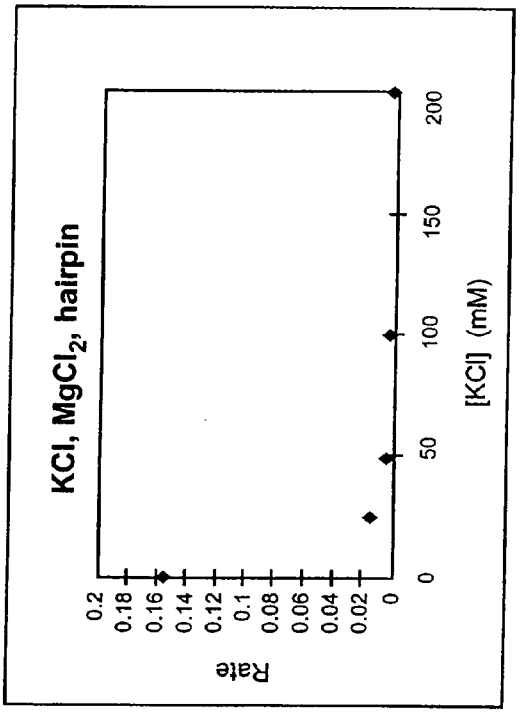

KCl, MgCl2, hairpin
Rate
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
[KCl] (mM)

FIGURE 133D

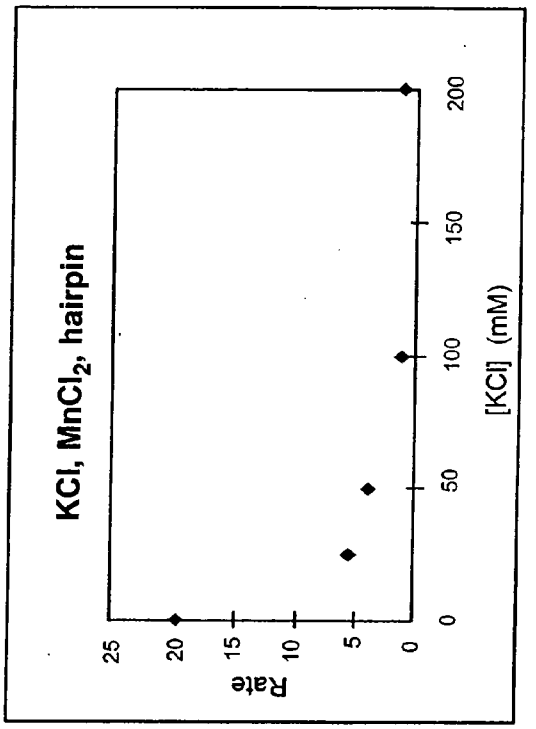


FIGURE 133E

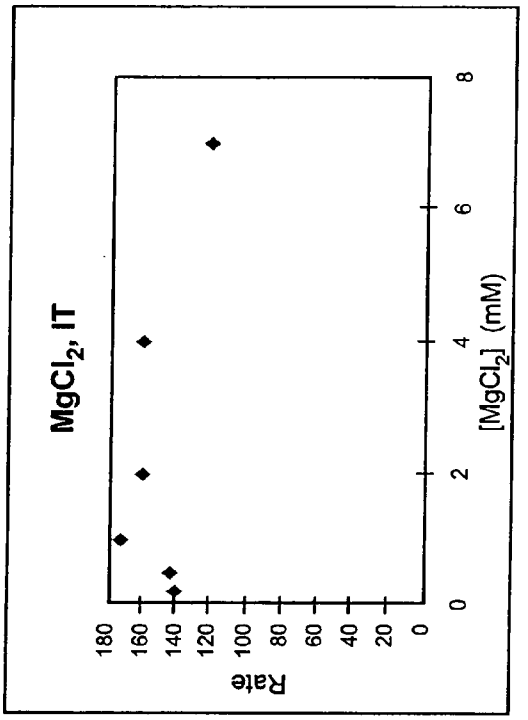


FIGURE 133F

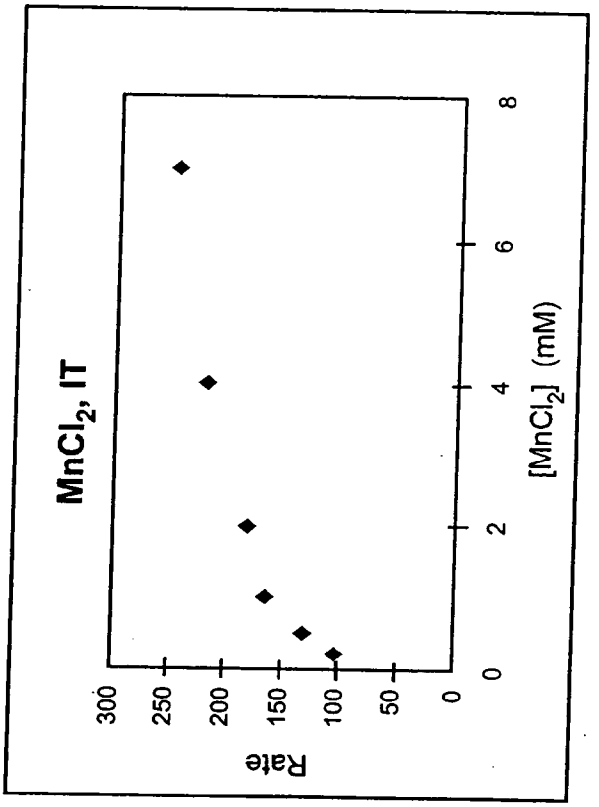


FIGURE 133G

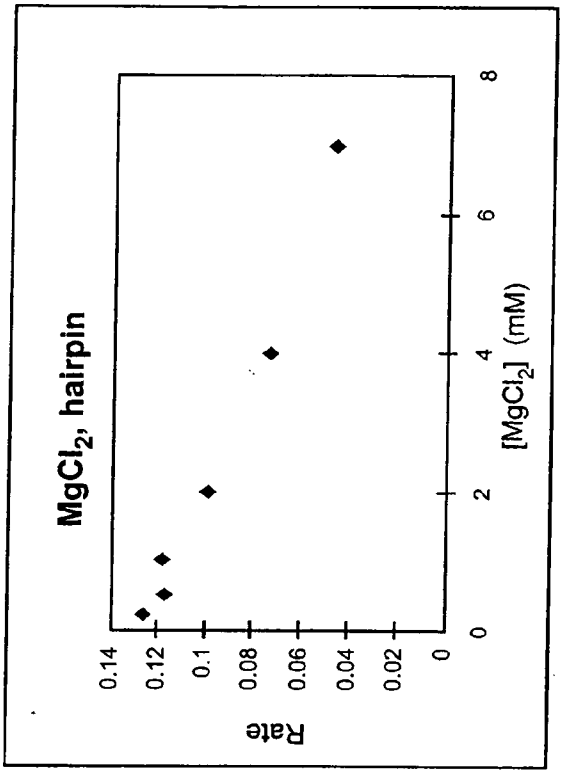


FIGURE 133H

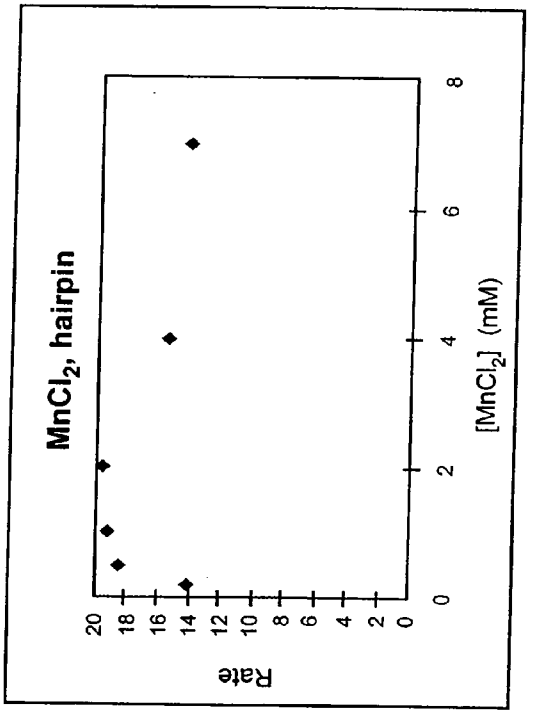


FIGURE 133I

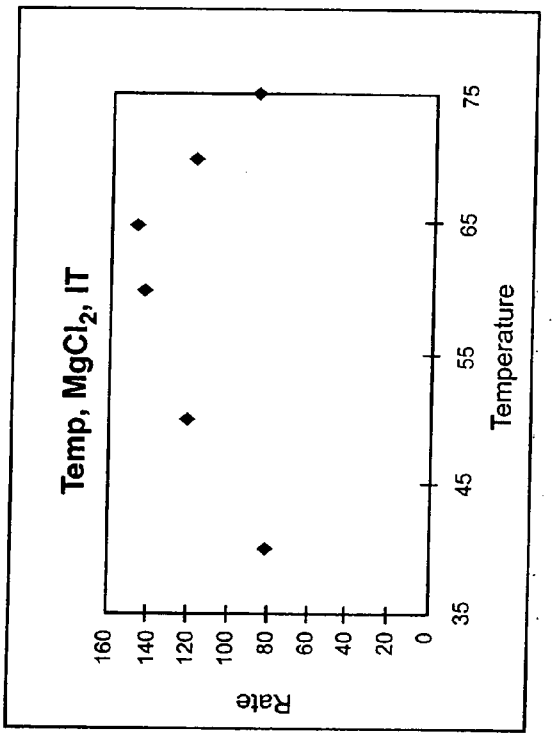

Temp, MgCl2, IT
Rate
160
140
120
100
80
60
40
20
0
35
45
55
65
75
Temperature

FIGURE 133J

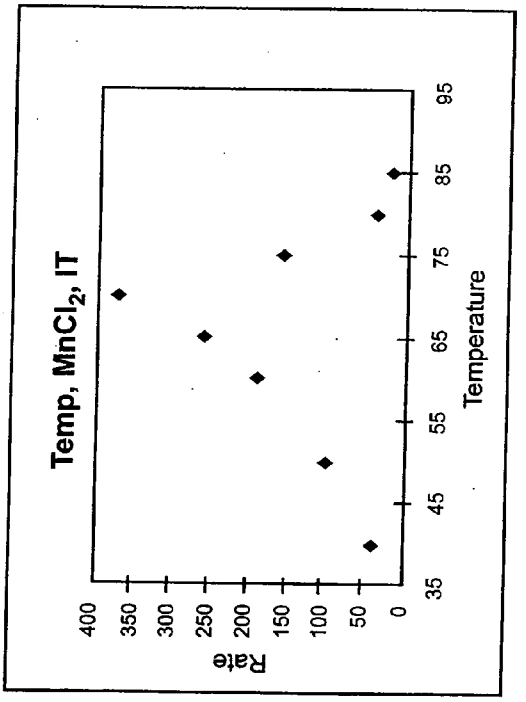

Temp, MnCl2, IT
Rate
400
350
300
250
200
150
100
50
0
35
45
55
65
75
85
95
Temperature

FIGURE 134A

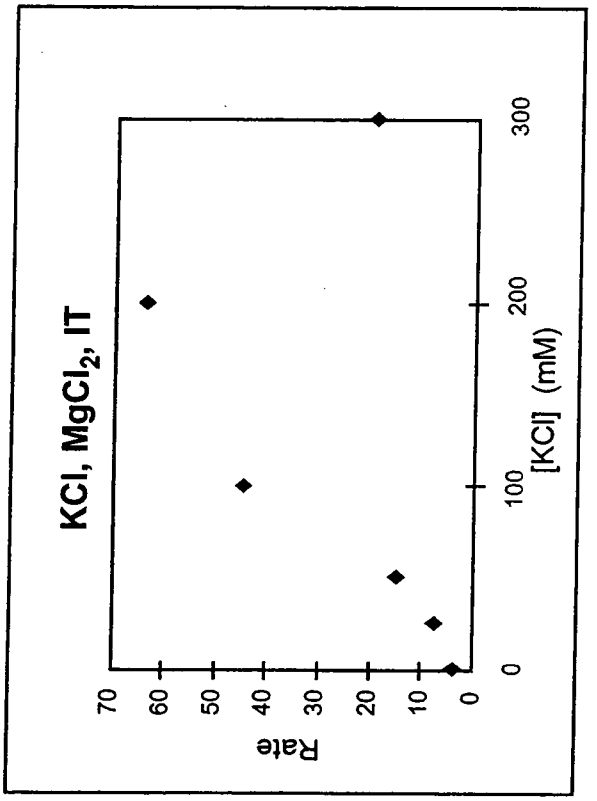


FIGURE 134B

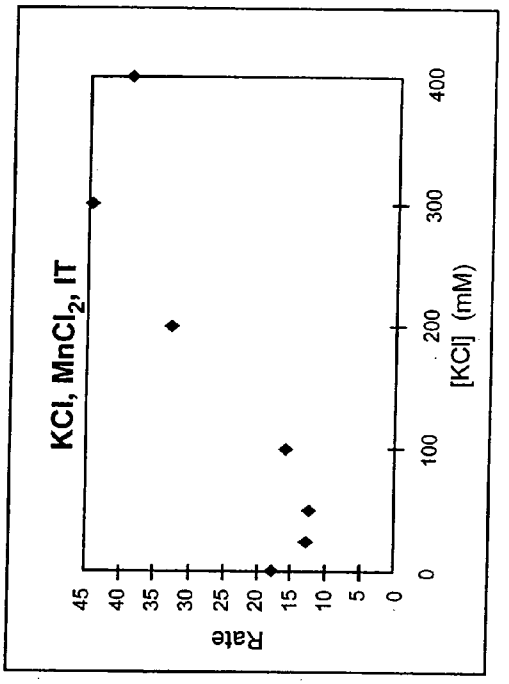

KCl, MnCl2, IT
Rate
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
[KCl] (mM)

FIGURE 134D

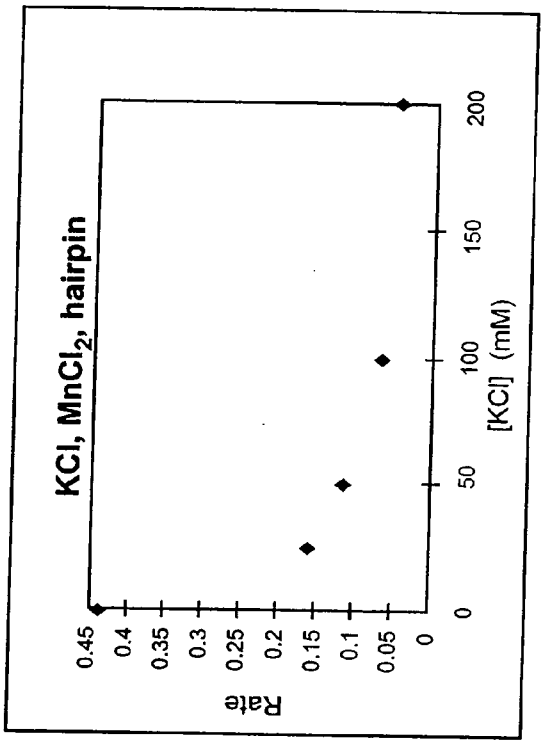

KCl, MnCl2, hairpin
Rate
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
[KCl] (mM)

FIGURE 134E

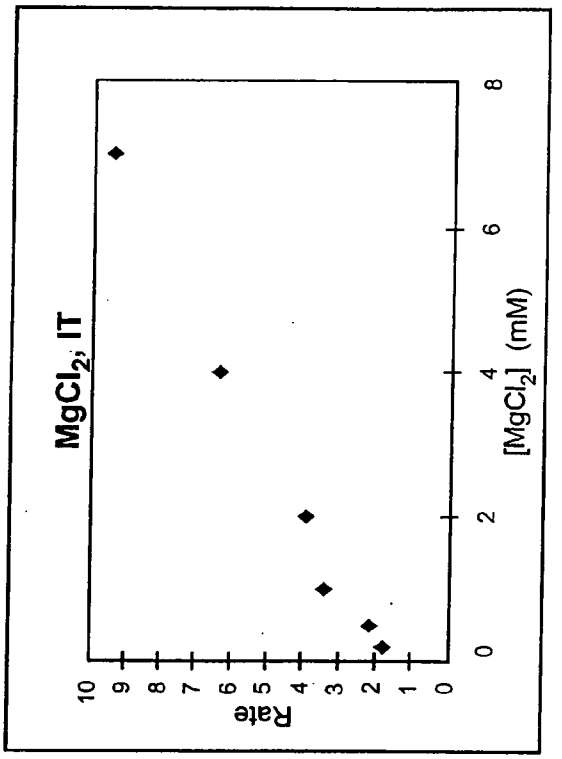


FIGURE 134F

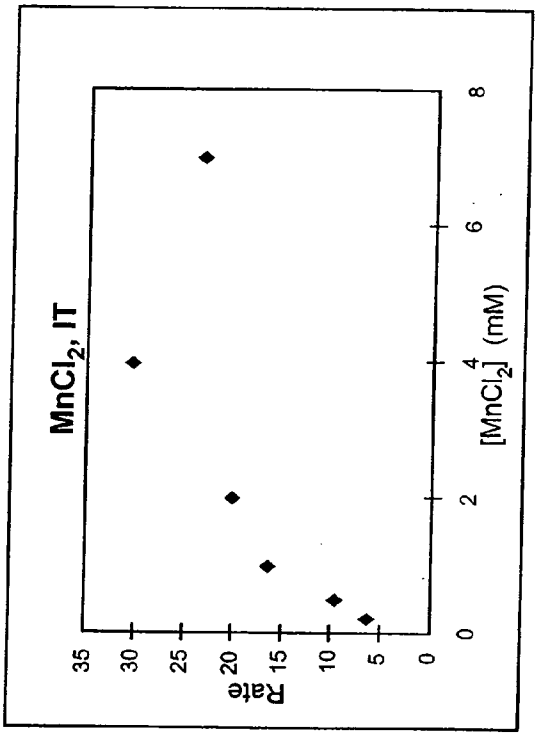


FIGURE 134H

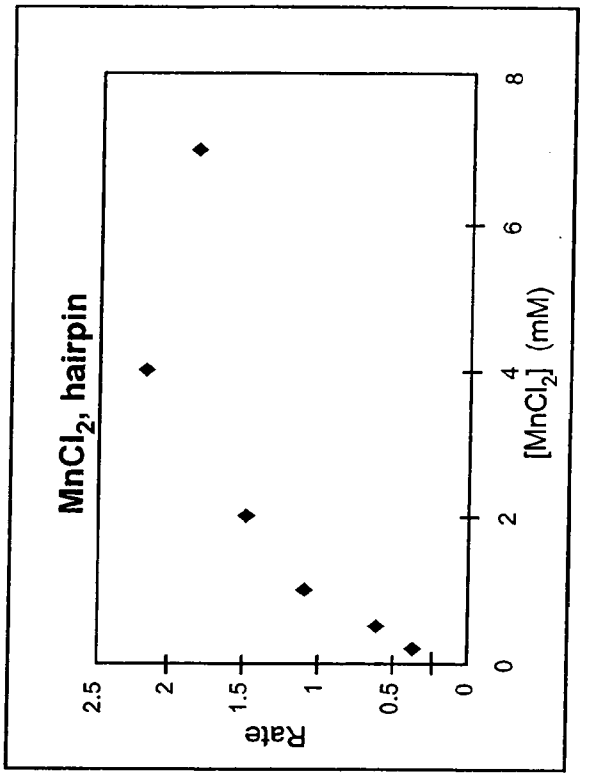


FIGURE 134I

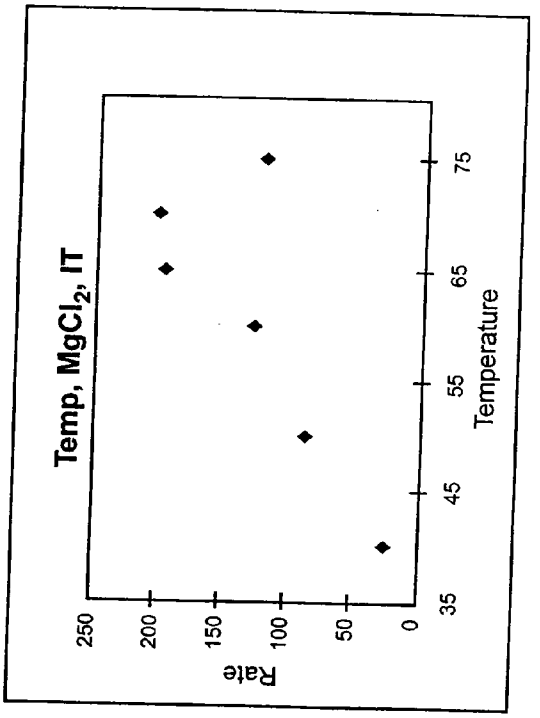

Temp, MgCl2, IT
Rate
250
200
150
100
50
0
35
45
55
65
75
Temperature

FIGURE 134J

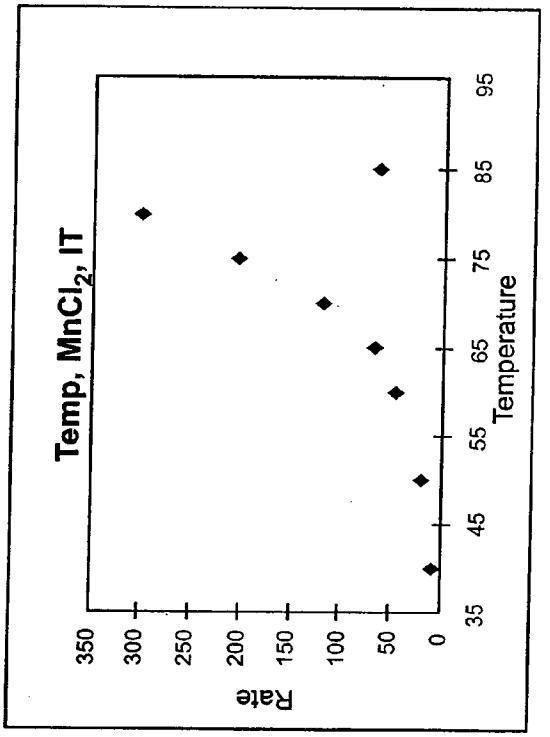

Temp, MnCl2, IT
Rate
350
300
250
200
150
100
50
0
35
45
55
65
75
85
95
Temperature

FIGURE 135A

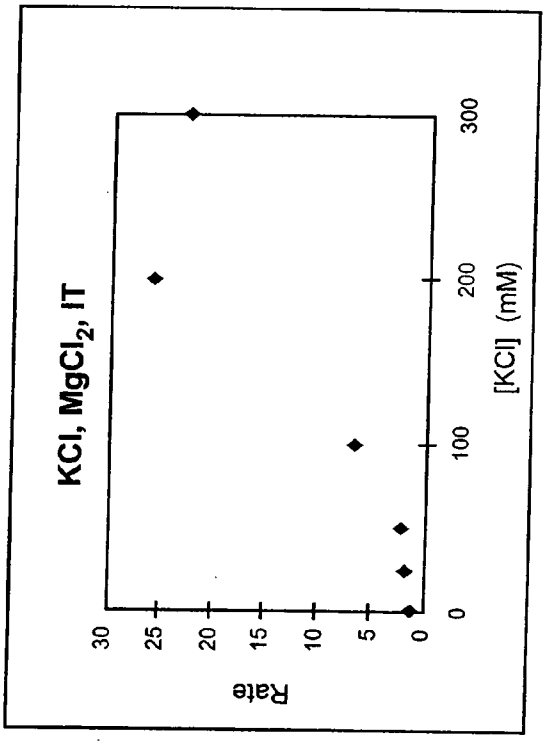


FIGURE 135B

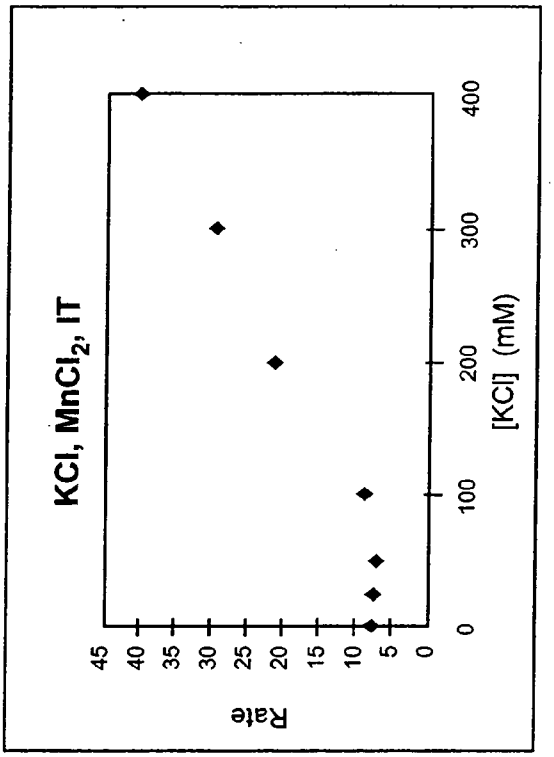

KCl, MnCl2, IT
Rate
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
[KCl] (mM)

FIGURE 135D

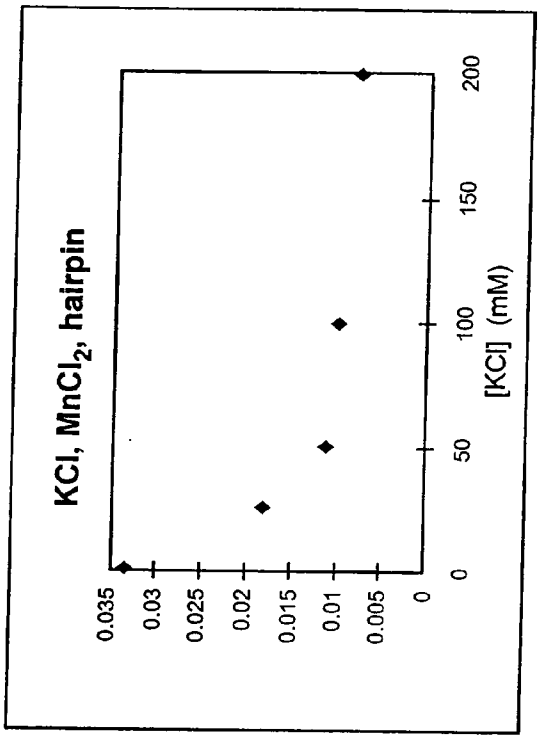

KCl, MnCl2, hairpin
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
50
100
150
200
[KCl] (mM)

FIGURE 135E

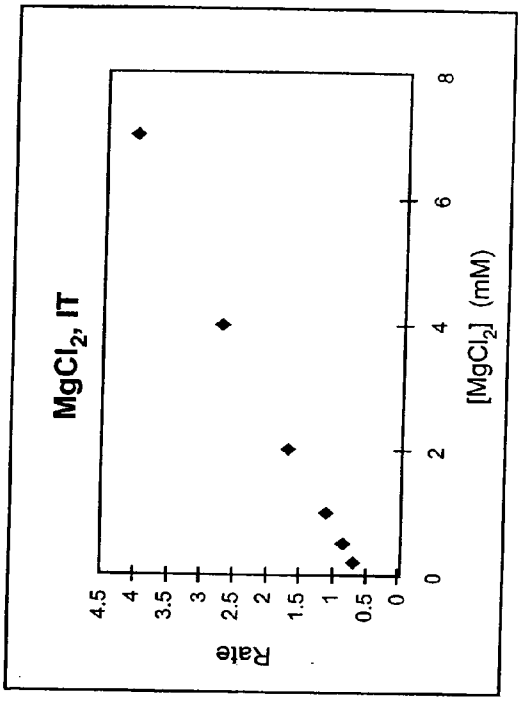


FIGURE 135F

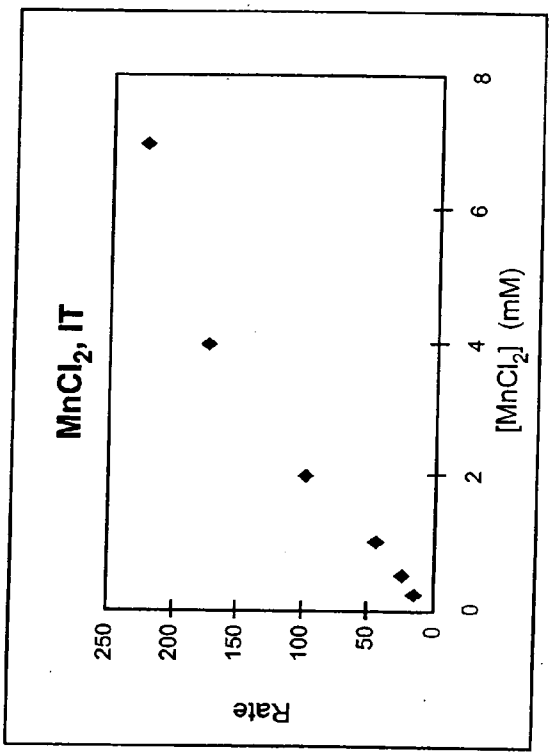


FIGURE 135H

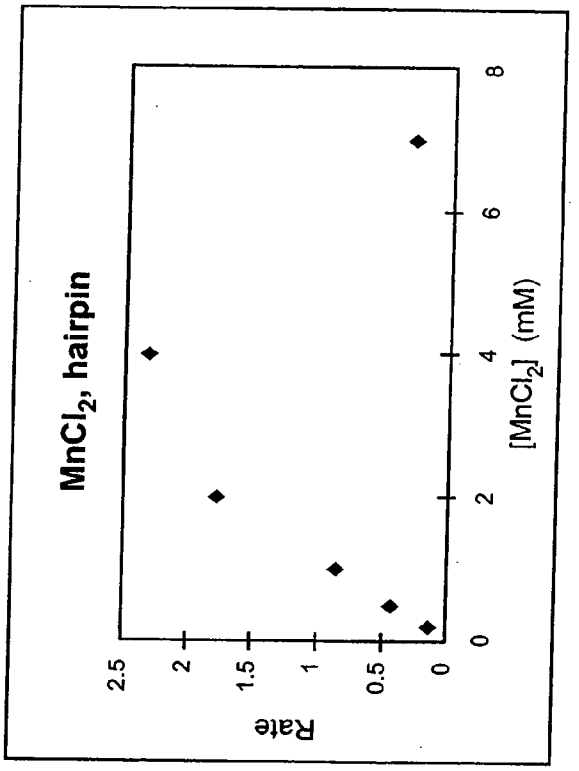


FIGURE 135I

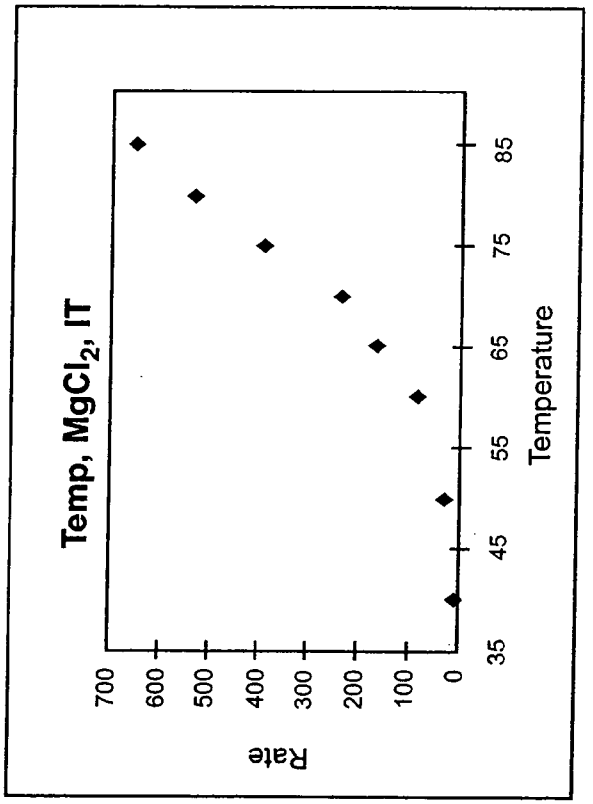

Temp, MgCl2, IT
Rate
700
600
500
400
300
200
100
0
35
45
55
65
75
85
Temperature

FIGURE 135J

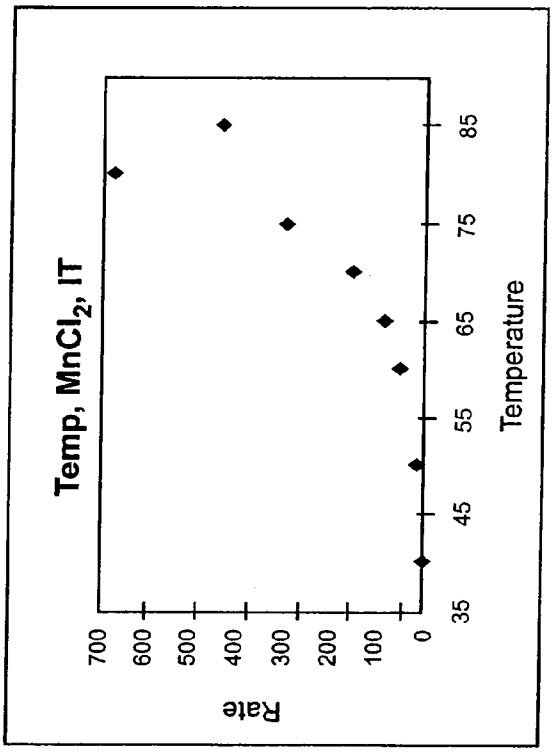

Temp, MnCl2, IT
Rate
700
600
500
400
300
200
100
0
35
45
55
65
75
85
Temperature

FIGURE 136A

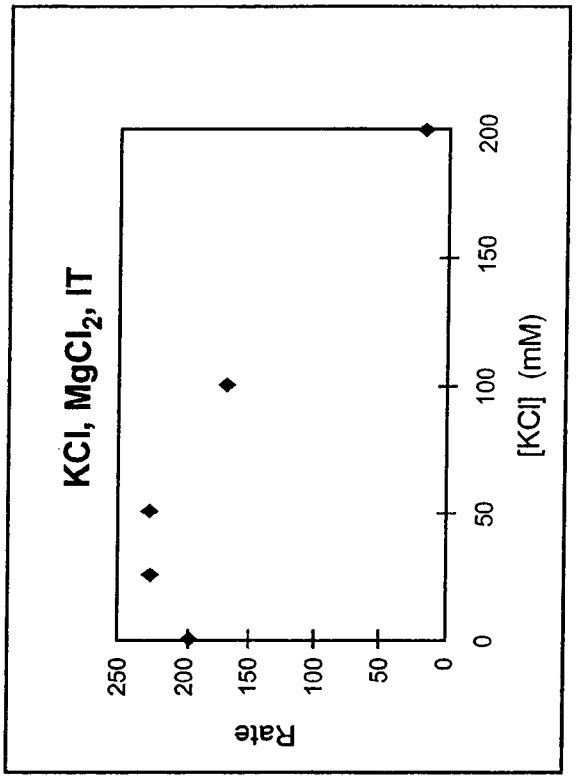


FIGURE 136B

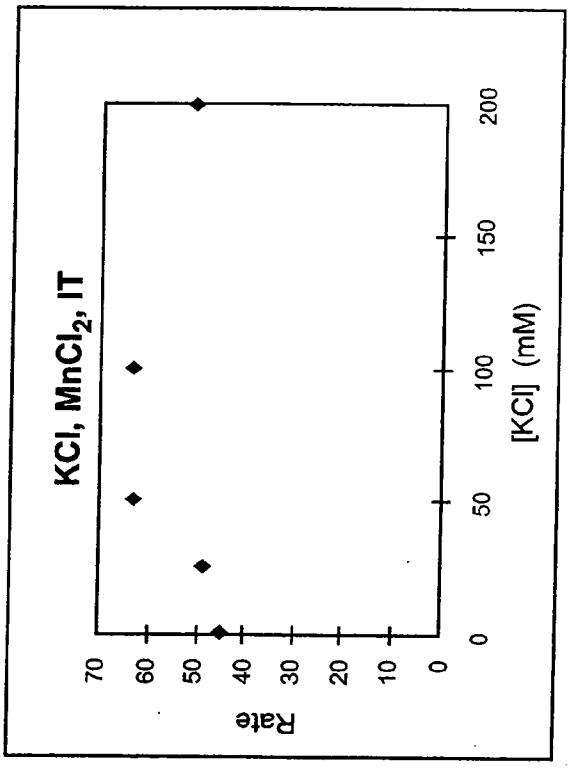


FIGURE 136D

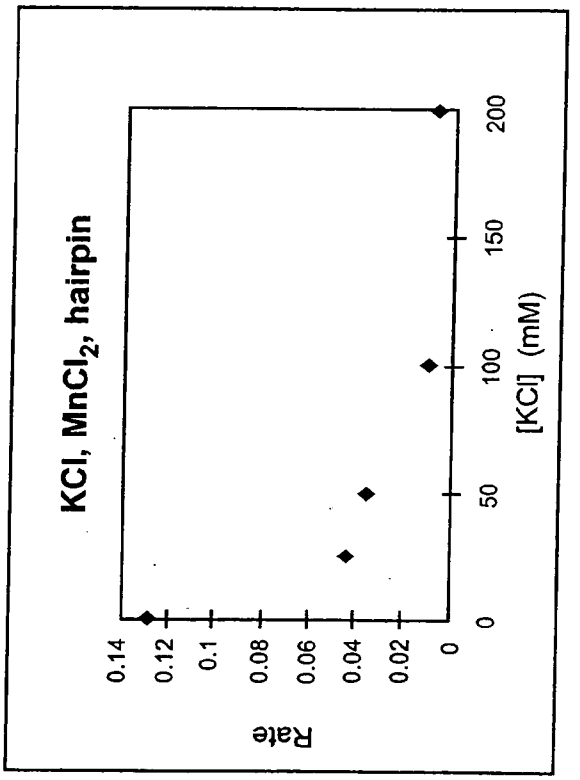

KCl, MnCl2, hairpin
Rate
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
50
100
150
200
[KCl] (mM)

FIGURE 136E

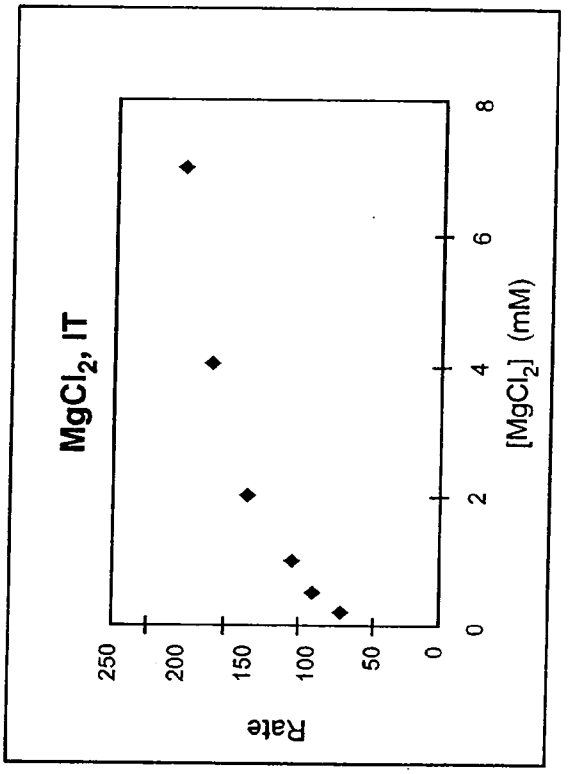


FIGURE 136F

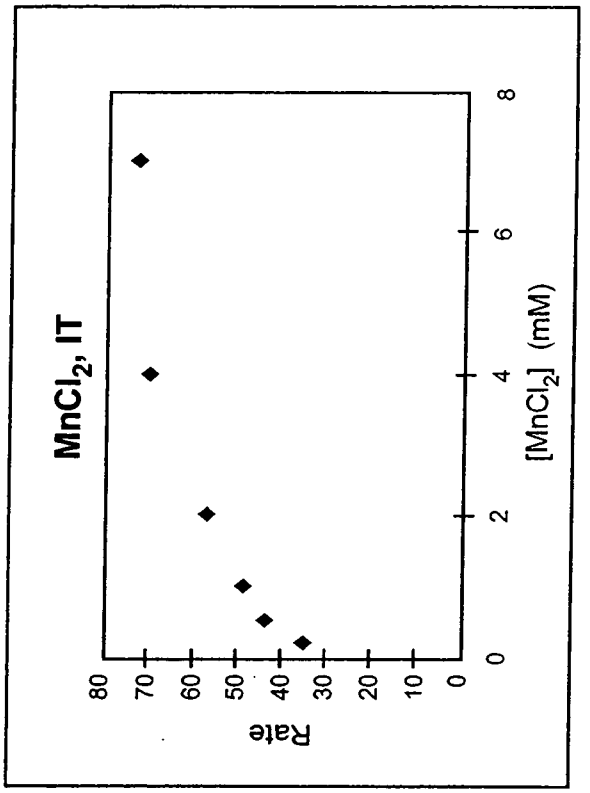


FIGURE 136H

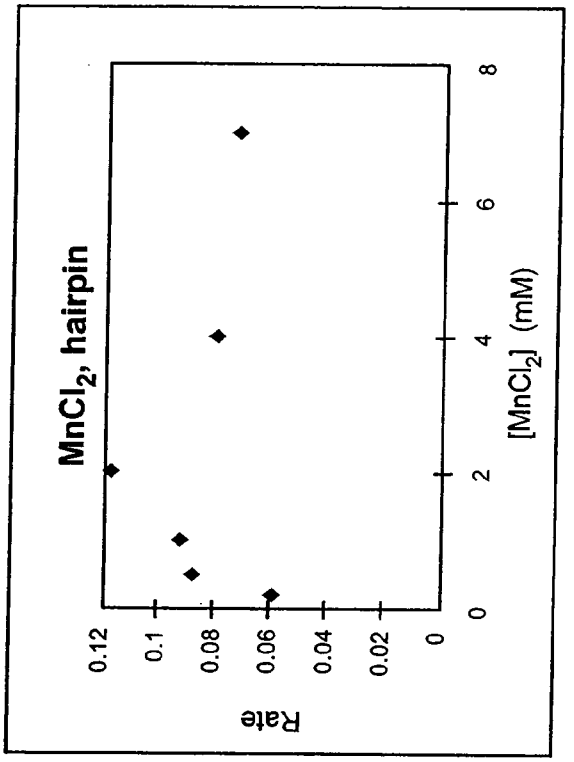


FIGURE 136I

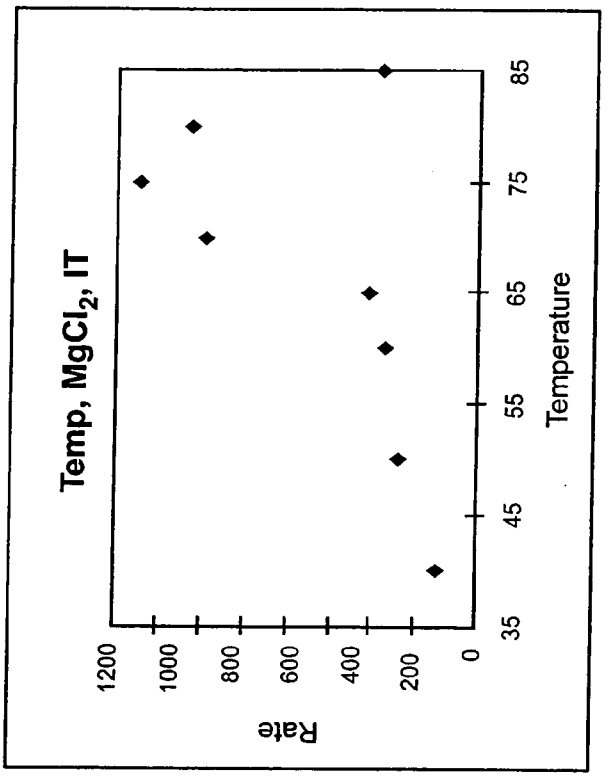

Temp, MgCl2, IT
Rate
1200
1000
800
600
400
200
0
35
45
55
65
75
85
Temperature

FIGURE 136J

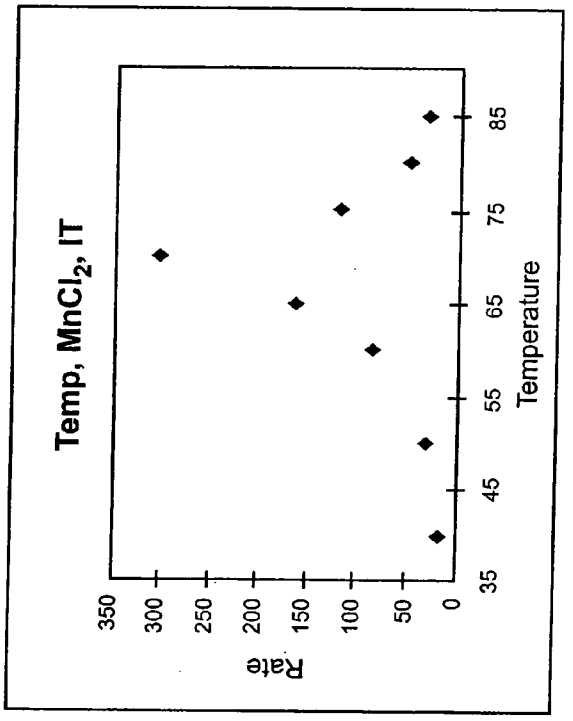

Temp, MnCl2, IT
Rate
350
300
250
200
150
100
50
0
35
45
55
65
75
85
Temperature

FIGURE 137A

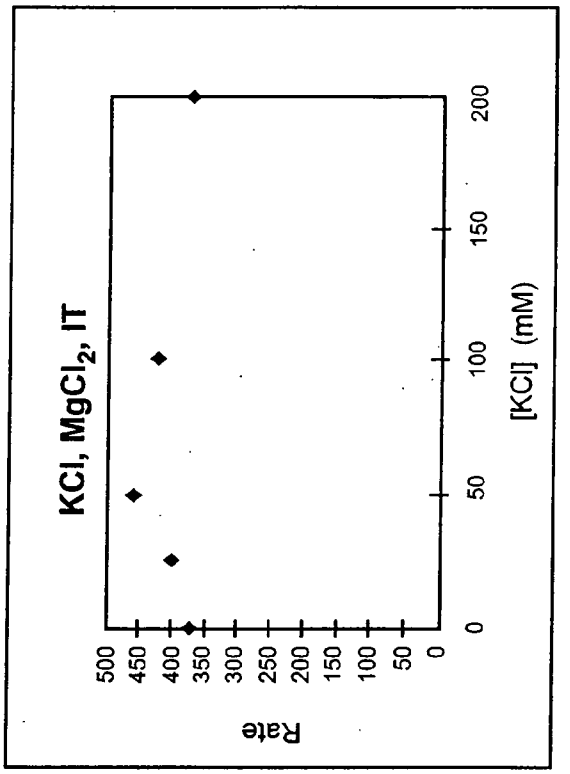

KCl, MgCl2, IT
Rate
500
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200
[KCl] (mM)

FIGURE 137B

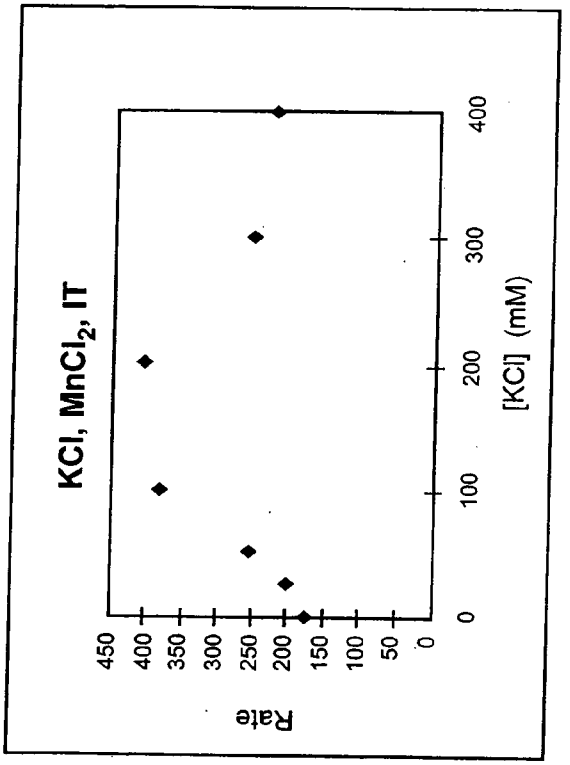

KCl, MnCl2, IT
Rate
0
50
100
150
200
250
300
350
400
450
0
100
200
300
400
[KCl] (mM)

FIGURE 137C

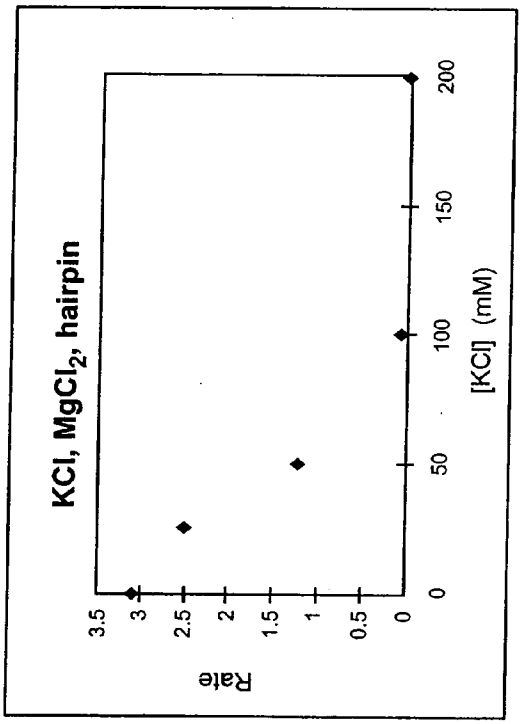


FIGURE 137D

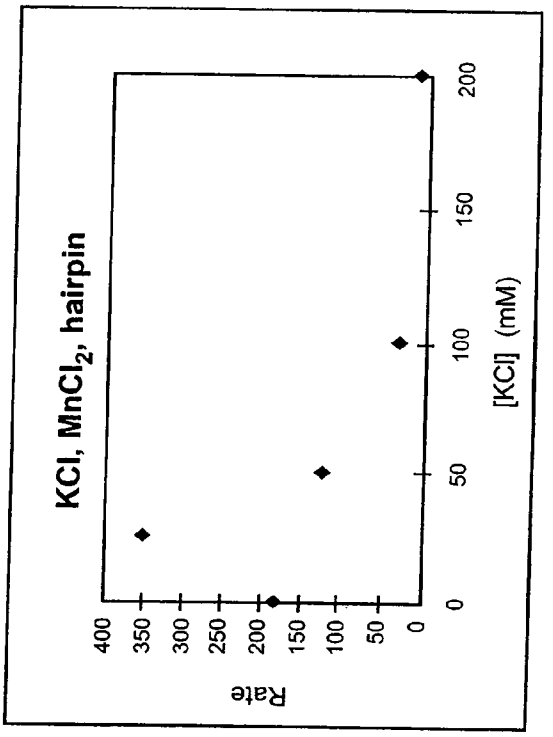

KCl, MnCl2, hairpin
Rate
400
350
300
250
200
150
100
50
0
0
50
100
150
200
[KCl] (mM)

FIGURE 137E

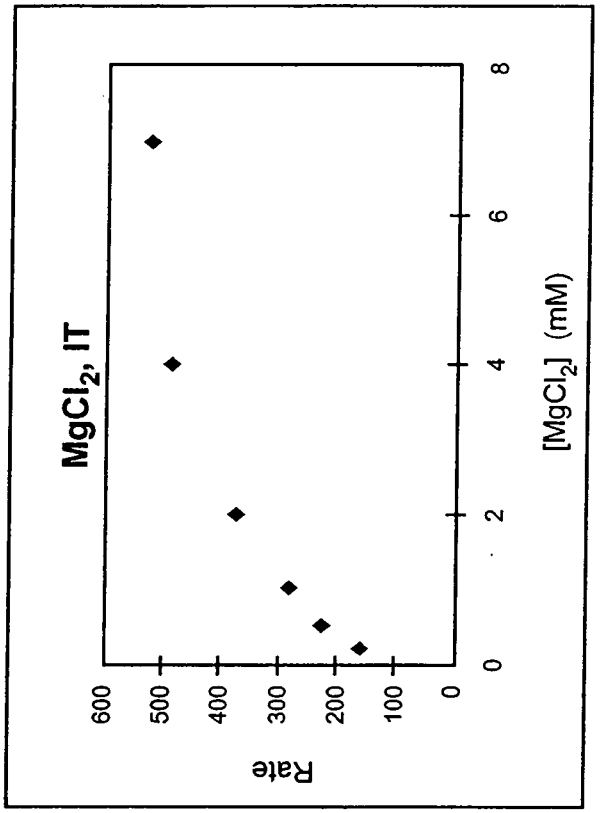


FIGURE 137F

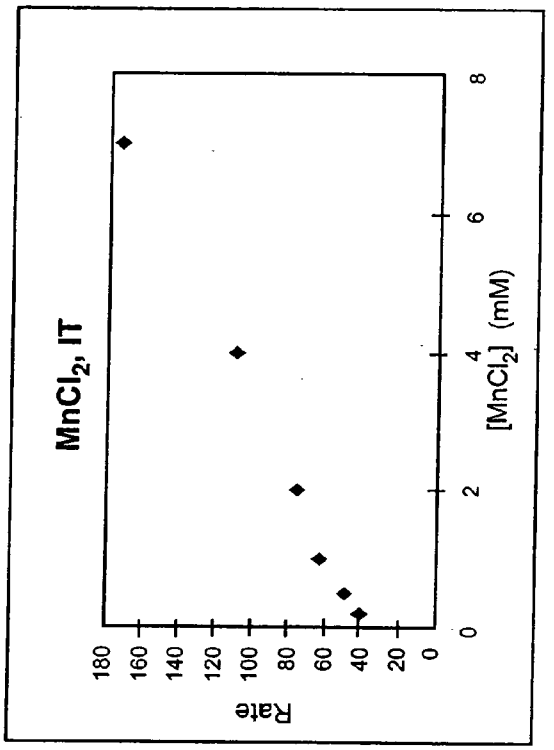


FIGURE 137G

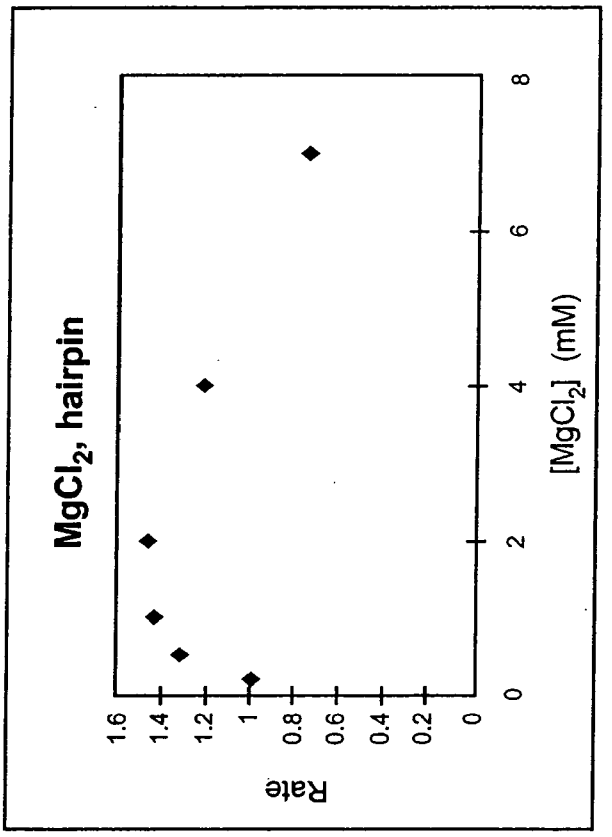


FIGURE 137H

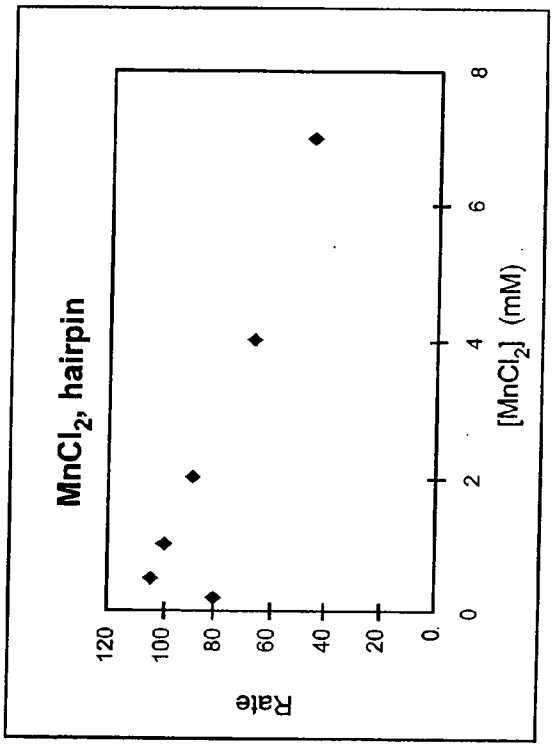


FIGURE 137I

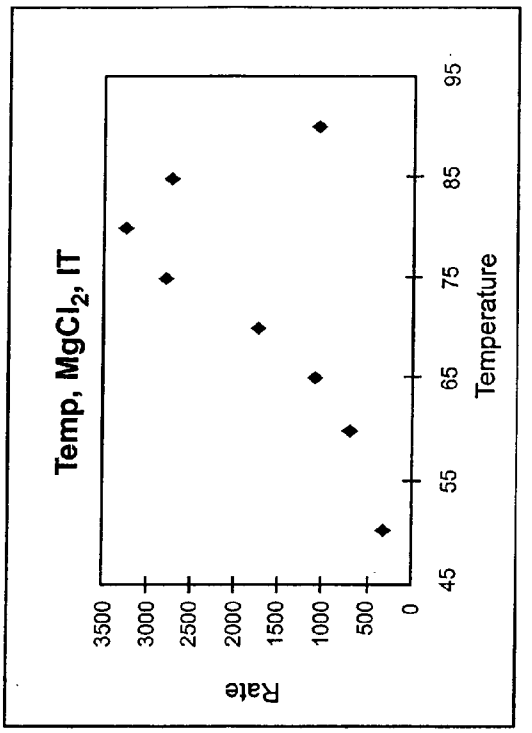

Temp, MgCl2, IT
Rate
3500
3000
2500
2000
1500
1000
500
0
45
55
65
75
85
95
Temperature

FIGURE 137J

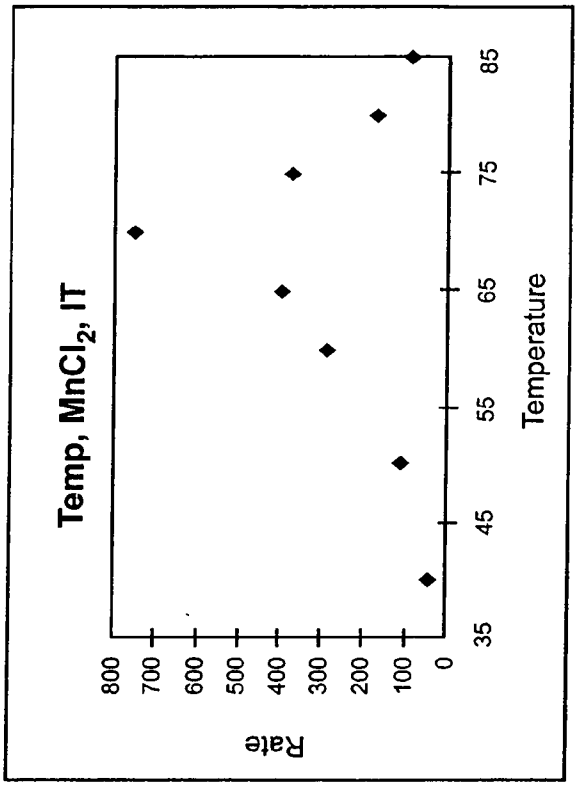

Temp, MnCl2, IT
Rate
800
700
600
500
400
300
200
100
0
35
45
55
65
75
85
Temperature

FIGURE 138A

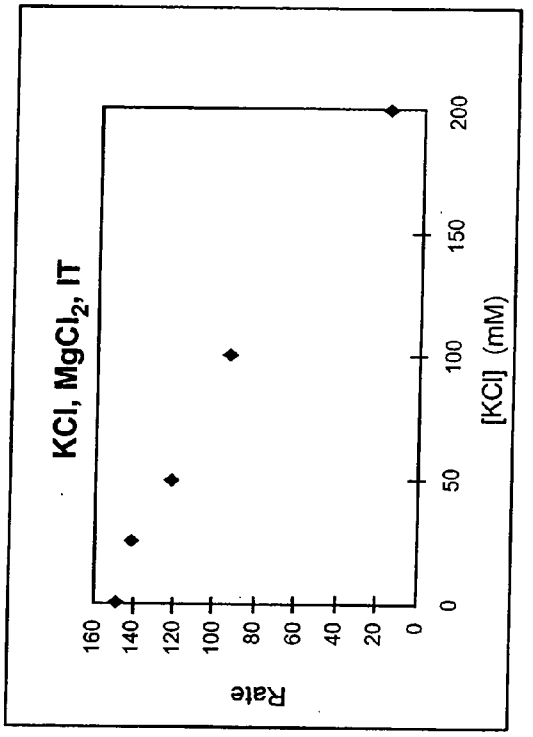

KCl, MgCl2, IT
Rate
160
140
120
100
80
60
40
20
0
0
50
100
150
200
[KCl] (mM)

FIGURE 138B

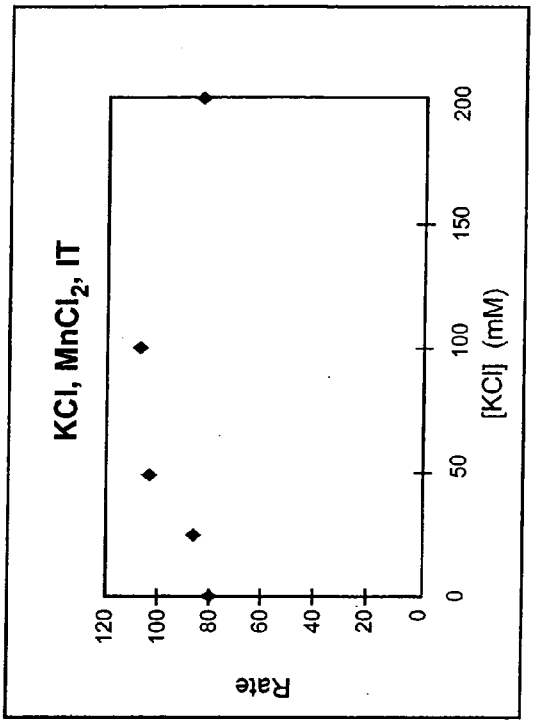


FIGURE 138D

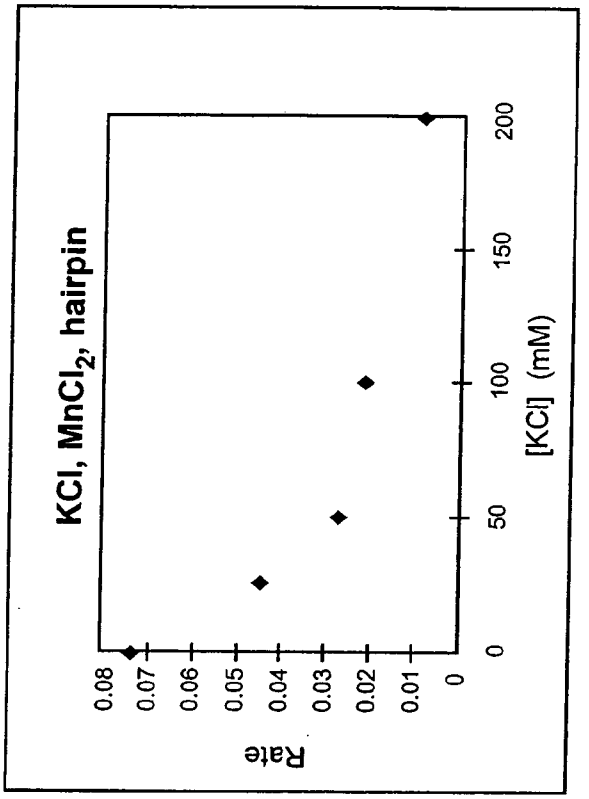

KCl, MnCl2, hairpin
Rate
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
50
100
150
200
[KCl] (mM)

FIGURE 138E

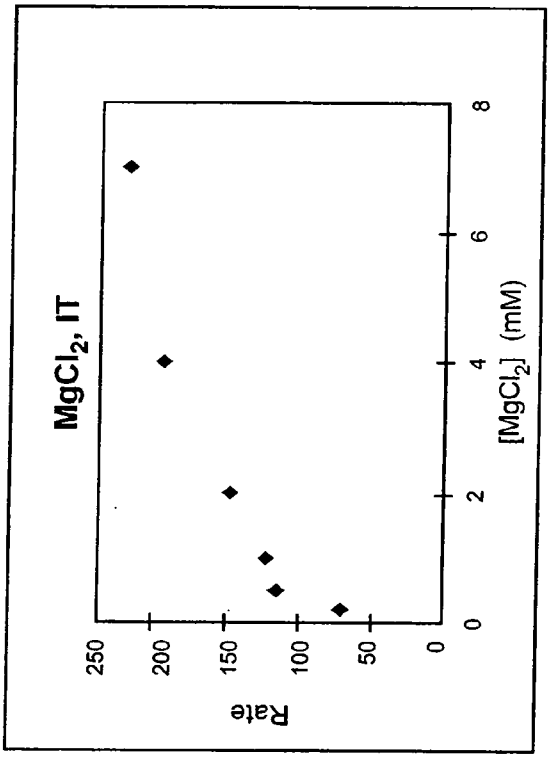


FIGURE 138F

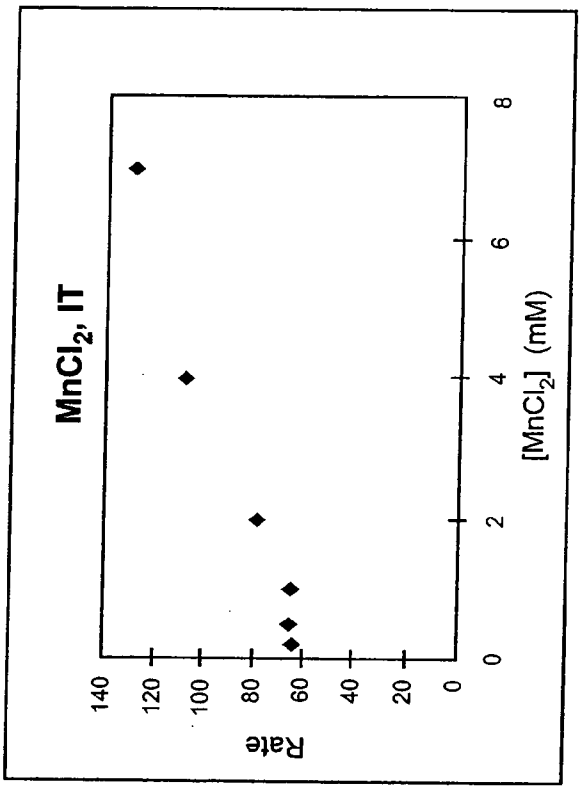


FIGURE 138H

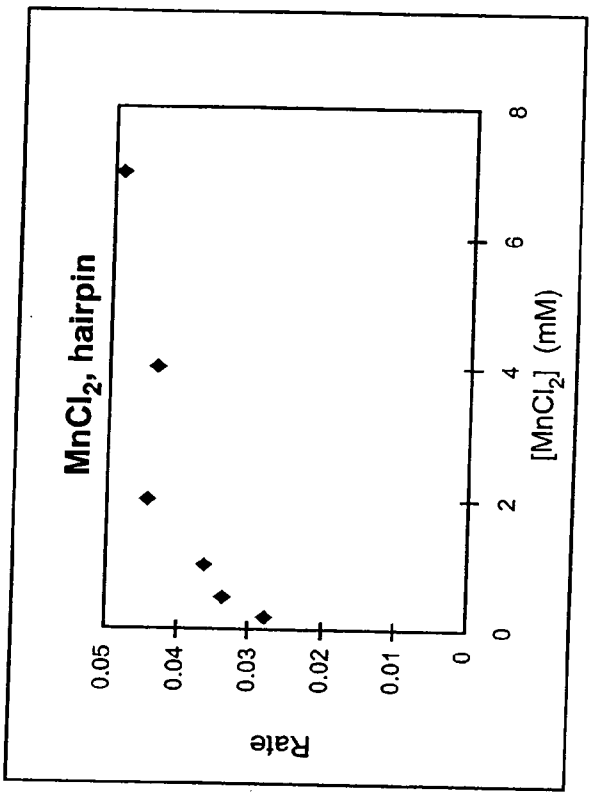


FIGURE 138I

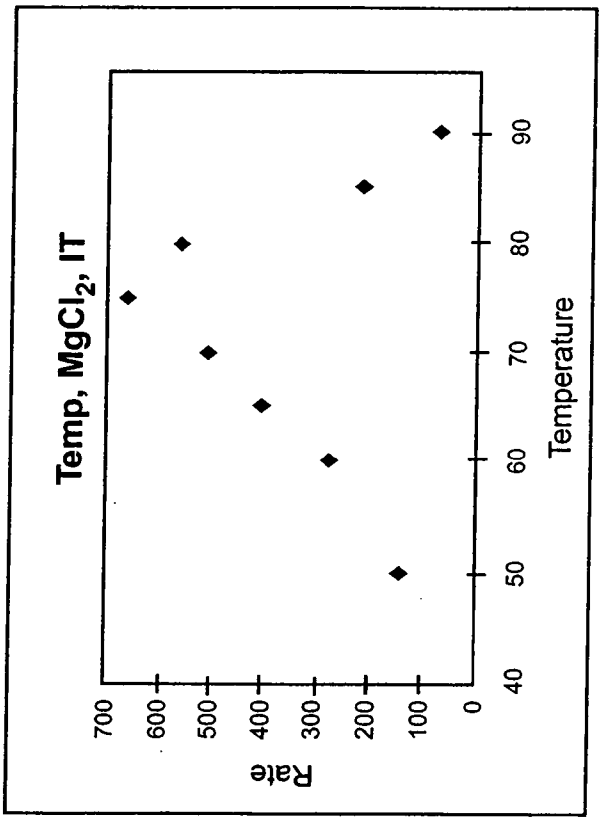

Temp, MgCl2, IT
Rate
700
600
500
400
300
200
100
0
40
50
60
70
80
90
Temperature

FIGURE 138J

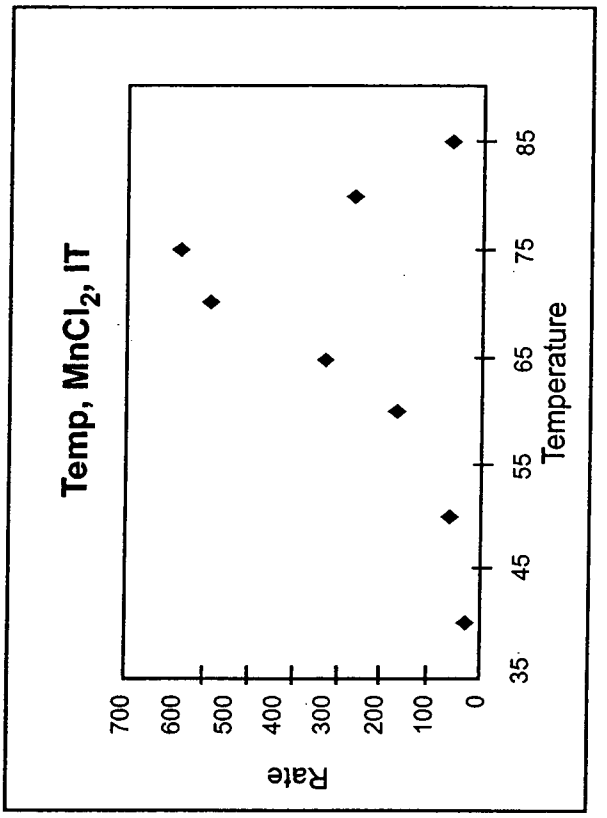

Temp, MnCl2, IT
Rate
700
600
500
400
300
200
100
0
35
45
55
65
75
85
Temperature

FIGURE 139A

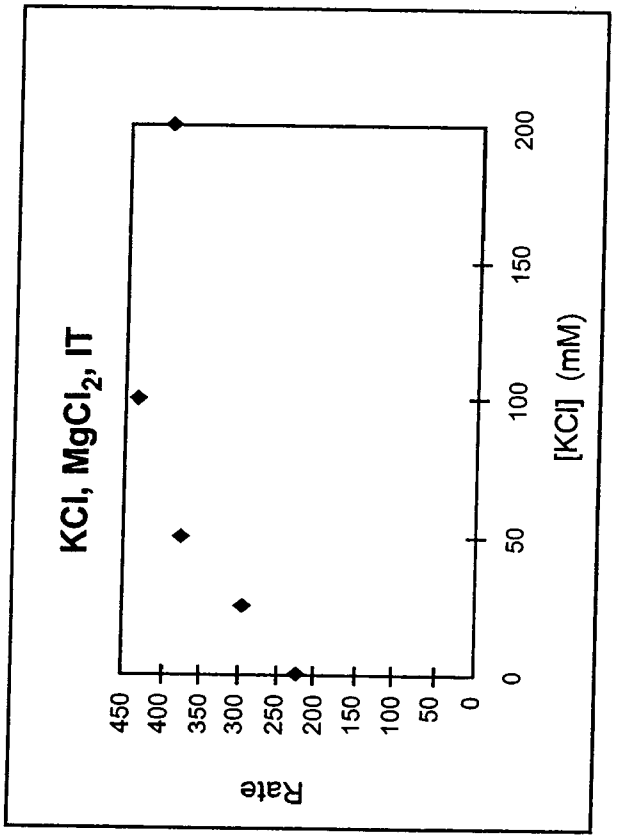

KCl, MgCl2, IT
Rate
450
400
350
300
250
200
150
100
50
0
0
50
100
150
200
[KCl] (mM)

FIGURE 139B

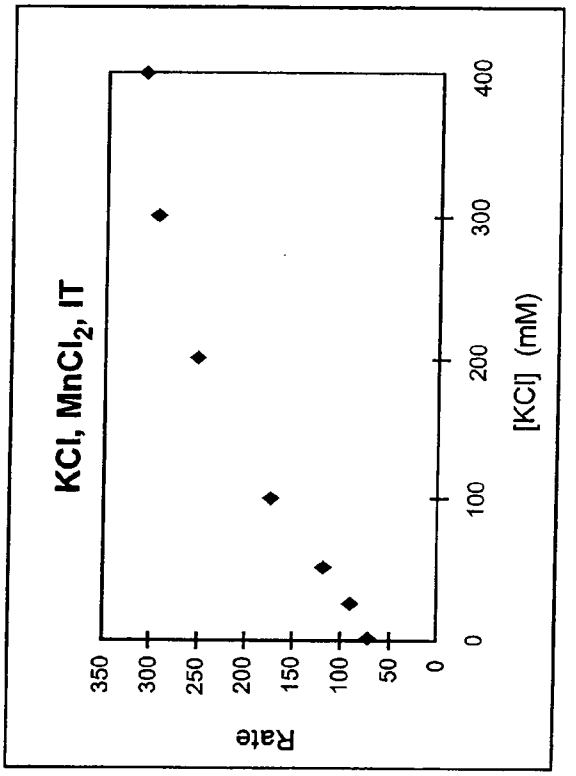

KCl, MnCl2, IT
Rate
350
300
250
200
150
100
50
0
0
100
200
300
400
[KCl] (mM)

FIGURE 139C

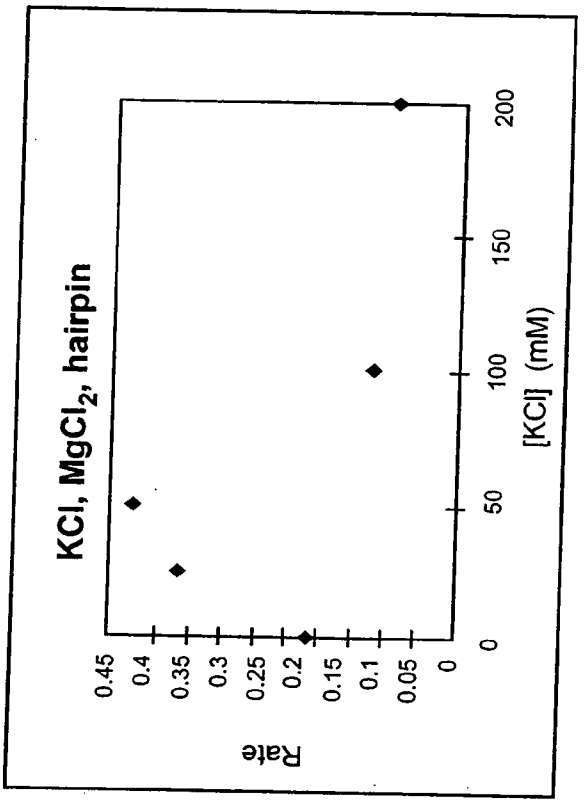

KCl, MgCl2, hairpin
Rate
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
[KCl] (mM)

FIGURE 139D

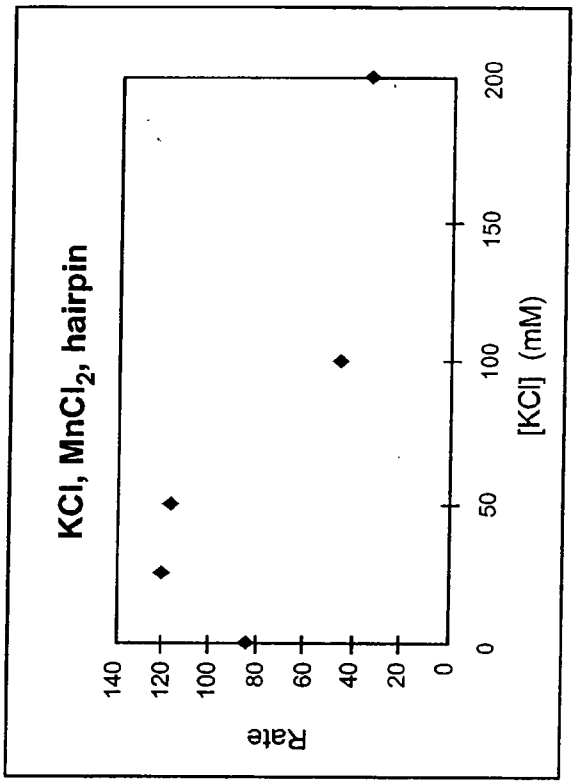

KCl, MnCl2, hairpin
Rate
140
120
100
80
60
40
20
0
0
50
100
150
200
[KCl] (mM)

FIGURE 139E

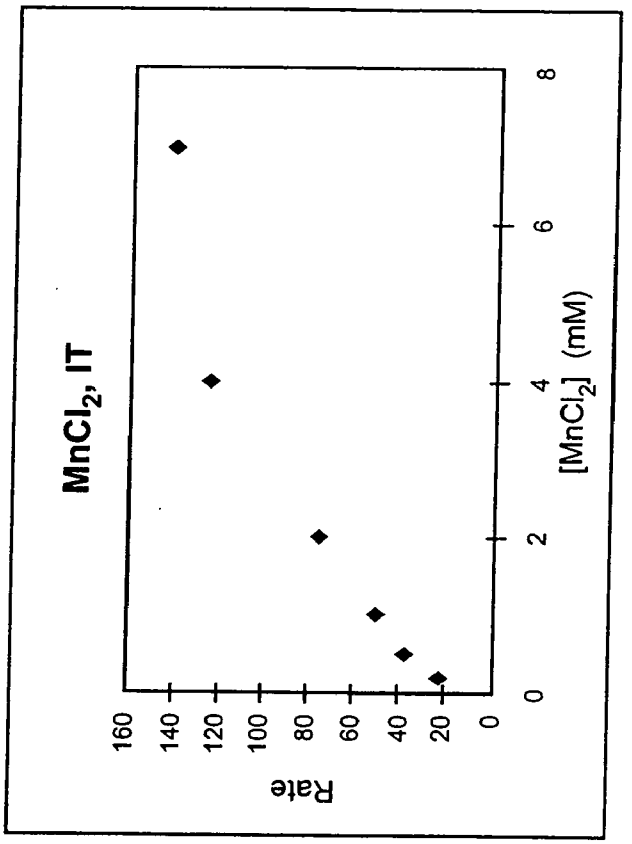


FIGURE 139F

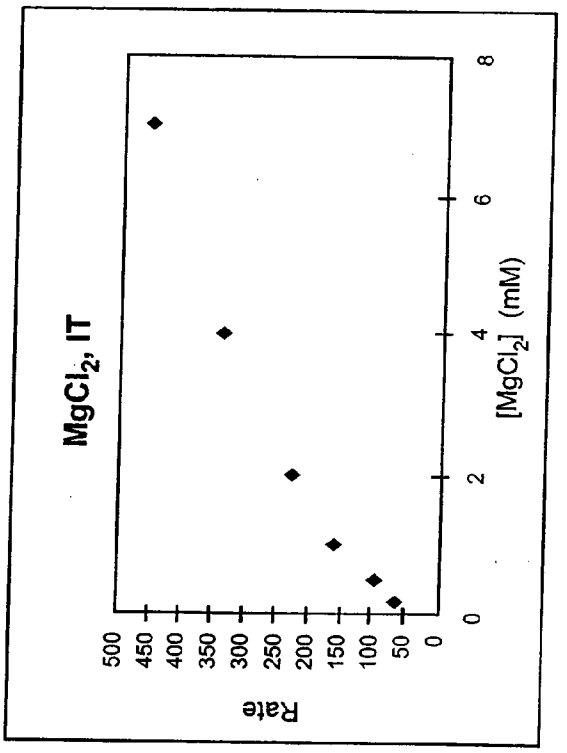

MgCl2, IT
Rate
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
[MgCl2] (mM)

FIGURE 139G

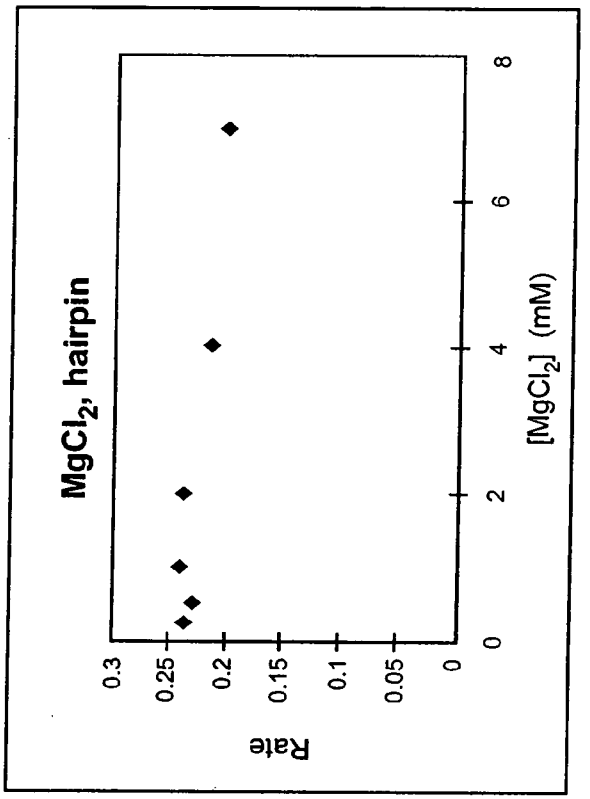


FIGURE 139H

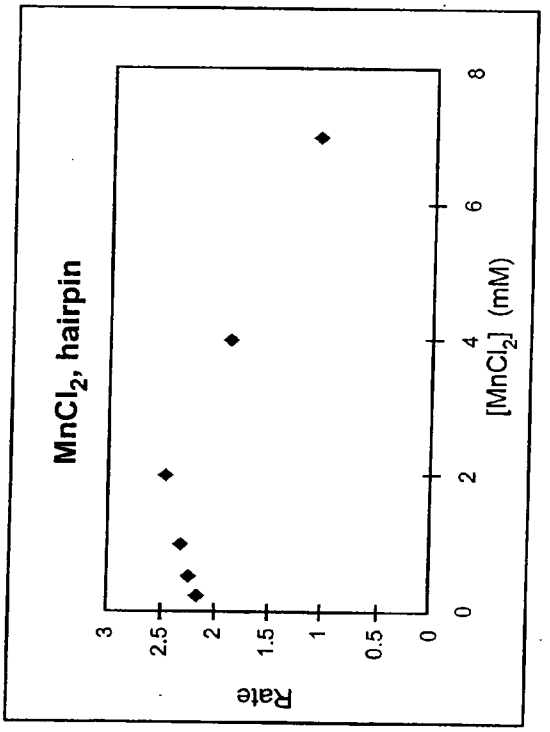


FIGURE 139I

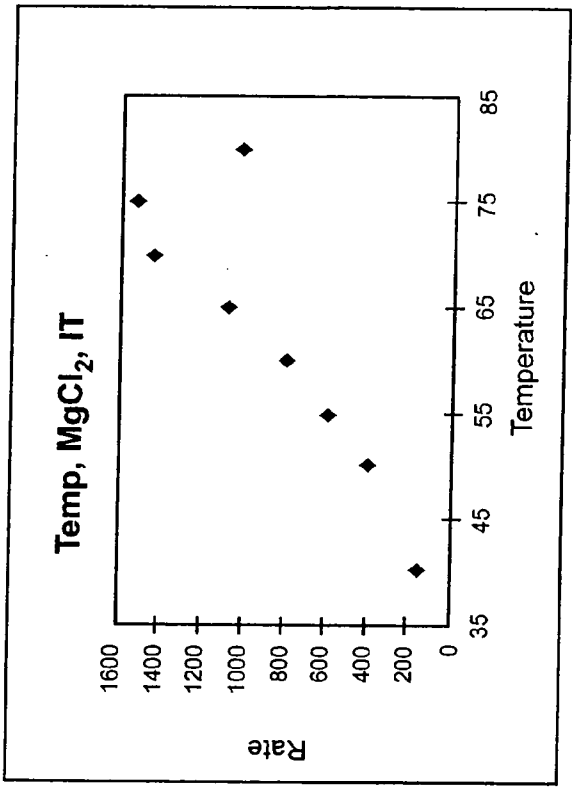

Temp, MgCl2, IT
Rate
1600
1400
1200
1000
800
600
400
200
0
35
45
55
65
75
85
Temperature

FIGURE 139J

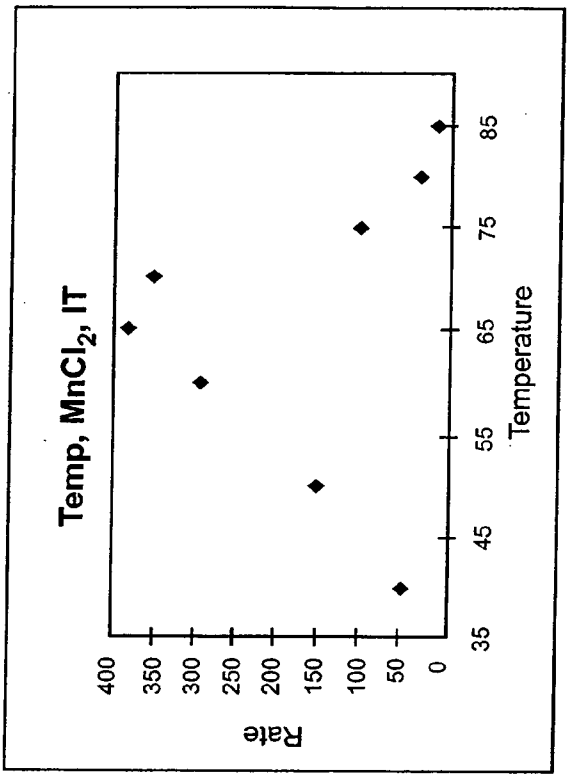
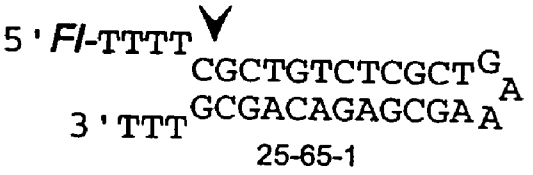

Temp, MnCl2, IT
Rate
400
350
300
250
200
150
100
50
0
35
45
55
65
75
85
Temperature

FIGURE 140

A.

Hairpin Substrate



B.

Invader (IT) substrate

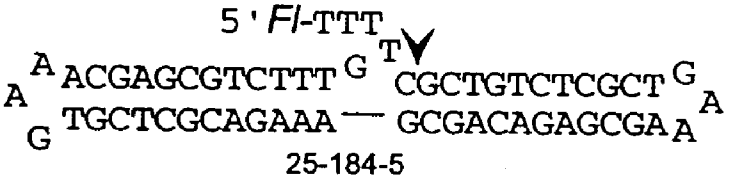
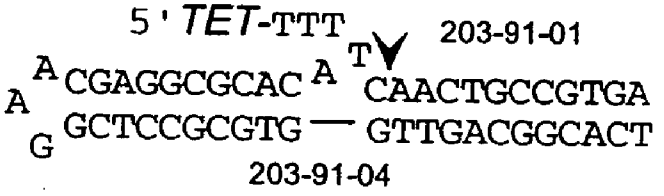


FIGURE 141

Invader (IT) substrate

A.



B.

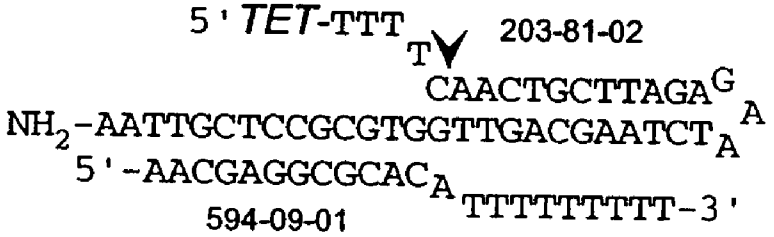
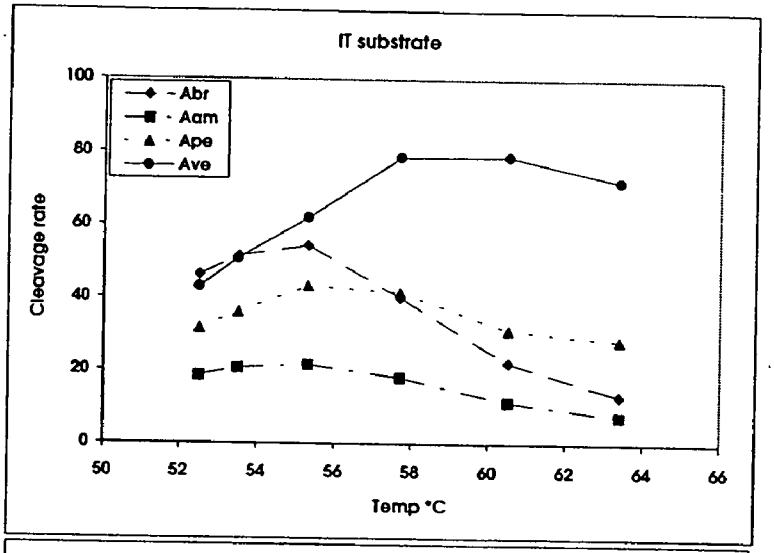
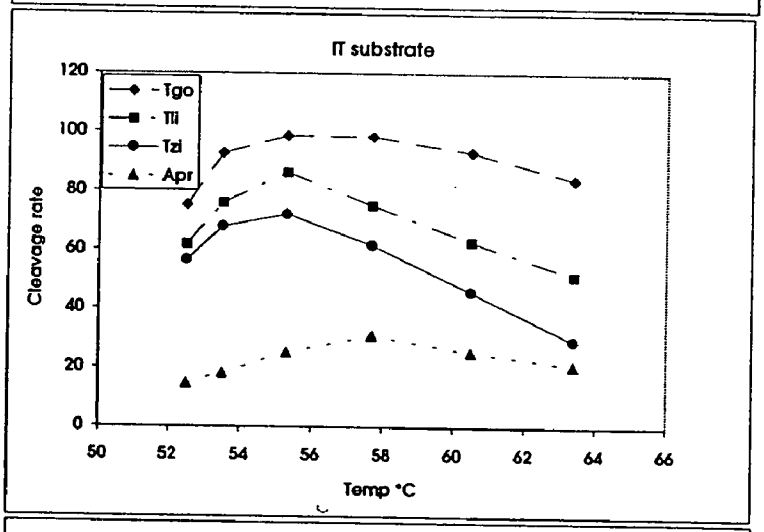


FIGURE 142

A.



B.



C.

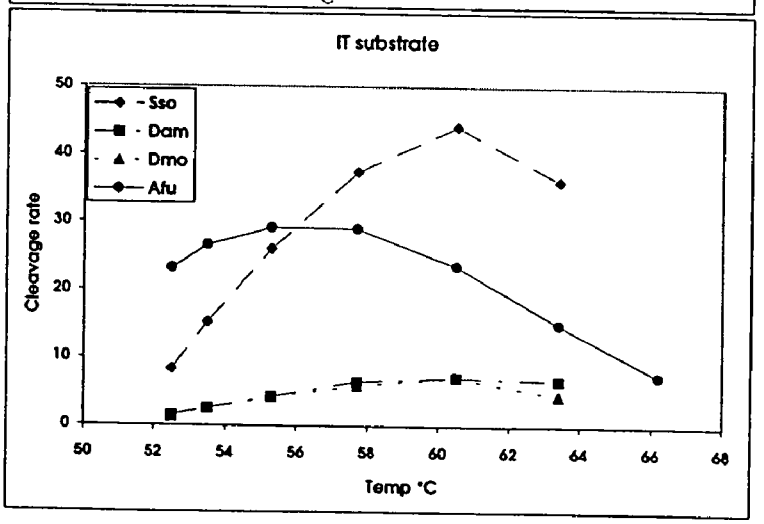


FIGURE 143

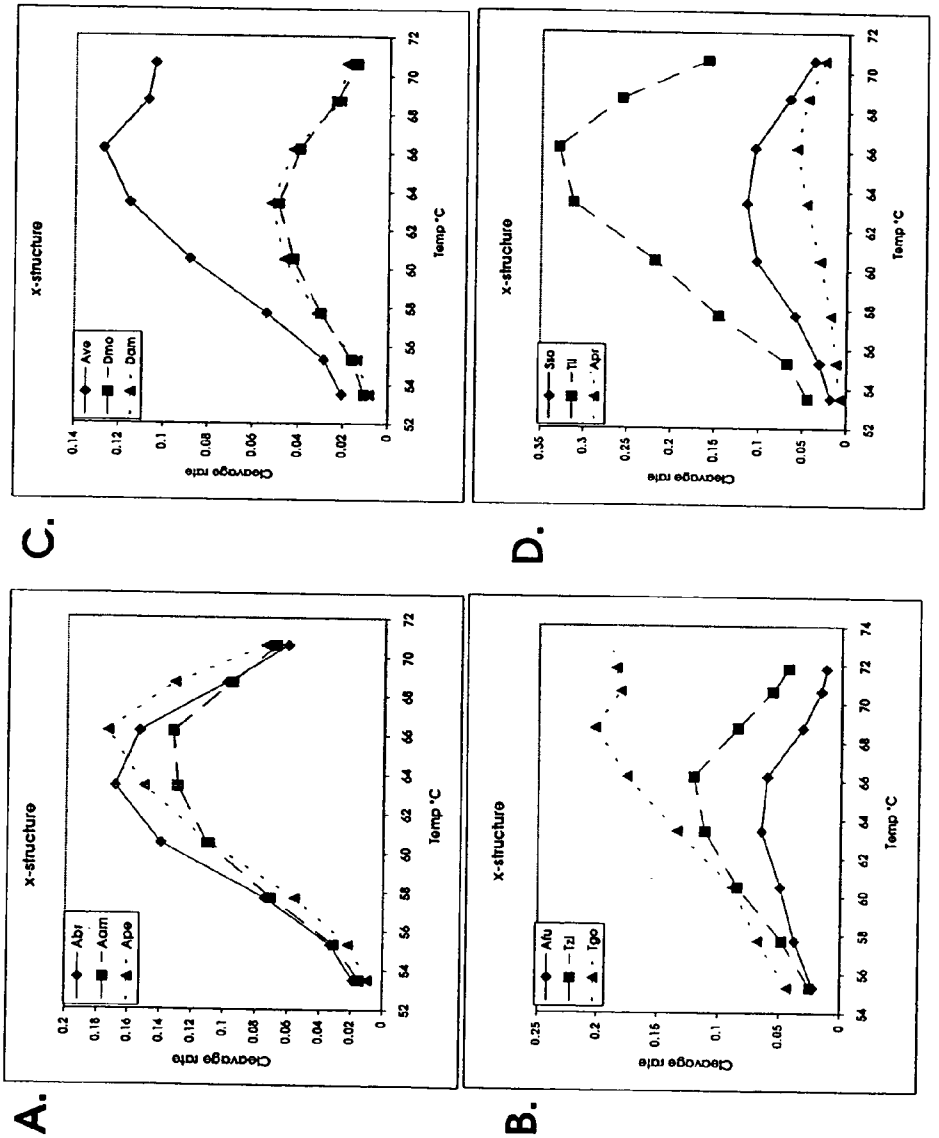

A.
B.
C.
D.
x-structure
Cleavage rate
Temp °C
Abr
Aam
Ape
Afu
Tzl
Tgo
Ave
Dmo
Dam
Ste
Tti
Apr

FIGURE 144

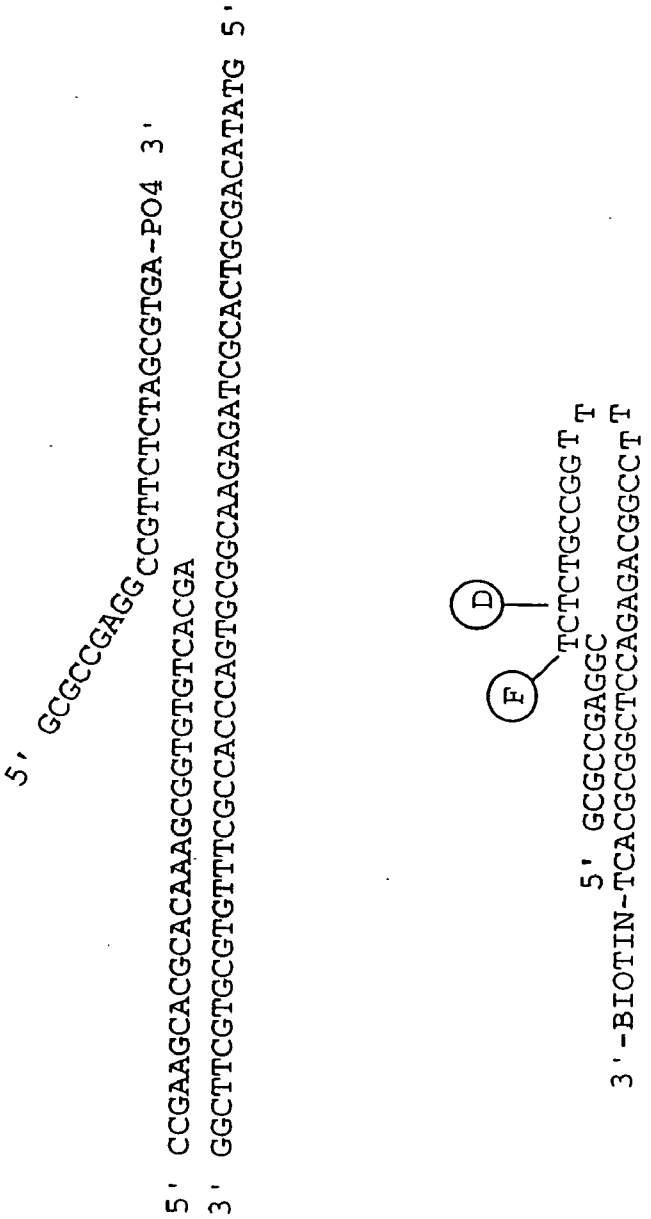

5' GCGCCGAGGCCGTTCTCTAGCGTGA-PO4 3'
5' CCGAAGCACGCACAAAGCGGTGTGTCACGA
3' GGCTTCGTGCGTGTTTCGCCACCCAGTGCGGCAAGAGATCGCACTGCGACATATG 5'
D
F
TCTCTGCCGGTT
5' GCGCCGAGGC
3'-BIOTIN-TCACGCGGCTCCAGAGACGGCCTT

FIGURE 145

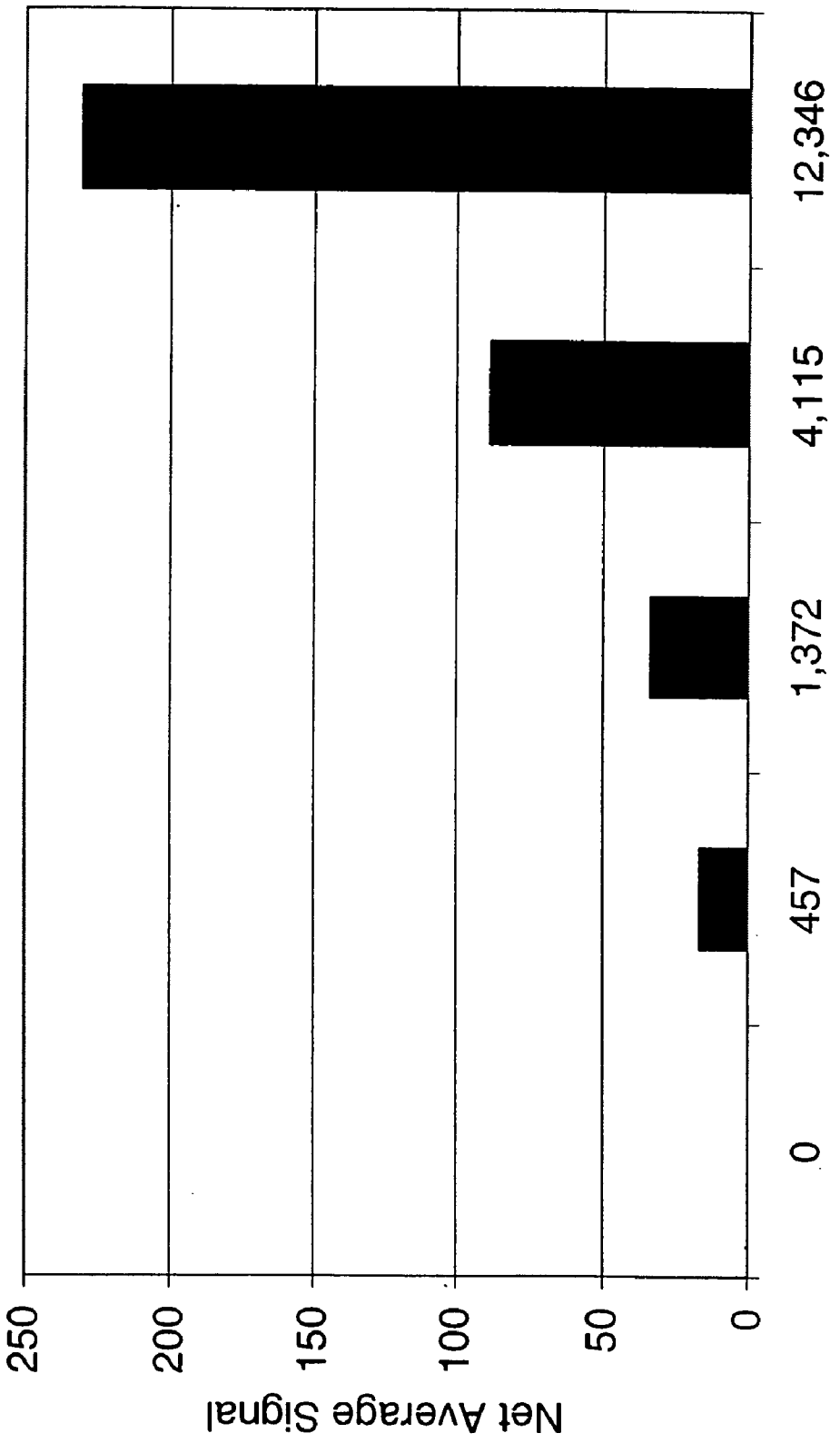


FIGURE 146A

Pae FEN1 ORF DNA sequence

GTGGGAGTTACTGAGTTGGGTAAGCTTATTGGCAAAGAGGTCCGCCGCGAGGTTAAACTGGAAAGT
CTCTCGGGCAAGTGTATTGCCCTTGACGCGTACAACGCCTTGTACCAATTCCTTGCGTCTATTAGA
CAGCCAGATGGGACGCCTCTAATGGACAGAGCTGGGAGGATTACTAGTCATCTCTCGGGTTTGTTC
TACCGTACTATCAACCTCCTTGAGGCCGGCATTAGGCCTGTTTATGTTTTTGATGGGAAGCCTCCC
GAATTTAAACTGGCTGAAATTGAAGAAAGGAGGAAGACGCGTGAGAAGGCCATGGAAGAGGTGTTG
AGGGCCATTAAGGAGGGGAGGAGGGAAGACGTGGCTAAATACGCCAAAAGGGCTGTTTTTATTACC
AGCGAAATGGTGGACGAGGCCAAGAGGCTGCTGAGCTATATGGGCGTACCCTGGGTCCAAGCTCCA
AGCGAGGGGGAGGCGCAAGCGGCTTATATGGCTAGAAAAGGACACTGCTGGGCCGTGGGAAGCCAG
GATTACGATTCGCTGTTATTTGGATCCCCCAAGTTAGTCAGAAATCTAGCGGTATCCCCTAAGCGT
AAAATTGGAGAAGAGGTAATAGAGCTCACGCCGGAAATTATTGAGCTAGACGCCGTCCTCAGGGCT
TTGAGGCTAAAGAACAGAGAGCAACTAATAGACTTGGCTATTTTACTCGGCACAGATTACAACCCA
GACGGCGTTCCCGGAGTGGGCCCCCAGAAGGCGTTAAAACTAATATGGGAATTTGGATCGCTTGAA
AAACTATTAGAAACTGTATTAAAGGGGGCGTATTTCCCCATTGACCCCCTGGAGATAAAGAAGTTC
TTCCTCAATCCCCCAGTCACTGATCAATACGCCACTGAGGTGAGAGACCCAGACGAGGCGGCCCTC
AAGGACTTTCTTATACGCGAACACGACTTCAGCGAGGAGAGGGTGTCTAAGGCACTTGAGAGGCTG
AGAAAAGCCCGGGGGAAGTTAAAAACTTCCTCTCTCGACTCCTTTTTCTAA

Pae FEN1 protein sequence

VGVTELGKLIGKEVRREVKLESLSGKCIALDAYNALYQFLASIRQPDGTPLMDRAGRITSHLSGLF
YRTINLLEAGIRPVYVFDGKPPEFKLAEIEERRKTREKAMEEVLRAIKEGRREDVAKYAKRAVFIT
SEMVDEAKRLLSYMGVPWVQAPSEGEAQAAYMARKGHCWAVGSQDYDSLLFGSPKLVRNLAVSPKR
KIGEEVIELTPEIIELDAVLRALRLKNREQLIDLAILLGTDYNPDGVPGVGPQKALKLIWEFGSLE
KLLETVLKGAYFPIDPLEIKKFFLNPPVTDQYATEVRDPDEAALKDFLIREHDFSEERVSKALERL
RKARGKLKTSSLDSFF

Sso FEN1 ORF DNA sequence

ATAGGTGTAGATTTAGGCGAAATAGTTGAAGATGTTAAGAGAGAGATTAACTTAAATGAGATGAAA
GGAAAGAAAATTAGTATAGATGCTTACAACACAATTTATCAGTTTTTAGCTGCAATAAGACAGCCT
GATGGGACACCTTTAATTGACAGTAAAGGCAGAATAACAAGCCATTTAAATGGGCTATTTTATAGG
ACTATTAGTATAATAGAAAGTGGAATAATCCCCATTTTTGTATTTGATGGAAAGCCACCTGAAAAG
AAGAGTGAAGAAATCGAAAGAAGGAAAAGAGCTAAGGAGGAGGCAGAAAAGAAATTAGAGAAAGCT
AAGTTAGAGGGGGAGTACAGAGAAATTAGAAAATATGCTCAGGCTGCTGTTAGATTAAGCAATGAA
ATGGTAGAGGAAAGTAAAAAACTATTAGATGCTATGGGTATACCTGTAGTTCAAGCTCCAGGAGAA
GGAGAGGCTGAGGCAGCTTATATAAATTCAATTGATCTTTCTTGGGCTGCTGCAAGCCAAGATTAT
GATTCCTTATTATTTGGCGCTAAAAGATTAGTCAGAAACATAACAATTTCAGGTAAAAGAAAGCTT
CCAAATAAGGATGTTTATGTAGAAATAAAGCCTGAGTTGATAGAACTAGAGAGTTTATTGAAAAAA
CTCGGCATCAATAGAGAACAGTTAATAGACATTGCGATTCTTATAGGTACAGATTACAATCCAGAC
GGCGTTAAAGGAATTGGTGTAAAGACGGCATTAAGAATTATAAAGAAATATAATAATATCGAGAAC
GCAATAGAAAAAGGTGAAATTCAATTATCTAAAATAAACTTTGATATACGAGAGATAAGAAAATTA
TTCATTACACCTGAAGTTAAAAAGCCTACTGAACGACTAGAATTAGCAGAATGTAATGAAAGGGAA
ATAATAGAACTTTTGGTTAAAAATCATGATTTTAATGAAGATCGTGTAAATAACGGAATAGAGAGA
TTAAAGAAGGCTATAAAAGAAGCTAAGTCTGTTGAAAAACAGACAGGTCTTGATCAGTGGTTTTAA

FIGURE 146B

Sso FEN1 protein sequence

IGVDLGEIVEDVKREINLNEMKGKKISIDAYNTIYQFLAAIRQPDGTPLIDSKGRITSHLNGLFYR
TISIIESGIIPIFVFDGKPPEKKSEEIERRKRAKEEAEKKLEKAKLEGEYREIRKYAQAAVRLSNE
MVEESKKLLDAMGIPVVQAPGEGEAEAAYINSIDLSWAAASQDYDSLLFGAKRLVRNITISGKRKL
PNKDVYVEIKPELIELESLLKKLGINREQLIDIAILIGTDYNPDGVKGIGVKTALRIIKKYNNIEN
AIEKGEIQLSKINFDIREIRKLFITPEVKKPTERLELAECNEREIIELLVKNHDFNEDRVNNGIER
LKKAIKEAKSVEKQTGLDQWF

Tli FEN1 ORF DNA sequence

ATGGGAGTCCAGATTGGTGAGCTTTTACCAAGAAAAGAGCTTGAGCTTGAAAATTTAAATGGGAGA
AAAGTTGCGATAGATGCATTTAACGCTATTTACCAGTTTCTCTCAACAATAAGACAACGAGATGGG
ACTCCTTTAATGGATTCCAAGGGAAGAATAACGTCCCATCTTTCAGGGCTTTTTTACAGGACTATA
AACCTAATGGAAGCGGGAATAAAGCCTGCGTATGTATTCGATGGGAAGCCTCCAGAGTTCAAGAAA
AAAGAGCTTGAAAAAAGAGCTGAGGCTAGGGAGGAAGCGCAGGAAAAATGGGAGGAAGCCCTAGCA
AGGGGAGACTTAGAAGAGGCGAAGAAATATGCACAGCGGGCGAGCAAAGTAAATGAGATGCTTATC
GAGGATGCTAAGAAGCTTTTGGAGCTTATGGGCATCCCATGGGTGCAGGCTCCTAGCGAAGGTGAA
GCGCAGGCAGCTTATATGGCATCTAAAGGGCACGTTTGGGCCTCGGCGAGCCAGGACTACGACTCG
CTCCTCTTCGGAACACCAAGGCTAGTGAGAAACCTCACCATAACTGGAAAGAGAAAGCTTCCTGGG
AAGGATATTTACGTAGAAGTTAAACCGGAGCTCATAGTTCTTGAAGAGGTGTTAAAGGAGCTTAAG
ATAACGAGGGAGAAGTTGGTAGAGCTTGCAATTCTCGTGGGAACGGACTACAATCCTGGAGGCATA
AAAGGGATTGGACCAAAAAAGGCCCTTGAAATAGTCAAATACTCCAAAGATCCTCTGGCAAAGTAC
CAAAAAATGAGCGATGTTGATCTCTATGCAATAAAGGAGTTCTTCCTAAACCCGCCGACAACAGAC
GAATACAAGCTCGAATGGAAAATGCCCGATGAAGAAGGAATACTGAAGTTTCTCTGTGATGAGCAC
GATTTCAGTGAAGAAAGAGTTAAAAACGGCTTAGAAAGGCTTAAAAAAGCGGTTAAGGCAGGAAGA
CAGTTTACGCTGGACAGCTGGTTTAAAAAGTGA

Tli FEN1 protein sequence

MGVQIGELLPRKELELENLNGRKVAIDAFNAIYQFLSTIRQRDGTPLMDSKGRITSHLSGLFYRTI
NLMEAGIKPAYVFDGKPPEFKKKELEKRAEAREEAQEKWEEALARGDLEEAKKYAQRASKVNEMLI
EDAKKLLELMGIPWVQAPSEGEAQAAYMASKGHVWASASQDYDSLLFGTPRLVRNLTITGKRKLPG
KDIYVEVKPELIVLEEVLKELKITREKLVELAILVGTDYNPGGIKGIGPKKALEIVKYSKDPLAKY
QKMSDVDLYAIKEFFLNPPTTDEYKLEWKMPDEEGILKFLCDEHDFSEERVKNGLERLKKAVKAGR
QFTLDSWFKK

Aam FEN1 ORF DNA sequence

ATAGGAGTAGACCTTGCTGATTTGGTAAAAGAAATCAAAAGAGAAGTTCAGCTAAGTGAATTAAAA
GGGAAGAAAGTAAGCATAGATGCTTATAACGCTATTTACCAGTTTTTGACTGCAATAAGACAGCCA
GATGGTACTCCACTAATGGACTCACAAGGAAGAGTTACTAGTCATCTTAGTGGAATATTTTATAGA
ACAATAAGCCTTTTAGAAGAAGGAGTAATTCCAATTTATGTATTCGATGGAAAACCACCAGAACTT
AAAGCTCAAGAATTAGAAAGAAGAAGAAAAATAAAGGAAGAAGCTGAGAAAAAATTGGAAAAAGCC
AAAGAAGAAGGAGAAACAAAGGAATTAAAGAAGTATTCGCAAATGGCAACTAGGTTAACTAATGAC
ATGGCAGAAGAAAGTAAAAAACTTTTAGAGGCAATGGGAATTCCAGTAGTGCAAGCTCCAAGTGAA
GGAGAAGCTGAGGCAGCGTATTTATGTAGTCAAGGGTATACTTGGGCAGCGGCTAGCCAAGATTAC

FIGURE 146C

GATTCTTTGCTTTTTGGTGCAAATAAATTAATTAGAAACTTAACATTAACTGGAAAGAGGAAATTA
CCTAAAAAAGACGTATATGTAGAAATTAAGCCAGAACTTATAGAACTTGAAGATTTGCTTAAAAAG
TTCGGAATTACTAGAGAACAACTAGTTGATATAGGAATATTAATAGGAACTGATTATGACCCTGAC
GGAATAAAGGGAATAGGGCCAGTTACTGCTCTAAGAATAATAAAGAAATACGGAAATATAGAAAAA
GCTGTAGAAAAAGGAGAATTACCGAAATACATTCTTGATCTTAATATTAATGAAATTAGATCTATC
TTTCTTAATCCGCCAGTAGTTAAGCCTGAGGGCTCGTTAGATCTAAAAGAGCCTAATGAGGAAGAA
ATCAAGAAAATCCTCATAGATGAGCATAACTTTAGTGAGGATAGAGTAACTAATGGAATAGAAAGA
CTGATTAAAGCCGGTAAGGAAGCTAAAGGAGCTAGTAGGCAGAGCGGTTTAGATCAGTGGTTTTAG

Aam FEN1 protein sequence

IGVDLADLVKEIKREVQLSELKGKKVSIDAYNAIYQFLTAIRQPDGTPLMDSQGRVTSHLSGIFYR
TISLLEEGVIPIYVFDGKPPELKAQELERRRKIKEEAEKKLEKAKEEGETKELKKYSQMATRLTND
MAEESKKLLEAMGIPVVQAPSEGEAEAAYLCSQGYTWAAASQDYDSLLFGANKLIRNLTLTGKRKL
PKKDVYVEIKPELIELEDLLKKFGITREQLVDIGILIGTDYDPDGIKGIGPVTALRIIKKYGNIEK
AVEKGELPKYILDLNINEIRSIFLNPPVVKPEGSLDLKEPNEEEIKKILIDEHNFSEDRVTNGIER
LIKAGKEAKGASRQSGLDQWF

Abr FEN1 ORF DNA sequence

ATCGGAGTAGATTTATCTGACTTAGTTGAAGACGTAAAAGCTGAGATAAACTTAGCTGAGTTGCGT
GGGAAAAAAGTAAGTATTGATGCATATAATGCAATATATCAATTTTTGACAGCTATACGCCAACCA
GACGGTACACCACTTATAGATTCACAAGGTAAAATAACAAGCCACCTTAGTGGAATTTTTTATCGA
ACCATTAATCTAATGGAAAATGGTATAATACCGATATATGTTTTTGATGGAAAACCACCAGAGCTT
AAATCTGCAGAATTACAAAGACGTAAAAAAATAAAAGAAGAAGCGGAAAAGAAGTTAGAGAAAGCA
AAAGAAGAGGGAAAAACTACAGAGTTAAAAAAGTATTCTCAAATGGCAACCAGACTTACAAACGAG
ATGGCAGACGAAGGAAAAAAATTGCTTAAAAGTATGGGTATTCCAATAGTAGAAGCACCGTCTGAA
GGTGAAGCGGAATCAGCATATATTAACGCAATAGGATTAAGTTTTGCTACTGCAAGCCAGGATTAT
GATTCACTATTATTTGGTGCGAAAAATTTGATAAGAAACTTAACTATAACTGGAAAAAGAAAATTA
CCTAATAAAGACATATACGTCGAAATAAAACCTGAAAGAATTGAACTCGAACCACTACTTAAAAAG
CTTGGTATAACAAGAGAACAATTAATAGATATAGCGATTTTAATTGGAACAGATTATGATCCTTCA
GGGATAAAAGGAATAGGCCCCAAGACCGCTTATAGGCTAATTAAGAAATATGGAAGAATAGAAAAA
ATTATTGAAGCGAATGAAATTCCAAAGAATTCTATTGATTTCGATATTAATCAAATAAGGCAACTA
TTTCTAAATCCGAATGTGAAAAAACCAGAAGAGAATTTAGACTTGCAAAATCCTGAAGAACAAGAA
ATTATAGAAATTTTAGTAAATCAACATAATTTTAATGAAGAAAGAGTTAAAAGTGCATTAGAAAGA
TTAAATAAAGCAATAAAAGAAACTAAAGGTCTCTCAAGACAAACTGGACTTGACCAATGGTTTTAA

Abr FEN1 protein sequence

IGVDLSDLVEDVKAEINLAELRGKKVSIDAYNAIYQFLTAIRQPDGTPLIDSQGKITSHLSGIFYR
TINLMENGIIPIYVFDGKPPELKSAELQRRKKIKEEAEKKLEKAKEEGKTTELKKYSQMATRLTNE
MADEGKKLLKSMGIPIVEAPSEGEAESAYINAIGLSFATASQDYDSLLFGAKNLIRNLTITGKRKL
PNKDIYVEIKPERIELEPLLKKLGITREQLIDIAILIGTDYDPSGIKGIGPKTAYRLIKKYGRIEK
IIEANEIPKNSIDFDINQIRQLFLNPNVKKPEENLDLQNPEEQEIIEILVNQHNFNEERVKSALER
LNKAIKETKGLSRQTGLDQWF

Ape FEN1 ORF DNA sequence

FIGURE 146D

TTGGGAGTCAACCTTAGGGAGTTGATTCCTCCCGAGGCTAGGAGGGAGGTGGAGCTTAGGGCTCTC
TCGGGGTATGTTCTAGCGCTTGACGCGTATAACATGCTCTACCAGTTCCTCACCGCCATCAGGCAG
CCCGACGGCACTCCCCTTTTGGATAGGGAGGGCAGGGTTACAAGCCACCTCAGCGGCCTGTTCTAC
AGGACCATTAACCTGGTGGAGGAGGGTATTAAGCCCGTCTACGTCTTCGACGGGAAGCCTCCTGAA
ATGAAGAGCCGGGAGGTTGAAGAGAGGCTTAGGAGGAAGGCGGAGGCTGAGGCGAGGTATAGGAGG
GCTGTCGAGGCGGGAGAGGTTGAGGAGGCTAGGAAGTACGCTATGATGGCTGCGAGGCTTACGAGC
GACATGGTGGAGGAGTCGAAGGAGCTGCTGGATGCTATGGGGATGCCCTGGGTTCAGGCGCCTGCC
GAGGGTGAGGCTCAGGCAGCCTATATGGCTAGGAAGGGTGATGCATGGGCGACGGGGAGCCAGGAC
TACGATAGCCTCCTGTTCGGCTCGCCTAGGCTTGTGAGAAACCTAGCCATAACAGGTCGTAGGAAG
CTCCCGGGTAGGGATCAGTATGTCGAGATAAAGCCGGAGATCATAGAGCTCGAGCCTCTGCTCAGC
AAGCTGGGGATAACAAGGGAGCAGTTGATAGCGGTGGGTATCCTCCTCGGCACGGACTACAACCCC
GGCGGTGTGAGGGGTTATGGGCCTAAGACAGCCCTAAGGCTTGTTAAGAGCCTGGGAGACCCGATG
AAGGTGTTGGCTTCCGTCCCACGGGGGGAATATGACCCGGATTATCTTAGAAAGGTGTACGAGTAC
TTCTTGAACCCCCCCGTCACAGACGACTACAAGATTGAGTTTAGGAAGCCGGATCAGGACAAGGTT
AGGGAGATTCTTGTAGAGAGGCACGACTTCAATCCCGAGAGGGTGGAGAGGGCCCTCGAGAGGCTG
GGGAAGGCTTACAGGGAGAAGCTCAGGGGCAGGCAGTCGAGGCTCGACATGTGGTTCGGATAG

Ape FEN1 protein sequence

LGVNLRELIPPEARREVELRALSGYVLALDAYNMLYQFLTAIRQPDGTPLLDREGRVTSHLSGLFY
RTINLVEEGIKPVYVFDGKPPEMKSREVEERLRRKAEAEARYRRAVEAGEVEEARKYAMMAARLTS
DMVEESKELLDAMGMPWVQAPAEGEAQAAYMARKGDAWATGSQDYDSLLFGSPRLVRNLAITGRRK
LPGRDQYVEIKPEIIELEPLLSKLGITREQLIAVGILLGTDYNPGGVRGYGPKTALRLVKSLGDPM
KVLASVPRGEYDPDYLRKVYEYFLNPPVTDDYKIEFRKPDQDKVREILVERHDFNPERVERALERL
GKAYREKLRGRQSRLDMWFG

Apr FEN1 ORF DNA sequence

ATGGGCGCTGATATAGGAGAGCTCTTGAAGAGGGAAGAAGTTGAGATAGAATACTTTTCAGGAAAG
AAGATTGCAATAGATGCCTTTAACACGTTATACCAGTTCCTAGCGACAATAAGACAGCCTGACGGA
ACACCTTTGATGGATTCAAAGGGTAGGATAACATCTCACCTTTCAGGAATTCTTTATAGGGTTTCA
AATATGGTGGAGGTCGGAATAAAGCCGATATTTGTTTTTGATGGAGAACCGCCTGAGTTCAAAAAG
AAGGAGATTGAGAGAAGGAGAAAAATTAGGGAAGAAGCTGAGATCAAGTGGAAAACAGCTTTGGAT
ATAGCTGAAGCGAGGAAGTATGCACAGCAAGCTGTGAGAGTTGATGAGTATATTATCGAATCTTCT
AAGAAGCTTTTGAATTTGATGGGAATTCCCATAGTTCAGGCACCCTCAGAGGGAGAAGCTCAGGCC
GCATACATAGTTAGAAAGGGTGATGCGGATTACACAGGTTCGCAAGATTACGATTCCCTTCTTTTC
GGCTCGCCAAGACTGGCAAGGAATTTGGCCATAACTGGGAGGAGAAAGTTGCCCGGAAAGAACGTT
TACACCGAAGTTAAACCCGAGGTGATAGACTTAGAATACAACCTGAAAAAGCTTGGAATTACTAGA
GAACAGCTAATTGATATAGCTTTACTTGTAGGAACAGACTACAACGAGGGGGTTGAGGGGATAGGT
GTTAAGAAGGCCTACAAGTACGTCAAGGCTTATGGAGACATATTCAAGGTTCTGAGGGTTCTGAAG
GTTAAAGTTGAGGAGCCCATAGAGGAGATAAGAAACTTCTTCTTAAATCCTCCGGTGACAGATGAT
TACGAGATAAAGTTTAGGGAGCCCAATGTCGATGGAATAATTGAGTTTCTATGTGAGGAGCACGAT
TTCAGTAGGGAGAGGGTTGAAAAAGCTGTAGAGAAGCTTAGAGCCATTAAAAGCGATCAGCTTACT
CTGGACAGGTGGTTTTAA

Apr FEN1 protein sequence

FIGURE 146E

MGADIGELLKREEVEIEYFSGKKIAIDAFNTLYQFLATIRQPDGTPLMDSKGRITSHLSGILYRVS
NMVEVGIKPIFVFDGEPPEFKKKEIERRRKIREEAEIKWKTALDIAEARKYAQQAVRVDEYIIESS
KKLLNLMGIPIVQAPSEGEAQAAYIVRKGDADYTGSQDYDSLLFGSPRLARNLAITGRRKLPGKNV
YTEVKPEVIDLEYNLKKLGITREQLIDIALLVGTDYNEGVEGIGVKKAYKYVKAYGDIFKVLRVLK
VKVEEPIEEIRNFFLNPPVTDDYEIKFREPNVDGIIEFLCEEHDFSRERVEKAVEKLRAIKSDQLT
LDRWF

Ave FEN1 ORF DNA sequence

ATGGGTGCAGACATAGGCGAACTACTCGAGAGAGAAGAAGTTGAACTTGAGTACTTCTCCGGGAGA
AAAATAGCTATTGATGCTTTTAACACTCTTTACCAGTTCATATCTATCATAAGGCAACCTGACGGC
ACTCCTTTGAAGGATTCTCAGGGTAGAATGACCTCACACCTCTCCGGCATCCTGTACCGCGTGTCA
AACATGATCGAGGTTGGAATGAGACCCATTTTCGTTTTCGATGGTGAGCCTCCTGTTTTCAAGCAG
AAGGAGATAGAGGAACGAAAGGAAAGAAGAGCTGAAGCAGAGGAGAAGTGGATCGCTGCGATAGAG
AGAGGAGAGAAGTACGCAAAGAAGTACGCTCAGGCAGCGGCGAGGGTTGATGAATACATCGTCGAG
TCGTCAAAGAAGCTGCTTGAGTATATGGGAGTTCCATGGGTTCAGGCGCCGAGTGAGGGAGAGGCA
CAGGCTGCATACATGGCAGCGAAGGGCGATGTAGATTTTACTGGCTCGCAGGATTACGACTCGCTT
CTCTTCGGCAGCCCAAAGCTTGCAAGAAATCTCGCGATTACTGGAAAGAGGAAGCTGCCCGGAAAG
AATGTTTACGTTGAGGTCAAACCAGAGATAATAGACTTAAACGGCAACCTGAGAAGGCTTGGAATA
ACAAGGGAACAGCTCGTCGATATCGCGTTGCTCGTGGGAACGGACTACAACGAAGGAGTGAAGGGC
GTTGGGGTCAAGAAGGCCTACAAGTACATAAAAACCTACGGAGATGTTTTCAAAGCTCTCAAGGCC
TTAAAGGTAGAGCAGGAGAACATAGAGGAGATAAGAAACTTCTTCCTGAACCCGCCTGTTACGAAC
AACTACAGCCTCCACTTCGGAAAGCCAGACGATGAGAAGATTATCGAGTTCCTGTGTGAAGAGCAC
GACTTTAGCAAGGATAGGGTAGAGAAGGCCGTTGAGAAGCTGAAAGCAGGAATGCAAGCCTCGCAA
TCAACGCTTGAGAGGTGGTTTTCCTGA

Ave FEN1 protein sequence

MGADIGELLEREEVELEYFSGRKIAIDAFNTLYQFISIIRQPDGTPLKDSQGRMTSHLSGILYRVS
NMIEVGMRPIFVFDGEPPVFKQKEIEERKERRAEAEEKWIAAIERGEKYAKKYAQAAARVDEYIVE
SSKKLLEYMGVPWVQAPSEGEAQAAYMAAKGDVDFTGSQDYDSLLFGSPKLARNLAITGKRKLPGK
NVYYVEVKPEIIDLNGNLRRLGITREQLVDIALLVGTDYNEGVKGVGVKKAYKYIKTYGDVFKALKA
LKVEQENIEEIRNFFLNPPVTNNYSLHFGKPDDEKIIEFLCEEHDFSKDRVEKAVEKLKAGMQASQ
STLERWFS

Dam FEN1 ORF DNA sequence

ATGGGAGTAGACTTAAAAGACATTATACCAGGCGAAGCTAAAACGGTTATCGAGGATCTCAGGATC
CTACATGGCAAGATTATAGTGATAGATGGCTATAACGCATTATACCAGTTCCTAGCTGCAATCAGA
CAACCGGATGGGACCCCTCTAATGGATAACAACGGGAGGATCACGAGTCATTTAAGCGGTTTATTC
TATAGAACCATAAATATCGTTGAGGCAGGGATAAAACCAGTCTACGTGTTTGATGGTAAACCCCCT
GAATTGAAGGCGAGGGAGATAGAGAGGAGGAAAGCCGTTAAGGAGGAGGCAGCAAAGAAGTACGAG
GAAGCCGTTCAATCCGGAGACCTCGAGCTCGCGAGGAGATACGCAATGATGTCGGCCAAGCTGACA
GAGGAAATGGTGAGGGATGCTAAATCATTACTAGACGCAATGGGTATTCCATGGGTTCAAGCACCA
GCGGAGGGCGAGGCTCAGGCAGCCTATATTGTTAAGAAGGGGGATGCCTATGCATCCGCCTCACAG
GATTACGATAGCTTGCTATTCGGCTCCCCTAAGCTCGTTAGAAACCTGACCATAAGCGGTAGAAGA

FIGURE 146F

AAGCTACCGAGAAAAAACGAGTATGTTGAAGTAAAGCCGGAGCTCATAGAGCTCGACAAACTCCTT
GTTCAGCTAGGTATAACCCTTGAGAACCTCATCGATATAGGTATACTCCTGGGGACAGATTACAAT
CCAGACGGCTTCGAAGGCATAGGCCCCAAGAAGGCTCTTCAACTAGTTAAGGCATACGGGGGAATC
GAGAAGATACCGAAACCCATTTTGAAGTCGCCGATAGAAGTAGATGTTATAGCAATAAAGAAATAC
TTCCTTCAACCACAGGTAACAGACAACTACAGGATTGAATGGCATACCCCCGATCCCGATGCAGTG
AAAAGAATATTGGTGGATGAACATGATTTCAGTATAGATAGAGTTAGCACAGCGCTTGAGAGATAC
GTGAAGGCCTTTAAAGAAAATATACGGGGAGAACAGAAAGGTCTCTCTAAATGGTTCAGTAAGCCG
AAGTAG

Dam FEN1 protein sequence

MGVDLKDIIPGEAKTVIEDLRILHGKIIVIDGYNALYQFLAAIRQPDGTPLMDNNGRITSHLSGLF
YRTINIVEAGIKPVYVFDGKPPELKAREIERRKAVKEEAAKKYEEAVQSGDLELARRYAMMSAKLT
EEMVRDAKSLLDAMGIPWVQAPAEGEAQAAYIVKKGDAYASASQDYDSLLFGSPKLVRNLTISGRR
KLPRKNEYVEVKPELIELDKLLVQLGITLENLIDIGILLGTDYNPDGFEGIGPKKALQLVKAYGGI
EKIPKPILKSPIEVDVIAIKKYFLQPQVTDNYRIEWHTPDPDAVKRILVDEHDFSIDRVSTALERY
VKAFKENIRGEQKGLSKWFSKPK

Dmo FEN1 ORF DNA sequence

ATGGGCGTCGACCTAAGGGAACTCATCCCAGACGACGCCAAGATCATTATAGAGGATCTGAGGACC
CTACGGGGCAGGGTTATCGCGATAGACGGCTATAACGCGCTCTACCAGTTCCTAGCCGCCATCAGG
CAGCCCGACGGGACGCCCCTAATGGATGGAAGCGGCAGGATCACCAGCCACCTCAGCGGGCTCTTC
TACAGGACGATAAACATTGTGGAGGCAGGGATTAAACCCGTATACGTCTTCGATGGTAAACCCCCC
GAGTTGAAGGCGAAGGAGATAGAGAGGAGAAGGGTTGTCAGGGAGGAGGCTGCGAGAAAGTATGAG
GAGGCAGTGCAAGCCGGCGACTTAGAGTCAGCTAGAAGGTATGCGATGATGTCGGCTAGGCTCACC
GATGAAATGGTGAGGGATGCAAAAGCCCTGCTCGACGCCATGGGGATACCGTGGGTTCAAGCCCCG
GCTGAGGGCGAGGCGCAGGCAGCGTACATGGCTAGGAAGGGCGACGCCTACGCCTCTGCATCCCAG
GACTACGATAGCCTCCTCTTCGGGTCGCCCCGCCTAGTGAGGAATCTCACTATAAGTGGCCGTAGG
AAGCTCCCGAGAAGAGAGGAGTATGTCGAGGTGAAGCCCGAGGTAATAGAGCTCGATAAACTGCTT
TCAAAGCTGGGCGTAACCTATGAGAACCTGGTGGACATAGGCATCCTCCTGGGGACGGATTACAAC
CCAGACGGCTTCGAGGGCATTGGACCCAAGAAGGCGCTTCAATTAGTGAAGGTCTACGGGAGCGTT
GAGAAGATACCGAAGCCCCTCTTGAAATCCCCTGTTGAAGTAGATGTCGCAGCGATAAAAAAGTAC
TTCCTGCAACCCCAGGTGACAGACAACTATAGGCTTGAATGGCGTAACCCGGATCCCGAGGCTGTG
AAACGCATACTTGTCGGCGAACACGATTTCAGCGCTGAGAGAGTCAACGCAGCCCTCGACAGGTAT
CTTAAAGCCTTCAGGGAGAACATAAGGGGCGAACAGAAGGGGCTGTCGAAGTGGTTCGCTAAGCCC
GGTAAGCAGGGTTAA

Dmo FEN1 protein sequence

MGVDLRELIPDDAKIIIEDLRTLRGRVIAIDGYNALYQFLAAIRQPDGTPLMDGSGRITSHLSGLF
YRTINIVEAGIKPVYVFDGKPPELKAKEIERRRVVREEAARKYEEAVQAGDLESARRYAMMSARLT
DEMVRDAKALLDAMGIPWVQAPAEGEAQAAYMARKGDAYASASQDYDSLLFGSPRLVRNLTISGRR
KLPRREEYVEVKPEVIELDKLLSKLGVTYENLVDIGILLGTDYNPDGFEGIGPKKALQLVKVYGSV
EKIPKPLLKSPVEVDVAAIKKYFLQPQVTDNYRLEWRNPDPEAVKRILVGEHDFSAERVNAALDRY
LKAFRENIRGEQKGLSKWFAKPGKQG

Mig FEN1 ORF DNA sequence

FIGURE 146G

ATGGGAGTGCAGTTTAATGATTTAATCCCAAAAAAGGAAATTCCAATAAAGTACTTATCAGGAAAA
ACTGTGGCTATAGATGGGATGAATGTCCTTTATCAATTTTTATCAAGTATTAGATTGAGAGATGGG
TCCCCTTTAAGGAACAGGAAAGGAGAGATAACCTCAACATACAATGGCATATTTTACAAAACCATA
TACATGCTCGAAAATGATATAACACCGGTATGGGTGTTTGATGGAAAACCGCCAAAATTGAAAGAG
AAAACCAGAGAAGAAAGAAGAAAAATGAGAGAAAAAGCAAAAGAGGAATTCACAAAAGCAAAAGAA
ATGGAAAATATTGATGAGATGCAAAAATACGCAAAGAGGATGAACTTCTTAACAAAGGACATCGTA
GAGAACTCAAAAAAATTATTGGATTTGATGGGGGTACCTTATGTAAATGCCCCAGCAGAAGGGGAA
GGACAAGCATCATACATGGCAAAAAAGGGAGATGTATTCTGTGTTATTAGTCAGGACTATGATGCT
TTGCTTTATGGGGCCCCAAGGATAGTGAGAAACTTAACAGCAACAAAGGAAGAGTTGGAGTTAATA
GAGCTGGAAAATGTTTTAAATGAGTTGGGCATTTCTCATGATGATTTAATAGACATGGCAATTTTG
ATAGGGACTGATTATAATCCAAAGGGAGTTAAAGGCATTGGTCCAAAAAAAAGCTCTCGAAATAGTA
AAATCAAAAAACAAAGAACTCTACTTAAAGGCTGTTGAGAATTATGAAGAAATTAAAAATATATTT
AAAAATCCAAAAGTTACTGATGAATACAGCATCAAATTAAAAAAGCCAGATAAAGAAGGTATTATA
AAGTTTTTGGTTGAGGAAAATGATTTCTCTATGGAGAGAGTTCAGCCACATGTTGAAAAACTCTGT
AAATTGATTGAGAAAAAAACCAAACAAGTAACATTAGATGCATGGTTTGGGAGATGA

Mig FEN1 protein sequence

MGVQFNDLIPKKEIPIKYLSGKTVAIDGMNVLYQFLSSIRLRDGSPLRNRKGEITSTYNGIFYKTI
YMLENDITPVWVFDGKPPKLKEKTREERRKMREKAKEEFTKAKEMENIDEMQKYAKRMNFLTKDIV
ENSKKLLDLMGVPYVNAPAEGEGQASYMAKKGDVFCVISQDYDALLYGAPRIVRNLTATKEELELI
ELENVLNELGISHDDLIDMAILIGTDYNPKGVKGIGPKKALEIVKSKNKELYLKAVENYEEIKNIF
KNPKVTDEYSIKLKKPDKEGIIKFLVEENDFSMERVQPHVEKLCKLIEKKTKQVTLDAWFGR

Mka FEN1 ORF DNA sequence

TTGGGACTAGCTGAACTCCGAGAACTGATCGAACCCGAAGAGACGGACCTGAGAGCCCTCGCCGGT
CGGGAGATCGCTATCGACGCGTTCAACGCCCTGTATCAATTCCTGACCACGATCATGAAGGACGGA
CGACCTCTCATGGACTCGAGGGGCAGGATTACCAGCCACTTAAATGGCCTCCTGTATAGGACCGTG
AACTTGGTCGAAGAGGGTATCAAGCCGGTATACGTGTTCGATGGTGAGCCCCCGGACCTGAAGCGT
GAAACGCTGGAGCGTCGACGGGAACGGAAGGAGGAGGCGATGGAGAAACTGAGGCGGGCCAAAACG
AAGGAGGAGCGGGAGAAGTACGCCCGACAAGTCGCCAGACTCGACGAGTCGTTGGTGGAAGACGCG
AAGAGGCTGTTGGATCTCATGGGCATCCCGTGGGTACAGGCCCCCTCGGAAGGAGAGGCGCAGTGC
GCGTATATGGCGAGGTGCGGGGACGTATGGGCGACAGGCAGCCAAGACTACGACTCGCTGCTTTTC
GGCAGCCCCAGGTTGGTTCGCAACATCACGATAGTCGGAAAGCGGAAGCATCCACACACCGGCGAG
ATCATAGAGGTCAAGCCCGAGATCATGAGGTTGGAGGACGTGCTCGACCAGCTGGGATTGGAATCG
AGGGAGCAGCTGGTGGACCTAGCGATCCTTTTGGGCACGGACTACAACCCGGATGGAGTACCCGGG
ATTGGTCCGAAGCGCGCGCTGCAGTTGATCAGGAAGTACGGGTCGCTAGACGAGCTTAAGGACACC
GACATCTGGCCTAAGATCGAGCGGCACCTGCCGGTGGAACCGGAGAAGCTCAAAAGGCTCTTTCTC
GAGCCGGAAGTTACGGACGACTACCAGCTAGACTGGGACGAACCCGACCAAAAGGGACTGGTCGAG
TTCCTGGTTGAGGAGCGTGATTTCTTCCAGGATCGAGTCCGCCGCGCCGTCGAGCGTCTGA

Mka FEN1 protein sequence

FIGURE 146H

LGLAELRELIEPEETDLRALAGREIAIDAFNALYQFLTTIMKDGRPLMDSRGRITSHLNGLLYRTV
NLVEEGIKPVYVFDGEPPDLKRETLERRRERKEEAMEKLRRAKTKEEREKYARQVARLDESLVEDA
KRLLDLMGIPWVQAPSEGEAQCAYMARCGDVWATGSQDYDSLLFGSPRLVRNITIVGKRKHPHTGE
IIEVKPEIMRLEDVLDQLGLESREQLVDLAILLGTDYNPDGVPGIGPKRALQLIRKYGSLDELKDT
DIWPKIERHLPVEPEKLKRLFLEPEVTDDYQLDWDEPDQKGLVEFLVEERDFFQDRVRRAVERL

Pbr FEN1 ORF DNA sequence

GTGGGCGTCAACCTCCGCGAGATCATACCCAAGGAGGCTGTAACGGAAATAGAGCTCGACTCGCTG
CGCTACAAGGTTGTAGCCATAGACGCCTACAACGCGCTCTACCAGTTCCTCACCGCGATAAGGCAG
CCGGACGGCACGCCGCTCATGGACTCGCGTGGCAGGGTCACCAGCCATCTCAGCGGCCTCTTCTAC
CGCACCATAAACCTGGCCGAGCACGGGGTAAAGGTGGTCTACGTCTTCGACGGGAAGCCGCCGGAG
ATGAAGTATCTCGAGATAGAGAGGAGGAAGCGTGTCAAGGCGGAGGCTGTGCGGAAGTACGAGGAG
GCAGTGAAGAGGGGCGACCAGGAGGCGGCGAGGCGCTACGCCCAGGCAGCGGCGAGACTCACCGAC
GAGATGGTGGAGGACGCTAAGAAGCTGCTGGAGGCCATGGGGATACCCTACGTGCAGGCGCCGGCG
GAGGGGGAGGCGCAGGCCGCCTACATGGCCCGGAAGGGCGACGCCTGGGCCGCGGCGAGCCAGGAC
TACGACTCCCTGCTCTTCGGGGCCCCGAGGCTTGCCCGGAACCTCGCTATAACGGGTAAGAGGAAG
CTGCCCAGGAAGAACGTCTACGTAGAGGTTAAGCCGGAGCTGGTGGAGCTCGAGAAGCTGCTCAAG
GCACTGGGCATTACCAGGGAGCAGTTGATAGCCCTAGGCATACTCATAGGCACCGACTACAACCCG
GACGGCGTCCGGGGGATCGGGCCCAAGACGGCGCTGAAGATGGTGCAGACCCACCGGGACCCCGTG
AAGCTCCTCCAGGGGCTCCCGCGCCACGAGTTCCCGGTCGACCCACTGAAGATCTACGAGTACTTC
CTGAACCCCCCAGTGACCAGCGACTATAAGCTCGAGTGGAGGGAGCCCGACGAGAAGAGGGTCCTC
GAGATACTCGTGGAGGAGCACGACTTCAACCCGGAGCGTGTTAAGAACGCCCTGGAGAGGCTGCGG
AGGGCGTACCGCGAGCACTTCCAGGGCCGCCAGATGGGTCTGGATGCGTGGCTGCGCCGCTAG

Pbr FEN1 protein sequence

VGVNLREIIPKEAVTEIELDSLRYKVVAIDAYNALYQFLTAIRQPDGTPLMDSRGRVTSHLSGLFY
RTINLAEHGVKVVYVFDGKPPEMKYLEIERRKRVKAEAVRKYEEAVKRGDQEAARRYAQAAARLTD
EMVEDAKKLLEAMGIPYVQAPAEGEAQAAYMARKGDAWAAASQDYDSLLFGAPRLARNLAITGKRK
LPRKNVYVEVKPELVELEKLLKALGITREQLIALGILIGTDYNPDGVRGIGPKTALKMVQTHRDPV
KLLQGLPRHEFPVDPLKIYEYFLNPPVTSDYKLEWREPDEKRVLEILVEEHDFNPERVKNALERLR
RAYREHFQGRQMGLDAWLRR

Pho FEN1 ORF DNA sequence

ATGGGTGTTCCTATCGGTGACCTCGTTCCGAGGAAGGAGATAGATCTTGAAAATCTGTATGGAAAG
AAGATAGCGATAGATGCCCTAAACGCCATCTATCAGTTTTTATCAACGATAAGACAGAGGGATGGA
ACACCACTTATGGACTCTAAGGGTAGGATAACCTCTCATTTAAGTGGGCTCTTTTATAGAACGATA
AATCTAATGGAAGCCGGTATTAAGCCGGCCTACGTCTTTGATGGAAAGCCTCCGGAATTCAAAAGG
AAGGAGCTCGAAAAAAGGAGGGAAGCTAGAGAAGAGGCAGAACTAAAATGGAAAGAAGCTCTAGCC
AAGGGAAACCTGGAGGAAGCTAGGAAATACGCTCAAAGGGCAACTAAGGTTAATGAAATGCTAATC
GAAGATGCAAAGAAGCTTTTGCAACTAATGGGAATACCAATAATTCAGGCTCCAAGTGAAGGAGAA
GCCCAAGCGGCATACATGGCAAGTAAAGGGGATGTCTACGCGTCAGCGAGTCAAGATTATGATTCA
CTACTCTTTGGTGCTCCAAGGTTGATTAGGAATCTGACAATTACGGGAAAAAGAAAGATGCCTGGG
AAAGATGTTTACGTTGAAATAAAGCCAGAGTTAGTAGTTCTAGATGAGGTACTAAAAGAGCTTAAG
ATAACAAGAGAAAAGCTTATAGAACTTGCAATTCTGGTTGGGACTGACTATAATCCTGGGGGCGTA

FIGURE 146I

AAGGGGATAGGACCTAAGAAGGCCCTTGAGATTGTAAGATATTCAAGGGATCCCCTAGCAAAGTTC
CAAAGACAGAGCGATGTGGATCTTTACGCTATTAAGGAATTCTTCCTTAACCCTCCTGTCACTAAT
GAATACTCGCTTAGTTGGAAGGAGCCTGATGAGGAAGGAATATTAAAATTCCTCTGTGATGAGCAT
AATTTTAGCGAAGAAAGGGTAAAAAATGGGATAGAAAGACTAAAAAAGGCGATAAAAGCTGGAAGA
CAATCAACGCTTGAGAGTTGGTTCGTTAAAAAGAAACCCTAA

Pho FEN1 protein sequence

MGVPIGDLVPRKEIDLENLYGKKIAIDALNAIYQFLSTIRQRDGTPLMDSKGRITSHLSGLFYRTI
NLMEAGIKPAYVFDGKPPEFKRKELEKRREAREEAELKWKEALAKGNLEEARKYAQRATKVNEMLI
EDAKKLLQLMGIPIIQAPSEGEAQAAYMASKGDVYASASQDYDSLLFGAPRLIRNLTITGKRKMPG
KDVYVEIKPELVVLDEVLKELKITREKLIELAILVGTDYNPGGVKGIGPKKALEIVRYSRDPLAKF
QRQSDVDLYAIKEFFLNPPVTNEYSLSWKEPDEEGILKFLCDEHNFSEERVKNGIERLKKAIKAGR
QSTLESWFVKKKP

Tgo FEN1 ORF DNA sequence

ATGGGAGTTCAGATAGGTGAGCTTGTGCCAAGGAAGGAGATCGAACTTGAAGCTCTCTACGGGAAG
AAGGTTGCGATCGATGCCTTCAACGCCATGTACCAGTTCCTCTCAACGATAAGACAGCGCGATGGA
ACTCCTCTAATGGACTCGAAGGGCAGGATAACCTCCCACCTCAGCGGCTTCTTTTACAGGACGATC
AACCTCATGGAGGCCGGAATAAAGCCCGCCTACGTCTTCGACGGAAAGCCGCCGGAGTTCAAGAAG
AAGGAGATAGAGAAAAGGAGAGAGGCAAGGGAAGAAGCCGAGGAGAAGTGGTACGAGGCCCTTGAA
AAGGGTGACTTGGAGGAAGCGAAGAAGTACGCGATGAGGGCAACCCGCGTTAACGAGCAACTCATA
AACGATGCCAAAAAGCTTCTCGAACTGATGGGGATTCCAGTCGTGCAGGCGCCGAGCGAAGGTGAA
GCTCAGGCCGCATACATGGCCGCCAAAGGAAAGGTCTACGCCTCCGCCAGTCAGGACTACGATTCG
CTCCTCTTCAGCGCGCCGAGACTTGTAAGGAACCTCACGATAACGGGAAGGAGAAAGCTCCCCGGA
AAGAACGTCTACGTCGAAGTGAAGCCCGAACTCATCGTTCTGGATGAGGTTCTCAAGGAGCTCGGC
ATAGACAGGGAAAAGCTTATAGAGCTGGCGATTCTGGTTGGAACCGACTACAACCCCGGCGGGATA
AAGGGTATCGGGCCCAAGAAGGCCCTGATGATAGTCAAGAGAACCAAAGACCCGCTCAAGAAATAC
CAGAAGGAGAGCGACGTTGACCTCTACGCTATAAAGGAGTTCTTTCTCAACCCGCCTGTTACCGAC
GACTACGAGCTGAGATGGCGCGAACCCGACGAGGAGGGGATTCTGAAGTTCCTCTGCGACGAGCAC
GACTTCAGCGAAGAGCGCGTTAAAACCGGCCTTGAAAGACTGAAGAAGGCGGTAAAGAGCGGAAAA
CAGAGAACACTTGAAAGCTGGTTCACACGGTAG

Tgo FEN1 protein sequence

MGVQIGELVPRKEIELEALYGKKVAIDAFNAMYQFLSTIRQRDGTPLMDSKGRITSHLSGFFYRTI
NLMEAGIKPAYVFDGKPPEFKKKEIEKRREAREEAEEKWYEALEKGDLEEAKKYAMRATRVNEQLI
NDAKKLLELMGIPVVQAPSEGEAQAAYMAAKGKVYASASQDYDSLLFSAPRLVRNLTITGRRKLPG
KNVYVEVKPELIVLDEVLKELGIDREKLIELAILVGTDYNPGGIKGIGPKKALMIVKRTKDPLKKY
QKESDVDLYAIKEFFLNPPVTDDYELRWREPDEEGILKFLCDEHDFSEERVKTGLERLKKAVKSGK
QRTLESWFTR

Tzi FEN1 ORF DNA sequence

ATGGGAGTTCAGATCGGTGAGCTCGTGCCGAGGAAGGAGATAGGGCTGGAAAACCTTCATGGGAAA
AAAGTTGCAGTTGATGCCTTCAACGCCATGTACCAGTTTCTCTCGACGATAAGGCAGCCTGATGGG

FIGURE 146J

ACTCCTTTAATGGACTCGAAGGGCAGGATAACCTCTCATCTCAGCGGCTTCTTCTATAGGACAATA
AACCTGATGGAGGCCGGAATAAAACCCGCCTACGTCTTCGACGGGAAGCCACCGGAGTTCAAGAAG
AAGGAGATAGAGAAGAGGAGGGAGGCAAGGGAAGAGGCAGAAGAGAAGTGGCAGGAGGCCCTTGAG
AAGGGCGACCTGGAGGAGGCGAAGAAGTACGCGATGAGGGCAACCCGCGTTAACGAGGAGCTCATA
AGCGATGCCAAAAAGCTTCTTGAGCTAATGGGCATTCCGGTTGTCCAGGCACCGAGCGAGGGAGAG
GCTCAGGCGGCCTACATGGCCGCAAAGGGCAAGGTTTACGCCTCAGCGAGCCAGGATTATGACTCA
CTCCTCTTCAGCGCGCCGAAACTCGTGAGAAACCTCACGATAACGGGAAGAAGGAAGCTGCCGGGG
AAGGATGTCTACGTTGAAGTGAAGCCCGAGCTGATCGTCCTGGAAGAGGTTCTCAAGGAGCTTGGC
ATAGACCGGGAGAAACTCATAGAGCTGGCGATTCTTGTGGGGACGGACTACAACCCCGGGGGGATA
AAGGGCATCGGGCCCAAGAAGGCCCTTATGATAGTCAAGAGAATCAATGACCCGCTCAGGAAGTAC
AGCAATGAGAGTGAGGTCGACCTCTACGCGATAAAGGAGTTCTTTCTCAATCCCCCCGTTACAGAT
GACTACGAGCTGAGATGGCGCGAGCCCGATGAAGATGGGATTCTAAGGTTTCTCTGTGAGGAGCAC
GACTTCAGCGAGGAGAGGGTTAAGGGTGGCCTTGAAAGGCTGAGGAAAGCGGTGGAGAGTGGAAAG
CAGAGAACGCTTGAGAGCTGGTTCGGAAGGTGA

Tzi FEN1 protein sequence

MGVQIGELVPRKEIGLENLHGKKVAVDAFNAMYQFLSTIRQPDGTPLMDSKGRITSHLSGFFYRTI
NLMEAGIKPAYVFDGKPPEFKKKEIEKRREAREEAEEKWQEALEKGDLEEAKKYAMRATRVNEELI
SDAKKLLELMGIPVVQAPSEGEAQAAYMAAKGKVYASASQDYDSLLFSAPKLVRNLTITGRRKLPG
KDVYVEVKPELIVLEEVLKELGIDREKLIELAILVGTDYNPGGIKGIGPKKALMIVKRINDPLRKY
SNESEVDLYAIKEFFLNPPVTDDYELRWREPDEDGILRFLCEEHDFSEERVKGGLERLRKAVESGK
QRTLESWFGR

NUCLEIC ACID CLEAVAGE ASSAYS

[0001] The present invention is a continuation of co-pending U.S. application Ser. No. 09/714,935, filed Nov. 17, 2000, which is a continuation-in-part of application Ser. No. 09/577,304, filed on May 24, 2000, which issued as U.S. Pat. No. 6,759,226 on Jul. 6, 2004. U.S. application Ser. No. 09/714,935 is also a continuation-in-part of U.S. application Ser. No. 09/308,825, filed May 25, 1999, which issued as U.S. Pat. No. 6,562,611 on May 13, 2003, which is a national entry of PCT Application No. US97/21783, filed on Nov. 26, 1997. PCT Application No. US97/21783 claims priority to U.S. application Ser. No. 08/757,653, filed on Nov. 29, 1996, which issued as U.S. Pat. No. 5,843,669 on Dec. 1, 1998, which is a continuation-in-part of U.S. application Ser. No. 08/599,491, filed Jan. 24, 1996, which issued as U.S. Pat. No. 5,846,717 on Dec. 8, 1998. PCT US97/21783 also claims priority to U.S. application Ser. No. 08/758,314, filed on Dec. 2, 1996, which issued as U.S. Pat. No. 6,090,606 on Jul. 18, 2000, which is a continuation-in-part of application Ser. No. 08/756,386, filed on Nov. 29, 1996, which issued as U.S. Pat. No. 5,985,557 on Nov. 16, 1999, which is a continuation-in-part of U.S. application Ser. No. 08/682,853, filed Jul. 12, 1996, which issued as U.S. Pat. No. 6,001,567 on Dec. 14, 1999, which is a continuation-in-part of U.S. application Ser. No. 08/599,491. Application Ser. No. 09/714,935 is also a continuation-in-part of U.S. patent application Ser. No. 09/350,309, filed Jul. 9, 1999, which issued as U.S. Pat. No. 6,348,314 on Feb. 19, 2002 and which is a divisional of application Ser. No. 08/756,386, and is also a continuation-in-part of co-pending application Ser. No. 09/381,212, which is a national entry of PCT Application No. US 98/05809, filed Mar. 24, 1998, which claims priority to U.S. application Ser. No. 08/823,516, filed Mar. 24, 1997, which issued as U.S. Pat. No. 5,994,069 on Nov. 30, 1999, Ser. No. 08/759,038, filed Dec. 2, 1996, which issued as U.S. Pat. No. 6,090,543 on Jul. 18, 2000, Ser. Nos. 08/756,386, 08/682,853, and 08/599,491, and PCT Application No. US 97/01072, filed on Jan. 22, 1997. Each of the above-named applications is incorporated herein by reference in its entirety.

[0002] This invention was made with United States Government support under Cooperative Agreement Number 70NANB5H1030, awarded by the National Institute of Standards and Technology (NIST). The United States Government has certain rights in the invention.

[0003] Filed herewith on compact disk, and expressly incorporated herein by reference, is a Sequence Listing provided as a file entitled "FORS-08364.txt," created Jul. 19, 2006, 507 kb in size.

FIELD OF THE INVENTION

[0004] The present invention provides novel cleavage agents and polymerases for the cleavage and modification of nucleic acid. The cleavage agents and polymerases find use, for example, for the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. In some embodiments, the 5' nuclease activity of a variety of enzymes is used to cleave a target-dependent cleavage structure, thereby indicating the presence of specific nucleic acid sequences or specific variations thereof.

BACKGROUND OF THE INVENTION

[0005] Methods for the detection and characterization of specific nucleic acid sequences and sequence variations have been used to detect the presence of viral or bacterial nucleic acid sequences indicative of an infection, to detect the presence of variants or alleles of genes associated with disease and cancers. These methods also find application in the identification of sources of nucleic acids, as for forensic analysis or for paternity determinations.

[0006] Various methods are known to the art that may be used to detect and characterize specific nucleic acid sequences and sequence variants. Nonetheless, with the completion of the nucleic acid sequencing of the human genome, as well as the genomes of numerous pathogenic organisms, the demand for fast, reliable, cost-effective and user-friendly-tests for the detection of specific nucleic acid sequences continues to grow. Importantly, these tests must be able to create a detectable signal from samples that contain very few copies of the sequence of interest. The following discussion examines two levels of nucleic acid detection assays currently in use: I. Signal Amplification Technology for detection of rare sequences; and II. Direct Detection Technology for quantitative detection of sequences.

I. Signal Amplification Technology Methods for Amplification

[0007] The "Polymerase Chain Reaction" (PCR) comprises the first generation of methods for nucleic acid amplification. However, several other methods have been developed that employ the same basis of specificity, but create signal by different amplification mechanisms. These methods include the "Ligase Chain Reaction" (LCR), "Self-Sustained Synthetic Reaction" (3SR/NASBA), and "Qβ-Replicase" (Qβ).

[0008] Polymerase Chain Reaction (PCR)

[0009] The polymerase chain reaction (PCR), as described in U.S. Pat. Nos. 4,683,195, 4,683,202, and 4,965,188 to Mullis and Mullis et al. (the disclosures of which are hereby incorporated by reference), describe a method for increasing the concentration of a segment of target sequence in a mixture of genomic DNA without cloning or purification. This technology provides one approach to the problems of low target sequence concentration. PCR can be used to directly increase the concentration of the target to an easily detectable level. This process for amplifying the target sequence involves introducing a molar excess of two oligonucleotide primers that are complementary to their respective strands of the double-stranded target sequence to the DNA mixture containing the desired target sequence. The mixture is denatured and then allowed to hybridize. Following hybridization, the primers are extended with polymerase so as to form complementary strands. The steps of denaturation, hybridization, and polymerase extension can be repeated as often as needed, in order to obtain relatively high concentrations of a segment of the desired target sequence.

[0010] The length of the segment of the desired target sequence is determined by the relative positions of the primers with respect to each other, and, therefore, this length is a controllable parameter. Because the desired segments of the target sequence become the dominant sequences (in terms of concentration) in the mixture, they are said to be "PCR-amplified."

[0011] Ligase Chain Reaction (LCR or LAR)

[0012] The ligase chain reaction (LCR; sometimes referred to as "Ligase Amplification Reaction" (LAR) described by Barany, Proc. Natl. Acad. Sci., 88:189 (1991); Barany, PCR Methods and Applic., 1:5 (1991); and Wu and Wallace, Genomics 4:560 (1989) has developed into a well-recognized alternative method for amplifying nucleic acids. In LCR, four oligonucleotides, two adjacent oligonucleotides which uniquely hybridize to one strand of target DNA, and a complementary set of adjacent oligonucleotides, that hybridize to the opposite strand are mixed and DNA ligase is added to the mixture. Provided that there is complete complementarity at the junction, ligase will covalently link each set of hybridized molecules. Importantly, in LCR, two probes are ligated together only when they base-pair with sequences in the target sample, without gaps or mismatches. Repeated cycles of denaturation, hybridization and ligation amplify a short segment of DNA. LCR has also been used in combination with PCR to achieve enhanced detection of single-base changes. Segev, PCT Public. No. WO9001069 A1 (1990). However, because the four oligonucleotides used in this assay can pair to form two short ligatable fragments, there is the potential for the generation of target-independent background signal. The use of LCR for mutant screening is limited to the examination of specific nucleic acid positions.

[0013] Self-Sustained Synthetic Reaction (3SR/NASBA)

[0014] The self-sustained sequence replication reaction (3SR) (Guatelli et al., Proc. Natl. Acad. Sci., 87:1874-1878 [1990], with an erratum at Proc. Natl. Acad. Sci., 87:7797 [1990]) is a transcription-based in vitro amplification system (Kwok et al., Proc. Natl. Acad. Sci., 86:1173-1177 [1989]) that can exponentially amplify RNA sequences at a uniform temperature. The amplified RNA can then be utilized for mutation detection (Fahy et al., PCR Meth. Appl., 1:25-33 [1991]). In this method, an oligonucleotide primer is used to add a phage RNA polymerase promoter to the 5' end of the sequence of interest. In a cocktail of enzymes and substrates that includes a second primer, reverse transcriptase, RNase H, RNA polymerase and ribo- and deoxyribonucleoside triphosphates, the target sequence undergoes repeated rounds of transcription, cDNA synthesis and second-strand synthesis to amplify the area of interest. The use of 3SR to detect mutations is kinetically limited to screening small segments of DNA (e.g., 200-300 base pairs).

[0015] Q-Beta (Qβ) Replicase

[0016] In this method, a probe that recognizes the sequence of interest is attached to the replicatable RNA template for Qβ replicase. A previously identified major problem with false positives resulting from the replication of unhybridized probes has been addressed through use of a sequence-specific ligation step. However, available thermostable DNA ligases are not effective on this RNA substrate, so the ligation must be performed by T4 DNA ligase at low temperatures (37° C.). This prevents the use of high temperature as a means of achieving specificity as in the LCR, the ligation event can be used to detect a mutation at the junction site, but not elsewhere.

[0017] Table 1 below, lists some of the features desirable for systems useful in sensitive nucleic acid diagnostics, and summarizes the abilities of each of the major amplification methods (See also, Landgren, Trends in Genetics 9:199 [1993]).

[0018] A successful diagnostic method must be very specific. A straight-forward method of controlling the specificity of nucleic acid hybridization is by controlling the temperature of the reaction. While the 3SR/NASBA, and Qβ systems are all able to generate a large quantity of signal, one or more of the enzymes involved in each cannot be used at high temperature (i.e., >55° C.). Therefore the reaction temperatures cannot be raised to prevent non-specific hybridization of the probes. If probes are shortened in order to make them melt more easily at low temperatures, the likelihood of having more than one perfect match in a complex genome increases. For these reasons, PCR and LCR currently dominate the research field in detection technologies.

TABLE 1

	Method				
Feature	PCR	LCR	PCR & LCR	3SR NASBA	Qβ
Amplifies Target	+	+	+	+	
Recognition of Independent Sequences Required	+	+	+	+	+
Performed at High Temp.	+	+			
Operates at Fixed Temp.				+	+
Exponential Amplification	+	+	+	+	+
Generic Signal Generation					+
Easily Automatable					

[0019] The basis of the amplification procedure in the PCR and LCR is the fact that the products of one cycle become usable templates in all subsequent cycles, consequently doubling the population with each cycle. The final yield of any such doubling system can be expressed as: $(1+X)^n=y$, where "X" is the mean efficiency (percent copied in each cycle), "n" is the number of cycles, and "y" is the overall efficiency, or yield of the reaction (Mullis, PCR Methods Applic., 1:1 [1991]). If every copy of a target DNA is utilized as a template in every cycle of a polymerase chain reaction, then the mean efficiency is 100%. If 20 cycles of PCR are performed, then the yield will be 2^{20}, or 1,048,576 copies of the starting material. If the reaction conditions reduce the mean efficiency to 85%, then the yield in those 20 cycles will be only 1.85^{20}, or 220,513 copies of the starting material. In other words, a PCR running at 85% efficiency will yield only 21% as much final product, compared to a reaction running at 100% efficiency. A reaction that is reduced to 50% mean efficiency will yield less than 1% of the possible product.

[0020] In practice, routine polymerase chain reactions rarely achieve the theoretical maximum yield, and PCRs are usually run for more than 20 cycles to compensate for the lower yield. At 50% mean efficiency, it would take 34 cycles to achieve the million-fold amplification theoretically possible in 20, and at lower efficiencies, the number of cycles required becomes prohibitive. In addition, any background products that amplify with a better mean efficiency than the intended target will become the dominant products.

[0021] Also, many variables can influence the mean efficiency of PCR, including target DNA length and secondary structure, primer length and design, primer and dNTP concentrations, and buffer composition, to name but a few. Contamination of the reaction with exogenous DNA (e.g.,

DNA spilled onto lab surfaces) or cross-contamination is also a major consideration. Reaction conditions must be carefully optimized for each different primer pair and target sequence, and the process can take days, even for an experienced investigator. The laboriousness of this process, including numerous technical considerations and other factors, presents a significant drawback to using PCR in the clinical setting. Indeed, PCR has yet to penetrate the clinical market in a significant way. The same concerns arise with LCR, as LCR must also be optimized to use different oligonucleotide sequences for each target sequence. In addition, both methods require expensive equipment, capable of precise temperature cycling.

[0022] Many applications of nucleic acid detection technologies, such as in studies of allelic variation, involve not only detection of a specific sequence in a complex background, but also the discrimination between sequences with few, or single, nucleotide differences. One method for the detection of allele-specific variants by PCR is based upon the fact that it is difficult for Taq polymerase to synthesize a DNA strand when there is a mismatch between the template strand and the 3' end of the primer. An allele-specific variant may be detected by the use of a primer that is perfectly matched with only one of the possible alleles; the mismatch to the other allele acts to prevent the extension of the primer, thereby preventing the amplification of that sequence. This method has a substantial limitation in that the base composition of the mismatch influences the ability to prevent extension across the mismatch, and certain mismatches do not prevent extension or have only a minimal effect (Kwok et al., Nucl. Acids Res., 18:999 [1990]).)

[0023] A similar 3'-mismatch strategy is used with greater effect to prevent ligation in the LCR (Barany, PCR Meth. Applic., 1:5 [1991]). Any mismatch effectively blocks the action of the thermostable ligase, but LCR still has the drawback of target-independent background ligation products initiating the amplification. Moreover, the combination of PCR with subsequent LCR to identify the nucleotides at individual positions is also a clearly cumbersome proposition for the clinical laboratory.

II. Direct Detection Technology

[0024] When a sufficient amount of a nucleic acid to be detected is available, there are advantages to detecting that sequence directly, instead of making more copies of that target, (e.g., as in PCR and LCR). Most notably, a method that does not amplify the signal exponentially is more amenable to quantitative analysis. Even if the signal is enhanced by attaching multiple dyes to a single oligonucleotide, the correlation between the final signal intensity and amount of target is direct. Such a system has an additional advantage that the products of the reaction will not themselves promote further reaction, so contamination of lab surfaces by the products is not as much of a concern. Traditional methods of direct detection including Northern and Southern blotting and RNase protection assays usually require the use of radioactivity and are not amenable to automation. Recently devised techniques have sought to eliminate the use of radioactivity and/or improve the sensitivity in automatable formats. Two examples are the "Cycling Probe Reaction" (CPR), and "Branched DNA" (bDNA)

[0025] The cycling probe reaction (CPR) (Duck et al., BioTech., 9:142 [1990]), uses a long chimeric oligonucleotide in which a central portion is made of RNA while the two termini are made of DNA. Hybridization of the probe to a target DNA and exposure to a thermostable RNase H causes the RNA portion to be digested. This destabilizes the remaining DNA portions of the duplex, releasing the remainder of the probe from the target DNA and allowing another probe molecule to repeat the process. The signal, in the form of cleaved probe molecules, accumulates at a linear rate. While the repeating process increases the signal, the RNA portion of the oligonucleotide is vulnerable to RNases that may be carried through sample preparation.

[0026] Branched DNA (bDNA), described by Urdea et al., Gene 61:253-264 (1987), involves oligonucleotides with branched structures that allow each individual oligonucleotide to carry 35 to 40 labels (e.g., alkaline phosphatase enzymes). While this enhances the signal from a hybridization event, signal from non-specific binding is similarly increased.

[0027] While both of these methods have the advantages of direct detection discussed above, neither the CPR or bDNA methods can make use of the specificity allowed by the requirement of independent recognition by two or more probe (oligonucleotide) sequences, as is common in the signal amplification methods described in Section I. above. The requirement that two oligonucleotides must hybridize to a target nucleic acid in order for a detectable signal to be generated confers an extra measure of stringency on any detection assay. Requiring two oligonucleotides to bind to a target nucleic acid reduces the chance that false "positive" results will be produced due to the non-specific binding of a probe to the target. The further requirement that the two oligonucleotides must bind in a specific orientation relative to the target, as is required in PCR, where oligonucleotides must be oppositely but appropriately oriented such that the DNA polymerase can bridge the gap between the two oligonucleotides in both directions, further enhances specificity of the detection reaction. However, it is well known to those in the art that even though PCR utilizes two oligonucleotide probes (termed primers) "non-specific" amplification (i.e., amplification of sequences not directed by the two primers used) is a common artifact. This is in part because the DNA polymerase used in PCR can accommodate very large distances, measured in nucleotides, between the oligonucleotides and thus there is a large window in which non-specific binding of an oligonucleotide can lead to exponential amplification of inappropriate product. The LCR, in contrast, cannot proceed unless the oligonucleotides used are bound to the target adjacent to each other and so the full benefit of the dual oligonucleotide hybridization is realized.

[0028] An ideal direct detection method would combine the advantages of the direct detection assays (e.g., easy quantification and minimal risk of carry-over contamination) with the specificity provided by a dual oligonucleotide hybridization assay.

SUMMARY OF THE INVENTION

[0029] The present invention provides novel cleavage agents and polymerases for the cleavage and modification of nucleic acids. The cleavage agent and polymerases find use, for example, for the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. In

some embodiments, the 5' nuclease activity of a variety of enzymes is used to cleave a target-dependent cleavage structure, thereby indicating the presence of specific nucleic acid sequences or specific variations thereof. The present invention contemplates use of novel detection methods for various uses, including, but not limited to, clinical diagnostic purposes.

[0030] The present invention provides structure-specific cleavage agents (e.g., nucleases) from a variety of sources, including mesophilic, psychrophilic, thermophilic, and hyperthermophilic organisms. The preferred structure-specific nucleases are thermostable. Thermostable structure-specific nucleases are contemplated as particularly useful in that they operate at temperatures where nucleic acid hybridization is extremely specific, allowing for allele-specific detection (including single-base mismatches). In one embodiment, the thermostable structure-specific nucleases are thermostable 5' nucleases comprising altered polymerases derived from the native polymerases of *Thermus* species, including, but not limited to *Thermus aquaticus, Thermus flavus*, and *Thermus thermophilus*. However, the invention is not limited to the use of thermostable 5' nucleases. Thermostable structure-specific nucleases from the FEN-1, RAD2 and XPG class of nucleases are also preferred.

[0031] The present invention provides a method for detecting a target sequence (e.g., a mutation, polymorphism, etc), comprising providing a sample suspected of containing the target sequence; oligonucleotides capable of forming an invasive cleavage structure in the presence of the target sequence; and an agent for detecting the presence of an invasive cleavage structure; and exposing the sample to the oligonucleotides and the agent. In some embodiments, the method further comprises the step of detecting a complex comprising the agent and the invasive cleavage structure (directly or indirectly). In some embodiments, the agent comprises a cleavage agent. In some preferred embodiments, the exposing of the sample to the oligonucleotides and the agent comprises exposing the sample to the oligonucleotides and the agent under conditions wherein an invasive cleavage structure is formed between the target sequence and the oligonucleotides if the target sequence is present in the sample, wherein the invasive cleavage structure is cleaved by the cleavage agent to form a cleavage product. In some embodiments, the method further comprises the step of detecting the cleavage product. In some embodiments, the target sequence comprises a first region and a second region, the second region downstream of and contiguous to the first region, and wherein the oligonucleotides comprise first and second oligonucleotides, wherein at least a portion of the first oligonucleotide is completely complementary to the first portion of the target sequence and wherein the second oligonucleotide comprises a 3' portion and a 5' portion, wherein the 5' portion is completely complementary to the second portion of said target nucleic acid.

[0032] The present invention also provides a kit for detecting such target sequences, said kit comprising oligonucleotides capable of forming an invasive cleavage structure in the presence of the target sequence. In some embodiments, the kit further comprises an agent for detecting the presence of an invasive cleavage structure (e.g., a cleavage agent). In some embodiments, the oligonucleotides comprise first and second oligonucleotides, said first oligonucleotide comprising a 5' portion complementary to a first region of the target nucleic acid and said second oligonucleotide comprising a 3' portion and a 5' portion, said 5' portion complementary to a second region of the target nucleic acid downstream of and contiguous to the first portion. In some preferred embodiments, the target sequence comprises human cytomegalovirus viral DNA; sequence containing polymorphisms in the human apolipoprotein E gene (ApoE); sequence containing mutations in the human hemochromatosis (HH) gene; sequence containing mutations in human MTHFR; sequence containing prothrombin 20210GA polymorphism; sequence containing HR-2 mutation in human factor V gene; sequence containing single nucleotide polymorphisms in human TNF-α gene, and sequence containing the Leiden mutation in human factor V gene. In some preferred embodiments, kits comprise oligonucleotides for detecting two or more target sequences. For example, information on two or more mutations may provide medically relevant information such that kits allowing detection of the plurality of mutations would be desired (e.g., Factor V and HR-2 detection). In some preferred embodiments kits are probed containing a probe oligonucleotide comprising a sequence of SEQ ID NOs: 197, 198, 199, 200, 208, 209, 211, 212, 217, 218, 223, 224, 229, 232, 236, 237, 241, 242, or 244. In still other embodiments, kits provide oligonucleotide sets, the sets including one or more of the oligonucleotides: SEQ ID NOs:195, 197, and 198 for ApoE detection; 196, 199, and 200 for ApoE detection; 202, 208, and 209 for HH detection; 203, 211, and 212 for HH detection; 216, 217, and 218 for MTHFR detection; 222, 223, and 224 for prothrombin polymorphism detection; 228, 229, 231, and 232 for HR-2 detection; 235, 236, and 237 for TNF-α detection; 240, 241, and 242 for Factor V detection; and 243, 244, 246, and 247 for MRSA detection.

[0033] The present invention also provides methods for detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising providing: a cleavage agent; a source of target nucleic acid, the target nucleic acid comprising a first region and a second region, the second region downstream of and contiguous to the first region; a first oligonucleotide, wherein at least a portion of the first oligonucleotide is completely complementary to the first portion of the target nucleic acid; and a second oligonucleotide comprising a 3' portion and a 5' portion, wherein the 5' portion is completely complementary to the second portion of the target nucleic acid; mixing the cleavage agent, the target nucleic acid, the first oligonucleotide and the second oligonucleotide to create a reaction mixture under reaction conditions such that at least the portion of the first oligonucleotide is annealed to the first region of said target nucleic acid and wherein at least the 5' portion of the second oligonucleotide is annealed to the second region of the target nucleic acid so as to create a cleavage structure, and wherein cleavage of the cleavage structure occurs to generate non-target cleavage product; and detecting the cleavage of the cleavage structure.

[0034] The detection of the cleavage of the cleavage structure can be carried out in any manner. In some embodiments, the detection of the cleavage of the cleavage structure comprises detecting the non-target cleavage product. In yet other embodiments, the detection of the cleavage of the cleavage structure comprises detection of fluorescence, mass, or fluorescence energy transfer. Other detection meth-

ods include, but are not limited to detection of radioactivity, luminescence, phosphorescence, fluorescence polarization, and charge. In some embodiments, detection is carried out by a method comprising providing the non-target cleavage product; a composition comprising two single-stranded nucleic acids annealed so as to define a single-stranded portion of a protein binding region; and a protein; and exposing the non-target cleavage product to the single-stranded portion of the protein binding region under conditions such that the protein binds to the protein binding region. In some embodiments, the protein comprises a nucleic acid producing protein, wherein the nucleic acid producing protein binds to the protein binding region and produces nucleic acid. In some embodiments, the protein binding region is a template-dependent RNA polymerase binding region (e.g., a T7 RNA polymerase binding region). In other embodiments, the detection is carried out by a method comprising providing the non-target cleavage product; a single continuous strand of nucleic acid comprising a sequence defining a single strand of an RNA polymerase binding region; a template-dependent DNA polymerase; and a template-dependent RNA polymerase; exposing the non-target cleavage product to the RNA polymerase binding region under conditions such that the non-target cleavage product binds to a portion of the single strand of the RNA polymerase binding region to produce a bound non-target cleavage product; exposing the bound non-target cleavage product to the template-dependent DNA polymerase under conditions such that a double-stranded RNA polymerase binding region is produced; and exposing the double-stranded RNA polymerase binding region to the template-dependent RNA polymerase under conditions such that RNA transcripts are produced. In some embodiments, the method further comprises the step of detecting the RNA transcripts. In some embodiments, the template-dependent RNA polymerase is T7 RNA polymerase.

[0035] The present invention is not limited by the nature of the 3' portion of the second oligonucleotide. In some preferred embodiments, the 3' portion of the second oligonucleotide comprises a 3' terminal nucleotide not complementary to the target nucleic acid. In some embodiments, the 3' portion of the second oligonucleotide consists of a single nucleotide not complementary to the target nucleic acid.

[0036] Any of the components of the method may be attached to a solid support. For example, in some embodiments, the first oligonucleotide is attached to a solid support. In other embodiments, the second oligonucleotide is attached to a solid support.

[0037] The cleavage agent can be any agent that is capable of cleaving invasive cleavage structures. In some preferred embodiments, the cleavage agent comprises a structure-specific nuclease. In particularly preferred embodiments, the structure-specific nuclease comprises a thermostable structure-specific nuclease (e.g., a thermostable 5' nuclease). Thermostable structure-specific nucleases include, but are not limited to, those having an amino acid sequence homologous to a portion of the amino acid sequence of a thermostable DNA polymerase derived from a thermophilic organism (e.g., *Thermus aquaticus, Thermus flavus*, and *Thermus thermophilus*). In other embodiments, the thermostable structure-specific nucleases is from the FEN-1, RAD2 or XPG class of nucleases, a chimerical structures containing one or more portions of any of the above cleavage agents.

[0038] The method is not limited by the nature of the target nucleic acid. In some embodiments, the target nucleic acid is single stranded or double stranded DNA or RNA. In some embodiments, double stranded nucleic acid is rendered single stranded (e.g., by heat) prior to formation of the cleavage structure. In some embodiment, the source of target nucleic acid comprises a sample containing genomic DNA. Sample include, but are not limited to, blood, saliva, cerebral spinal fluid, pleural fluid, milk, lymph, sputum and semen.

[0039] In some embodiments, the reaction conditions for the method comprise providing a source of divalent cations. In some preferred embodiments, the divalent cation is selected from the group comprising Mn^{2+} and Mg^{2+} ions. In some embodiments, the reaction conditions for the method comprise providing the first and the second oligonucleotides in concentration excess compared to the target nucleic acid.

[0040] In some embodiments, the method further comprises providing a third oligonucleotide complementary to a third portion of said target nucleic acid upstream of the first portion of the target nucleic acid, wherein the third oligonucleotide is mixed with the reaction mixture.

[0041] The present invention also provides a method for detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising providing: a cleavage agent; a source of target nucleic acid, the target nucleic acid comprising a first region and a second region, the second region downstream of and contiguous to the first region; a plurality of first oligonucleotides, wherein at least a portion of the first oligonucleotides is completely complementary to the first portion of the target nucleic acid; a second oligonucleotide comprising a 3' portion and a 5' portion, wherein said 5' portion is completely complementary to the second portion of the target nucleic acid; mixing the cleavage agent, the target nucleic acid, the plurality of first oligonucleotides and second oligonucleotide to create a reaction mixture under reaction conditions such that at least the portion of a first oligonucleotide is annealed to the first region of the target nucleic acid and wherein at least the 5' portion of the second oligonucleotide is annealed to the second region of the target nucleic acid so as to create a cleavage structure, and wherein cleavage of the cleavage structure occurs to generate non-target cleavage product, wherein the conditions permit multiple cleavage structures to form and be cleaved from the target nucleic acid; and detecting the cleavage of said cleavage structures. In some embodiments, the conditions comprise isothermal conditions that permit the plurality of first oligonucleotides to dissociate from the target nucleic acid. While the present invention is limited by the number of cleavage structure formed on a particular target nucleic acid, in some preferred embodiments, two or more (3, 4, 5, . . . , 10, . . . , 10000, . . .) of the plurality of first oligonucleotides form cleavage structures with a particular target nucleic acid, wherein the cleavage structures are cleaved to produce the non-target cleavage products.

[0042] The present invention also provide methods where a cleavage product from the above methods is used in a further invasive cleavage reaction. For example, the present invention provides a method comprising providing a cleavage agent; a first target nucleic acid, the first target nucleic acid comprising a first region and a second region, the second region downstream of and contiguous to the first

region; a first oligonucleotide, wherein at least a portion of the first oligonucleotide is completely complementary to the first portion of the first target nucleic acid; a second oligonucleotide comprising a 3' portion and a 5' portion, wherein the 5' portion is completely complementary to the second portion of the first target nucleic acid; a second target nucleic acid, said second target nucleic acid comprising a first region and a second region, the second region downstream of and contiguous to the first region; and a third oligonucleotide, wherein at least a portion of the third oligonucleotide is completely complementary to the first portion of the second target nucleic acid; generating a first cleavage structure wherein at least said portion of the first oligonucleotide is annealed to the first region of the first target nucleic acid and wherein at least the 5' portion of the second oligonucleotide is annealed to the second region of the first target nucleic acid and wherein cleavage of the first cleavage structure occurs via the cleavage agent thereby cleaving the first oligonucleotide to generate a fourth oligonucleotide, said fourth oligonucleotide comprising a 3' portion and a 5' portion, wherein the 5' portion is completely complementary to the second portion of the second target nucleic acid; generating a second cleavage structure under conditions wherein at least said portion of the third oligonucleotide is annealed to the first region of the second target nucleic acid and wherein at least the 5' portion of the fourth oligonucleotide is annealed to the second region of the second target nucleic acid and wherein cleavage of the second cleavage structure occurs to generate a cleavage fragment; and detecting the cleavage of the second cleavage structure. In some preferred embodiments, the 3' portion of the fourth oligonucleotide comprises a 3' terminal nucleotide not complementary to the second target nucleic acid. In some embodiments, the 3' portion of the third oligonucleotide is covalently linked to the second target nucleic acid. In some embodiments, the second target nucleic acid further comprises a 5' region, wherein the 5' region of the second target nucleic acid is the third oligonucleotide. The present invention further provides kits comprising: a cleavage agent; a first oligonucleotide comprising a 5' portion complementary to a first region of a target nucleic acid; and a second oligonucleotide comprising a 3' portion and a 5' portion, said 5' portion complementary to a second region of the target nucleic acid downstream of and contiguous to the first portion. In some embodiments, the 3' portion of the second oligonucleotide comprises a 3' terminal nucleotide not complementary to the target nucleic acid. In preferred embodiments, the 3' portion of the second oligonucleotide consists of a single nucleotide not complementary to the target nucleic acid. In some embodiments, the kit further comprises a solid support. For example, in some embodiments, the first and/or second oligonucleotide is attached to said solid support. In some embodiments, the kit further comprises a buffer solution. In some preferred embodiments, the buffer solution comprises a source of divalent cations (e.g., $Mn^{2+}$and/or Mg^{2+} ions). In some specific embodiments, the kit further comprises a third oligonucleotide complementary to a third portion of the target nucleic acid upstream of the first portion of the first target nucleic acid. In yet other embodiments, the kit further comprises a target nucleic acid. In some embodiments, the kit further comprises a second target nucleic acid. In yet other embodiments, the kit further comprises a third oligonucleotide comprising a 5' portion complementary to a first region of the second target nucleic acid. In some specific embodiments, the 3' portion of the third oligonucleotide is covalently linked to the second target nucleic acid. In other specific embodiments, the second target nucleic acid further comprises a 5' portion, wherein the 5' portion of the second target nucleic acid is the third oligonucleotide. In still other embodiments, the kit further comprises an ARRESTOR molecule (e.g., ARRESTOR oligonucleotide).

[0043] The present invention further provides a composition comprising a cleavage structure, the cleavage structure comprising: a) a target nucleic acid, the target nucleic acid having a first region, a second region, a third region and a fourth region, wherein the first region is located adjacent to and downstream from the second region, the second region is located adjacent to and downstream from the third region and the third region is located adjacent to and downstream from the fourth region; b) a first oligonucleotide complementary to the fourth region of the target nucleic acid; c) a second oligonucleotide having a 5' portion and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the second region of the target nucleic acid and wherein the 3' portion of the second oligonucleotide contains a sequence complementary to the third region of the target nucleic acid; and d) a third oligonucleotide having a 5' portion and a 3' portion wherein the 5' portion of the third oligonucleotide contains a sequence complementary to the first region of the target nucleic acid and wherein the 3' portion of the third oligonucleotide contains a sequence complementary to the second region of the target nucleic acid.

[0044] The present invention is not limited by the length of the four regions of the target nucleic acid. In one embodiment, the first region of the target nucleic acid has a length of 11 to 50 nucleotides. In another embodiment, the second region of the target nucleic acid has a length of one to three nucleotides. In another embodiment, the third region of the target nucleic acid has a length of six to nine nucleotides. In yet another embodiment, the fourth region of the target nucleic acid has a length of 6 to 50 nucleotides.

[0045] The invention is not limited by the nature or composition of the of the first, second, third and fourth oligonucleotides; these oligonucleotides may comprise DNA, RNA, PNA and combinations thereof as well as comprise modified nucleotides, universal bases, adducts, etc. Further, one or more of the first, second, third and the fourth oligonucleotides may contain a dideoxynucleotide at the 3' terminus.

[0046] In one preferred embodiment, the target nucleic acid is not completely complementary to at least one of the first, the second, the third and the fourth oligonucleotides. In a particularly preferred embodiment, the target nucleic acid is not completely complementary to the second oligonucleotide.

[0047] As noted above, the present invention contemplates the use of structure-specific nucleases in detection methods. In one embodiment, the present invention provides a method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising: a) providing: i) a cleavage means, ii) a source of target nucleic acid, the target nucleic acid having a first region, a second region, a third region and a fourth region, wherein the first region is located adjacent to and downstream from the

second region, the second region is located adjacent to and downstream from the third region and the third region is located adjacent to and downstream from the fourth region; iii) a first oligonucleotide complementary to the fourth region of the target nucleic acid; iv) a second oligonucleotide having a 5' portion and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the second region of the target nucleic acid and wherein the 3' portion of the second oligonucleotide contains a sequence complementary to the third region of the target nucleic acid; iv) a third oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the third oligonucleotide contains a sequence complementary to the first region of the target nucleic acid and wherein the 3' portion of the third oligonucleotide contains a sequence complementary to the second region of the target nucleic acid; b) mixing the cleavage means, the target nucleic acid, the first oligonucleotide, the second oligonucleotide and the third oligonucleotide to create a reaction mixture under reaction conditions such that the first oligonucleotide is annealed to the fourth region of the target nucleic acid and wherein at least the 3' portion of the second oligonucleotide is annealed to the target nucleic acid and wherein at least the 5' portion of the third oligonucleotide is annealed to the target nucleic acid so as to create a cleavage structure and wherein cleavage of the cleavage structure occurs to generate non-target cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and c) detecting the non-target cleavage products.

[0048] The invention is not limited by the nature of the target nucleic acid. In one embodiment, the target nucleic acid comprises single-stranded DNA. In another embodiment, the target nucleic acid comprises double-stranded DNA and prior to step c), the reaction mixture is treated such that the double-stranded DNA is rendered substantially single-stranded. In another embodiment, the target nucleic acid comprises RNA and the first and second oligonucleotides comprise DNA.

[0049] The invention is not limited by the nature of the cleavage means. In one embodiment, the cleavage means is a structure-specific nuclease; particularly preferred structure-specific nucleases are thermostable structure-specific nucleases. In one preferred embodiment, the thermostable structure-specific nuclease is encoded by a DNA sequence selected from the group consisting of SEQ ID NOS:1-3, 9, 10, 12, 21, 30, 31, 101, 106, 110, 114, 129, 131, 132, 137, 140, 141, 142, 143, 144, 145, 147, 150, 151, 153, 155, 156, 157, 158, 161, 163, 178, 180, and 182.

[0050] In another preferred embodiment, the thermostable structure-specific nuclease is a nuclease from the FEN-1/RAD2/XPG class of nucleases. In another preferred embodiment the thermostable structure specific nuclease is a chimerical nuclease.

[0051] In an alternative preferred embodiment, the detection of the non-target cleavage products comprises electrophoretic separation of the products of the reaction followed by visualization of the separated non-target cleavage products.

[0052] In another preferred embodiment, one or more of the first, second, and third oligonucleotides contain a dideoxynucleotide at the 3' terminus. When dideoxynucleotide-containing oligonucleotides are employed, the detection of the non-target cleavage products preferably comprises: a) incubating the non-target cleavage products with a template-independent polymerase and at least one labeled nucleoside triphosphate under conditions such that at least one labeled nucleotide is added to the 3'-hydroxyl group of the non-target cleavage products to generate labeled non-target cleavage products; and b) detecting the presence of the labeled non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed; in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label, the 5' end label being a different label than the label present upon the labeled nucleoside triphosphate. The invention is not limited by the nature of the 5' end label; a wide variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3 amidite, Cy5 amidite and digoxigenin.

[0053] In another embodiment, detecting the non-target cleavage products comprises: a) incubating the non-target cleavage products with a template-independent polymerase and at least one nucleoside triphosphate under conditions such that at least one nucleotide is added to the 3'-hydroxyl group of the non-target cleavage products to generate tailed non-target cleavage products; and b) detecting the presence of the tailed non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed; in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label. The invention is not limited by the nature of the 5' end label; a wide variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3 amidite, Cy5 amidite and digoxigenin.

[0054] In a preferred embodiment, the reaction conditions comprise providing a source of divalent cations; particularly preferred divalent cations are Mn^{2+} and Mg^{2+} ions.

[0055] The present invention further provides a method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising: a) providing: i) a cleavage means, ii) a source of target nucleic acid, the target nucleic acid having a first region, a second region and a third region, wherein the first region is located adjacent to and downstream from the second region and wherein the second region is located adjacent to and downstream from the third region; iii) a first oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the first oligonucleotide contains a sequence complementary to the second region of the target nucleic acid and wherein the 3' portion of the first oligonucleotide contains a sequence complementary to the third region of the target nucleic acid; iv) a second oligonucleotide having a length between eleven to fifteen nucleotides and further having a 5' and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the first region of the target nucleic acid and wherein the 3' portion of the second oligonucleotide contains a sequence complementary to the

second region of the target nucleic acid; b) mixing the cleavage means, the target nucleic acid, the first oligonucleotide and the second oligonucleotide to create a reaction mixture under reaction conditions such that at least the 3' portion of the first oligonucleotide is annealed to the target nucleic acid and wherein at least the 5' portion of the second oligonucleotide is annealed to the target nucleic acid so as to create a cleavage structure and wherein cleavage of the cleavage structure occurs to generate non-target cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and c) detecting the non-target cleavage products. In a preferred embodiment the cleavage means is a structure-specific nuclease, preferably a thermostable structure-specific nuclease.

[0056] The invention is not limited by the length of the various regions of the target nucleic acid. In a preferred embodiment, the second region of the target nucleic acid has a length between one to five nucleotides. In another preferred embodiment, one or more of the first and the second oligonucleotides contain a dideoxynucleotide at the 3' terminus. When dideoxynucleotide-containing oligonucleotides are employed, the detection of the non-target cleavage products preferably comprises: a) incubating the non-target cleavage products with a template-independent polymerase and at least one labeled nucleoside triphosphate under conditions such that at least one labeled nucleotide is added to the 3'-hydroxyl group of the non-target cleavage products to generate labeled non-target cleavage products; and b) detecting the presence of the labeled non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed; in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase is employed in the detection step, the second oligonucleotide may contain a 5' end label, the 5' end label being a different label than the label present upon the labeled nucleoside triphosphate. The invention is not limited by the nature of the 5' end label; a wide variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3 amidite, Cy5 amidite and digoxigenin.

[0057] In another embodiment, detecting the non-target cleavage products comprises: a) incubating the non-target cleavage products with a template-independent polymerase and at least one nucleoside triphosphate under conditions such that at least one nucleotide is added to the 3'-hydroxyl group of the non-target cleavage products to generate tailed non-target cleavage products; and b) detecting the presence of the tailed non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed; in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label. The invention is not limited by the nature of the 5' end label; a wide variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3 amidite, Cy5 amidite and digoxigenin.

[0058] The novel detection methods of the invention may be employed for the detection of target DNAs and RNAs including, but not limited to, target DNAs and RNAs comprising wild type and mutant alleles of genes, including genes from humans or other animals that are or may be associated with disease or cancer. In addition, the methods of the invention may be used for the detection of and/or identification of strains of microorganisms, including bacteria, fungi, protozoa, ciliates and viruses (and in particular for the detection and identification of RNA viruses, such as HCV).

[0059] The present invention further provides improved enzymatic cleavage means. In one embodiment, the present invention provides a thermostable structure-specific nuclease having an amino acid sequence selected from the group consisting of SEQ ID NOS:102, 107, 130, 132, 179, 181, 183, 184, 185, 186, 187, and 188. In another embodiment, the nuclease is encoded by a DNA sequence selected from the group consisting of SEQ ID NOS:101, 106, 129 131, 178, 180, and 182.

[0060] The present invention also provides a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a structure-specific nuclease, the nucleotide sequence selected from the group consisting of SEQ ID NOS:101, 106, 129 131, 137, 140, 141, 142, 143, 144, 145, 147, 150, 151, 153, 155, 156, 157, 158, 161, 163, 178, 180, and 182. In a preferred embodiment, the invention provides a host cell transformed with a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a structure-specific nuclease, the nucleotide sequence selected from the group consisting of SEQ ID NOS:101, 106, 129, 131, 178, 180, and 182. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of nucleotide sequences encoding structure-specific nucleases which can be expressed in a variety of prokaryotic and eukaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

[0061] The present invention provides purified FEN-1 endonucleases. In one embodiment, the present invention provides *Pyrococcus woesei* FEN-1 endonuclease. In a preferred embodiment, the purified *Pyrococcus woesei* FEN-1 endonuclease has a molecular weight of about 38.7 kilodaltons (the molecular weight may be conveniently estimated using SDS-PAGE as described in Ex. 28).

[0062] The present invention further provides an isolated oligonucleotide encoding a *Pyrococcus woesei* FEN-1 endonuclease, the oligonucleotide having a region capable of hybridizing to an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:116-119. In a preferred embodiment, the oligonucleotide encoding the purified *Pyrococcus woesei* FEN-1 endonuclease is operably linked to a heterologous promoter. The present invention is not limited by the nature of the heterologous promoter employed; in a preferred embodiment, the heterologous promoter is an inducible promoter (the promoter chosen will depend upon the host cell chosen for expression as is known in the art). The invention is not limited by the nature of the inducible promoter employed. Preferred inducible promoters include the -P_L promoter, the tac promoter, the trp promoter and the trc promoter.

[0063] In another preferred embodiment, the invention provides a recombinant DNA vector comprising an isolated oligonucleotide encoding a *Pyrococcus woesei* (Pwo)

FEN-1 endonuclease, the oligonucleotide having a region capable of hybridizing to an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:116-119. Host cells transformed with these recombinant vectors are also provided. In a preferred embodiment, the invention provides a host cell transformed with a recombinant DNA vector comprising DNA having a region capable of hybridizing to an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:116-119; these vectors may further comprise a heterologous promoter operably linked to the Pwo FEN-1-encoding polynucleotides. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of Pwo FEN-1-encoding polynucleotides which can be expressed in a variety of prokaryotic and eukaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

[0064] In yet another embodiment, the invention provides an isolated oligonucleotide comprising a gene encoding a *Pyrococcus woesei* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons. In another embodiment, the encoding a *Pyrococcus woesei* FEN-1 endonuclease is operably linked to a heterologous promoter. The present invention is not limited by the nature of the heterologous promoter employed; in a preferred embodiment, the heterologous promoter is an inducible promoter (the promoter chosen will depend upon the host cell chosen for expression as is known in the art). The invention is not limited by the nature of the inducible promoter employed. Preferred inducible promoter include the -P_L promoter, the tac promoter, the trp promoter and the trc promoter.

[0065] The invention further provides recombinant DNA vectors comprising DNA having a nucleotide sequence encoding FEN-1 endonucleases. In one preferred embodiment, the present invention provides a *Pyrococcus woesei* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons. Still further, a host cell transformed with a recombinant DNA vector comprising DNA having a nucleotide sequence encoding FEN-1 endonuclease. In a preferred embodiment, the host cell is transformed with a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a *Pyrococcus woesei* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons is provided. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of Pwo FEN-1-encoding polynucleotides which can be expressed in a variety of prokaryotic and eukaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

[0066] Thus, the present invention provides multiple purified FEN-1 endonucleases, both purified native forms of the endonucleases, as well as recombinant endonucleases. In preferred embodiments, the purified FEN-1 endonucleases are obtained from archaebacterial or eubacterial organisms. In particularly preferred embodiments, the FEN-1 endonucleases are obtained from organisms selected from the group consisting of *Archaeoglobus fulgidus, Methanobacterium thermoautotrophicum, Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii*, and *Aeropyrum pernix*. In a preferred embodiment, the purified FEN-1 endonucleases have molecular weights of about 39 kilodaltons (the molecular weight may be conveniently estimated using SDS-PAGE as described in Ex. 28).

[0067] The present invention further provides isolated oligonucleotides encoding *Archaeoglobus fulgidus* and *Methanobacterium thermoautotrophicum* FEN-1 endonucleases, the oligonucleotides each having a region capable of hybridizing to at least a portion of an oligonucleotide sequence, wherein the oligonucleotide sequence is selected from the group consisting of SEQ ID NOS:170, 171, 172, and 173. In some preferred embodiment, the oligonucleotides encoding the *Archaeoglobus fulgidus* and *Methanobacterium thermoautotrophicum* FEN-1 endonucleases are operably linked to heterologous promoters. However, it is not intended that the present invention be limited by the nature of the heterologous promoter employed. It is contemplated that the promoter chosen will depend upon the host cell chosen for expression as is known in the art. In some preferred embodiments, the heterologous promoter is an inducible promoter. The invention is not limited by the nature of the inducible promoter employed. Preferred inducible promoters include the -P_L promoter, the tac promoter, the trp promoter and the trc promoter.

[0068] In another preferred embodiment, the invention provides recombinant DNA vectors comprising isolated oligonucleotides encoding *Archaeoglobus fulgidus* or *Methanobacterium thermoautotrophicum* FEN-1 endonucleases, each oligonucleotides having a region capable of hybridizing to at least a portion of an oligonucleotide sequence, wherein the oligonucleotide sequence is selected from the group consisting of SEQ ID NOS:170, 171, 172, and 173. The present invention further provides host cells transformed with these recombinant vectors. In a preferred embodiment, the invention provides a host cell transformed with a recombinant DNA vector comprising DNA having a region capable of hybridizing to at least a portion of an oligonucleotide sequence, wherein the oligonucleotide sequence is selected from the group consisting of SEQ ID NOS:170, 171, 172 and 173. In some embodiments, these vectors may further comprise a heterologous promoter operably linked to the FEN-1-encoding polynucleotides. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of FEN-1-encoding polynucleotides which can be expressed in a variety of prokaryotic and eukaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

[0069] The present invention further provides chimeric structure-specific nucleases. In one embodiment, the present invention provides chimeric endonucleases comprising amino acid portions derived from the endonucleases selected from the group of FEN-1, XPG and RAD homologs. In a preferred embodiment, the chimeric endonucleases comprise amino acid portions derived from the FEN-1 endonucleases selected from the group of *Pyrococcus furiosus, Methanococcus jannaschi, Pyrococcus woesei, Archaeoglobus fulgidus, Methanobacterium thermoautotrophicum, Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrod-*

ictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii, and *Aeropyrum pernix*. In a more preferred embodiment, the chimeric FEN-1 endonucleases have molecular weights of about 39 kilodaltons (the molecular weight may be conveniently estimated using SDS-PAGE as described in Ex. 28).

[0070] The present invention further provides isolated oligonucleotides encoding chimeric endonucleases. In one embodiment, the oligonucleotides encoding the chimeric endonucleases comprise nucleic acid sequences derived from the genes selected from the group of FEN-1, XPG and RAD homologs. In a preferred embodiment the oligonucleotides encoding the chimeric endonucleases comprise nucleic acid sequences derived from the genes encoding the FEN-1 endonucleases selected from the group of *Pyrococcus furiosus, Methanococcus jannaschi, Pyrococcus woesei, Archaeoglobus fulgidus, Methanobacterium thermoautotrophicum, Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii*, and *Aeropyrum pernix*. In a particularly preferred embodiment, the genes for the chimeric endonucleases are operably linked to heterologous promoters. The present invention is not limited by the nature of the heterologous promoter employed. It is contemplated that the promoter chosen will depend upon the host cell selected for expression, as is known in the art. In preferred embodiments, the heterologous promoter is an inducible promoter. The invention is not limited by the nature of the inducible promoter employed. Preferred inducible promoter include the -P_L promoter, the tac promoter, the trp promoter and the trc promoter.

[0071] In another preferred embodiment, the invention provides recombinant DNA vectors comprising isolated oligonucleotides encoding the chimeric endonucleases described above. In one embodiment, the recombinant DNA vectors comprise isolated oligonucleotides encoding nucleic acid sequences derived from the genes selected from the group of FEN-1, XPG and RAD homologs. In a preferred embodiment, the recombinant DNA vectors comprise isolated oligonucleotides encoding the chimeric endonucleases comprising nucleic acid sequences derived from the genes encoding the FEN-1 endonucleases selected from the group of *Pyrococcus furiosus, Methanococcus jannaschi, Pyrococcus woesei, Archaeoglobus fulgidus, Methanobacterium thermoautotrophicum, Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii*, and *Aeropyrum pernix*. These vectors may further comprise a heterologous promoter operably linked to the chimeric nuclease-encoding polynucleotides.

[0072] Host cells transformed with these recombinant vectors are also provided. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of FEN-1-encoding polynucleotides which can be expressed in a variety of prokaryotic and eukaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

[0073] The present invention further provides mixtures comprising a first structure-specific nuclease, wherein the first nuclease consists of a purified FEN-1 endonuclease and a second structure-specific nuclease. In preferred embodiments, the second structure-specific nuclease of the mixture is selected from the group comprising *Pyrococcus woesei* FEN-1 endonuclease, *Pyrococcus furiosus* FEN-1, *Methanococcus jannaschi* FEN-1 endonuclease, *Methanobacterium thermoautotrophicum* FEN-1 endonuclease, *Archaeoglobus fulgidus* FEN-1, *Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii, Aeropyrum pernix*, and chimerical FEN-1 endonucleases. In alternative embodiments, the purified FEN-1 endonuclease of the mixture is selected from the group consisting *Pyrococcus woesei* FEN-1 endonuclease, *Pyrococcus furiosus* FEN-1 endonuclease, *Methanococcus jannaschi* FEN-1 endonuclease, *Methanobacterium thermoautotrophicum* FEN-1 endonuclease, *Archaeoglobus fulgidus* FEN-1, *Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii, Aeropyrum pernix*, and chimerical FEN-1 endonucleases. In yet other preferred embodiments of the mixture, the second nuclease is a 5' nuclease derived from a thermostable DNA polymerase altered in amino acid sequence such that it exhibits reduced DNA synthetic activity from that of the wild-type DNA polymerase but retains substantially the same 5' nuclease activity of the wild-type DNA polymerase. In some preferred embodiments of the mixture, the second nuclease is selected from the group consisting of the Cleavase® BN enzyme, *Thermus aquaticus* DNA polymerase, *Thermus thermophilus* DNA polymerase, *Escherichia coli* Exo III, *Saccharomyces cerevisiae* Rad1/Rad10 complex.

[0074] The present invention also provides methods for treating nucleic acid, comprising: a) providing a purified FEN-1 endonuclease; and a nucleic acid substrate; b) treating the nucleic acid substrate under conditions such that the substrate forms one or more cleavage structures; and c) reacting the endonuclease with the cleavage structures so that one or more cleavage products are produced. In some embodiments, the purified FEN-1 endonuclease is selected from the group consisting *Pyrococcus woesei* FEN-1 endonuclease, *Pyrococcus furiosus* FEN-1 endonuclease, *Methanococcus jannaschi* FEN-1 endonuclease, *Methanobacterium thermoautotrophicum* FEN-1 endonuclease, *Archaeoglobus fulgidus* FEN-1, *Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii, Aero-*

pyrum pernix, and chimerical FEN-1 endonucleases. In other embodiments, the method further comprises providing a structure-specific nuclease derived from a thermostable DNA polymerase altered in amino acid sequence such that it exhibits reduced DNA synthetic activity from that of the wild-type DNA polymerase but retains substantially the same 5' nuclease activity of the wild-type DNA polymerase.

[0075] In alternative embodiments of the methods, a portion of the amino acid sequence of the second nuclease is homologous to a portion of the amino acid sequence of a thermostable DNA polymerase derived from a eubacterial thermophile of the genus *Thermus*. In yet other embodiments, the thermophile is selected from the group consisting of *Thermus aquaticus, Thermus flavus* and *Thermus thermophilus*. In some alternative embodiments, the structure-specific nuclease is selected from the group consisting of the Cleavase® BN enzyme, *Thermus aquaticus* DNA polymerase, *Thermus thermophilus* DNA polymerase, *Escherichia coli* Exo III, *Saccharomyces cerevisiae* Rad1/Rad10 complex. In some preferred embodiments, the structure-specific nuclease is the Cleavase® BN nuclease. In yet other embodiments, the nucleic acid of step (a) is substantially single-stranded. In further embodiments, the nucleic acid is selected from the group consisting of RNA and DNA. In yet further embodiments, the nucleic acid of step (a) is double stranded.

[0076] In other embodiments of the methods, the treating of step (b) comprises: rendering the double-stranded nucleic acid substantially single-stranded; and exposing the single-stranded nucleic acid to conditions such that the single-stranded nucleic acid has secondary structure. In some preferred embodiments, the double stranded nucleic acid is rendered substantially single-stranded by the use of increased temperature. In alternative preferred embodiments, the method further comprises the step of detecting the one or more cleavage products.

[0077] The present invention also provides methods for treating nucleic acid, comprising: a) providing: a first structure-specific nuclease consisting of a purified FEN-1 endonuclease in a solution containing manganese; and a nucleic acid substrate; b) treating the nucleic acid substrate with increased temperature such that the substrate is substantially single-stranded; c) reducing the temperature under conditions such that the single-stranded substrate forms one or more cleavage structures; d) reacting the cleavage means with the cleavage structures so that one or more cleavage products are produced; and e) detecting the one or more cleavage products. In some embodiments of the methods, the purified FEN-1 endonuclease is selected from the group consisting *Pyrococcus woesei* FEN-1 endonuclease, *Pyrococcus furiosus* FEN-1 endonuclease, *Methanococcus jannaschi* FEN-1 endonuclease, *Methanobacterium thermoautotrophicum* FEN-1 endonuclease, *Archaeoglobus fulgidus* FEN-1, *Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii, Aeropyrum pernix*, and chimerical FEN-1 endonucleases. In alternative embodiments, the methods further comprise providing a second structure-specific nuclease. In some preferred embodiments, the second nuclease is selected from the group consisting of the Cleavase® BN enzyme, *Thermus aquaticus* DNA polymerase, *Thermus thermophilus* DNA polymerase, *Escherichia coli* Exo III, and the *Saccharomyces cerevisiae* Rad1/Rad10 complex. In yet other preferred embodiments, the second nuclease is a 5' nuclease derived from a thermostable DNA polymerase altered in amino acid sequence such that it exhibits reduced DNA synthetic activity from that of the wild-type DNA polymerase but retains substantially the same 5' nuclease activity of the wild-type DNA polymerase. In yet other embodiments, the nucleic acid is selected from the group consisting of RNA and DNA. In further embodiments, the nucleic acid of step (a) is double stranded.

[0078] The present invention also provides nucleic acid treatment kits, comprising: a) a composition comprising at least one purified FEN-1 endonuclease; and b) a solution containing manganese. In some embodiments of the kits, the purified FEN-1 endonuclease is selected from the group consisting *Pyrococcus woesei* FEN-1 endonuclease, *Pyrococcus furiosus* FEN-1 endonuclease, *Methanococcus jannaschi* FEN-1 endonuclease, *Methanobacterium thermoautotrophicum* FEN-1 endonuclease, *Archaeoglobus fulgidus* FEN-1, *Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii, Aeropyrum pernix*, and chimerical FEN-1 endonucleases. In other embodiments, the kits further comprise at least one second structure-specific nuclease. In some preferred embodiments, the second nuclease is a 5' nuclease derived from a thermostable DNA polymerase altered in amino acid sequence such that it exhibits reduced DNA synthetic activity from that of the wild-type DNA polymerase but retains substantially the same 5' nuclease activity of the wild-type DNA polymerase. In yet other embodiments of the kits, the portion of the amino acid sequence of the second nuclease is homologous to a portion of the amino acid sequence of a thermostable DNA polymerase derived from a eubacterial thermophile of the genus *Thermus*. In further embodiments, the thermophile is selected from the group consisting of *Thermus aquaticus, Thermus flavus* and *Thermus thermophilus*. In yet other preferred embodiments, the kits further comprise reagents for detecting the cleavage products.

[0079] The present invention further provides any of the compositions, mixtures, methods, and kits described herein, used in conjunction with endonucleases comprising *Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii*, and *Aeropyrum pernix* endonucleases. These include compositions comprising purified FEN-1 endonucleases from the organisms (including specific endonucleases described by sequences provided herein, as well as, variants and homologues), kits comprising these compositions, composition comprising chimerical endonucleases comprising at least a portion of the endonucleases from these organisms, kits comprising such compositions, compositions comprising nucleic acids encoding the endonu-

cleases from these organisms (including vectors and host cells), kits comprising such compositions, antibodies generated to the endonucleases, mixtures comprising endonucleases from these organisms, methods of using the endonuclease in cleavage assays (e.g., invasive cleavage assays, CFLP, etc.), and kits containing components useful for such methods. Example describing the generation, structure, use, and characterization of these endonucleases are provided in Examples 62-67.

[0080] The present invention also provides methods for improving the methods and enzymes disclosed herein. For example, the present invention provides methods of improving enzymes for any intended purpose (e.g., use in cleavage reactions, amplification reactions, binding reactions, or any other use) comprising the step of providing an enzyme disclosed herein and modifying the enzyme (e.g., altering the amino acid sequence, adding or subtracting sequence, adding post-translational modifications, adding any other component whether biological or not, or any other modification). Likewise, the present invention provides methods for improving the methods disclosed herein comprising, conducting the method steps with one or more changes (e.g., change in a composition provided in the method, change in the order of the steps, or addition or subtraction of steps).

[0081] The improved performance in a detection assay may arise from any one of, or a combination of several improved features. For example, in one embodiment, the enzyme of the present invention may have an improved rate of cleavage (kcat) on a specific targeted structure, such that a larger amount of a cleavage product may be produced in a given time span. In another embodiment, the enzyme of the present invention may have a reduced activity or rate in the cleavage of inappropriate or non-specific structures. For example, in certain embodiments of the present invention, one aspect of improvement is that the differential between the detectable amount of cleavage of a specific structure and the detectable amount of cleavage of any alternative structures is increased. As such, it is within the scope of the present invention to provide an enzyme having a reduced rate of cleavage of a specific target structure compared to the rate of the native enzyme, and having a further reduced rate of cleavage of any alternative structures, such that the differential between the detectable amount of cleavage of the specific structure and the detectable amount of cleavage of any alternative structures is increased. However, the present invention is not limited to enzymes that have an improved differential.

[0082] The present invention contemplates structure-specific nucleases from a variety of sources, including, but not limited to, mesophilic, psychrophilic, thermophilic, and hyperthermophilic organisms. The preferred structure-specific nucleases are thermostable. Thermostable structure-specific nucleases are contemplated as particularly useful in that they allow the INVADER assay (See e.g., U.S. Pat. Nos. 5,846,717, 5,985,557, 5,994,069, and 6,001,567 and PCT Publications WO 97/27214 and WO 98/42873, incorporated herein by reference in their entireties) to be operated near the melting temperature (T_m) of the downstream probe oligonucleotide, so that cleaved and uncleaved probes may cycle on and off the target during the course of the reaction. In one embodiment, the thermostable structure-specific enzymes are thermostable 5' nucleases that are selected from the group comprising altered polymerases derived from the native polymerases of *Thermus* species, including, but not limited to, *Thermus aquaticus, Thermus flavus, Thermus thermophilus, Thermus filiformus*, and *Thermus scotoductus*. However, the invention is not limited to the use of thermostable 5' nucleases. For example, certain embodiments of the present invention utilize short oligonucleotide probes that may cycle on and off of the target at low temperatures, allowing the use of non-thermostable enzymes.

[0083] In some preferred embodiments, the present invention provides a composition comprising an enzyme, wherein the enzyme comprises a heterologous functional domain, wherein the heterologous functional domain provides altered (e.g., improved) functionality in a nucleic acid cleavage assay. The present invention is not limited by the nature of the nucleic acid cleavage assay. For example, nucleic acid cleavage assays include any assay in which a nucleic acid is cleaved, directly or indirectly, in the presence of the enzyme. In certain preferred embodiments, the nucleic acid cleavage assay is an invasive cleavage assay. In particularly preferred embodiments, the cleavage assay utilizes a cleavage structure having at least one RNA component. In another particularly preferred embodiment, the cleavage assay utilizes a cleavage structure having at least one RNA component, wherein a DNA member of the cleavage structure is cleaved.

[0084] The present invention is not limited by the nature of the altered functionality provided by the heterologous functional domain. Illustrative examples of alterations include, but are not limited to, enzymes where the heterologous functional domain comprises an amino acid sequence (e.g., one or more amino acids) that provides an improved nuclease activity, an improved substrate binding activity and/or improved background specificity in a nucleic acid cleavage assay.

[0085] The present invention is not limited by the nature of the heterologous functional domain. For example, in some embodiments, the heterologous functional domain comprises two or more amino acids from a polymerase domain of a polymerase (e.g., introduced into the enzyme by insertion of a chimerical functional domain or created by mutation). In certain preferred embodiment, at least one of the two or more amino acids is from a palm or thumb region of the polymerase domain. The present invention is not limited by the identity of the polymerase from which the two or more amino acids are selected. In certain preferred embodiments, the polymerase comprises *Thermus thermophilus* polymerase. In particularly preferred embodiments, the two or more amino acids are from amino acids 300-650 of SEQ ID NO:267.

[0086] The novel enzymes of the invention may be employed for the detection of target DNAs and RNAs including, but not limited to, target DNAs and RNAs comprising wild type and mutant alleles of genes, including, but not limited to, genes from humans, other animal, or plants that are or may be associated with disease or other conditions. In addition, the enzymes of the invention may be used for the detection of and/or identification of strains of microorganisms, including bacteria, fungi, protozoa, ciliates and viruses (and in particular for the detection and identification of viruses having RNA genomes, such as the Hepatitis C and Human Immunodeficiency viruses). For example, the present invention provides methods for cleaving a nucleic

acid comprising providing: an enzyme of the present invention and a substrate nucleic acid; and exposing the substrate nucleic acid to the enzyme (e.g., to produce a cleavage product that may be detected).

Definitions

[0087] To facilitate an understanding of the present invention, a number of terms and phrases are defined below:

[0088] As used herein, the terms "complementary" or "complementarity" are used in reference to polynucleotides (i.e., a sequence of nucleotides such as an oligonucleotide or a target nucleic acid) related by the base-pairing rules. For example, for the sequence "5'-A-G-T-3'," is complementary to the sequence "3'-T-C-A-5'." Complementarity may be "partial," in which only some of the nucleic acids' bases are matched according to the base pairing rules. Or, there may be "complete" or "total" complementarity between the nucleic acids. The degree of complementarity between nucleic acid strands has significant effects on the efficiency and strength of hybridization between nucleic acid strands. This is of particular importance in amplification reactions, as well as detection methods which depend upon binding between nucleic acids. Either term may also be used in reference to individual nucleotides, especially within the context of polynucleotides. For example, a particular nucleotide within an oligonucleotide may be noted for its complementarity, or lack thereof, to a nucleotide within another nucleic acid strand, in contrast or comparison to the complementarity between the rest of the oligonucleotide and the nucleic acid strand.

[0089] The term "homology" and "homologous" refers to a degree of identity. There may be partial homology or complete homology. A partially homologous sequence is one that is less than 100% identical to another sequence.

[0090] As used herein, the term "hybridization" is used in reference to the pairing of complementary nucleic acids. Hybridization and the strength of hybridization (i.e., the strength of the association between the nucleic acids) is influenced by such factors as the degree of complementary between the nucleic acids, stringency of the conditions involved, and the T_m of the formed hybrid. "Hybridization" methods involve the annealing of one nucleic acid to another, complementary nucleic acid, i.e., a nucleic acid having a complementary nucleotide sequence. The ability of two polymers of nucleic acid containing complementary sequences to find each other and anneal through base pairing interaction is a well-recognized phenomenon. The initial observations of the "hybridization" process by Marmur and Lane, Proc. Natl. Acad. Sci. USA 46:453 (1960) and Doty et al., Proc. Natl. Acad. Sci. USA 46:461 (1960) have been followed by the refinement of this process into an essential tool of modern biology.

[0091] With regard to complementarity, it is important for some diagnostic applications to determine whether the hybridization represents complete or partial complementarity. For example, where it is desired to detect simply the presence or absence of pathogen DNA (such as from a virus, bacterium, fungi, mycoplasma, protozoan) it is only important that the hybridization method ensures hybridization when the relevant sequence is present; conditions can be selected where both partially complementary probes and completely complementary probes will hybridize. Other diagnostic applications, however, may require that the hybridization method distinguish between partial and complete complementarity. It may be of interest to detect genetic polymorphisms. For example, human hemoglobin is composed, in part, of four polypeptide chains. Two of these chains are identical chains of 141 amino acids (alpha chains) and two of these chains are identical chains of 146 amino acids (beta chains). The gene encoding the beta chain is known to exhibit polymorphism. The normal allele encodes a beta chain having glutamic acid at the sixth position. The mutant allele encodes a beta chain having valine at the sixth position. This difference in amino acids has a profound (most profound when the individual is homozygous for the mutant allele) physiological impact known clinically as sickle cell anemia. It is well known that the genetic basis of the amino acid change involves a single base difference between the normal allele DNA sequence and the mutant allele DNA sequence.

[0092] The complement of a nucleic acid sequence as used herein refers to an oligonucleotide which, when aligned with the nucleic acid sequence such that the 5' end of one sequence is paired with the 3' end of the other, is in "antiparallel association." Certain bases not commonly found in natural nucleic acids may be included in the nucleic acids of the present invention and include, for example, inosine and 7-deazaguanine. Complementarity need not be perfect; stable duplexes may contain mismatched base pairs or unmatched bases. Those skilled in the art of nucleic acid technology can determine duplex stability empirically considering a number of variables including, for example, the length of the oligonucleotide, base composition and sequence of the oligonucleotide, ionic strength and incidence of mismatched base pairs.

[0093] As used herein, the term "T_m" is used in reference to the "melting temperature." The melting temperature is the temperature at which a population of double-stranded nucleic acid molecules becomes half dissociated into single strands. Several equations for calculating the T_m of nucleic acids are well known in the art. As indicated by standard references, a simple estimate of the T_m value may be calculated by the equation: T_m=81.5+0.41(% G+C), when a nucleic acid is in aqueous solution at 1 M NaCl (see e.g., Anderson and Young, Quantitative Filter Hybridization, in Nucleic Acid Hybridization (1985). Other references (e.g., Allawi, H. T. & SantaLucia, J., Jr. Thermodynamics and NMR of internal G.T mismatches in DNA. Biochemistry 36, 10581-94 (1997) include more sophisticated computations which take structural and environmental, as well as sequence characteristics into account for the calculation of T_m.

[0094] As used herein the term "stringency" is used in reference to the conditions of temperature, ionic strength, and the presence of other compounds, under which nucleic acid hybridizations are conducted. With "high stringency" conditions, nucleic acid base pairing will occur only between nucleic acid fragments that have a high frequency of complementary base sequences. Thus, conditions of "weak" or "low" stringency are often required when it is desired that nucleic acids which are not completely complementary to one another be hybridized or annealed together.

[0095] "High stringency conditions" when used in reference to nucleic acid hybridization comprise conditions equivalent to binding or hybridization at 42 C in a solution

consisting of 5×SSPE (43.8 g/l NaCl, 6.9 g/l $NaH_2PO_4H_2O$ and 1.85 g/l EDTA, pH adjusted to 7.4 with NaOH), 0.5% SDS, 5×Denhardt's reagent and 100 μg/ml denatured salmon sperm DNA followed by washing in a solution comprising 0.1×SSPE, 1.0% SDS at 42 C when a probe of about 500 nucleotides in length is employed.

[0096] "Medium stringency conditions" when used in reference to nucleic acid hybridization comprise conditions equivalent to binding or hybridization at 42 C in a solution consisting of 5×SSPE (43.8 g/l NaCl, 6.9 g/l $NaH_2PO_4H_2O$ and 1.85 g/l EDTA, pH adjusted to 7.4 with NaOH), 0.5% SDS, 5×Denhardt's reagent and 100 μg/ml denatured salmon sperm DNA followed by washing in a solution comprising 1.0×SSPE, 1.0% SDS at 42 C when a probe of about 500 nucleotides in length is employed.

[0097] "Low stringency conditions" comprise conditions equivalent to binding or hybridization at 42 C in a solution consisting of 5×SSPE (43.8 g/l NaCl, 6.9 g/l $NaH_2PO_4H_2O$ and 1.85 g/l EDTA, pH adjusted to 7.4 with NaOH), 0.1% SDS, 5×Denhardt's reagent [50×Denhardt's contains per 500 ml: 5 g Ficoll (Type 400, Pharamcia), 5 g BSA (Fraction V; Sigma)] and 100 g/ml denatured salmon sperm DNA followed by washing in a solution comprising 5×SSPE, 0.1% SDS at 42 C when a probe of about 500 nucleotides in length is employed.

[0098] The term "gene" refers to a DNA sequence that comprises control and coding sequences necessary for the production of an RNA having a non-coding function (e.g., a ribosomal or transfer RNA), a polypeptide or a precursor. The RNA or polypeptide can be encoded by a full length coding sequence or by any portion of the coding sequence so long as the desired activity or function is retained.

[0099] The term "wild-type" refers to a gene or a gene product that has the characteristics of that gene or gene product when isolated from a naturally occurring source. A wild-type gene is that which is most frequently observed in a population and is thus arbitrarily designated the "normal" or "wild-type" form of the gene. In contrast, the term "modified,""mutant," or "polymorphic" refers to a gene or gene product which displays modifications in sequence and or functional properties (i.e., altered characteristics) when compared to the wild-type gene or gene product. It is noted that naturally-occurring mutants can be isolated; these are identified by the fact that they have altered characteristics when compared to the wild-type gene or gene product.

[0100] The term "recombinant DNA vector" as used herein refers to DNA sequences containing a desired heterologous sequence. For example, although the term is not limited to the use of expressed sequences or sequences that encode an expression product, in some embodiments, the heterologous sequence is a coding sequence and appropriate DNA sequences necessary for either the replication of the coding sequence in a host organism, or the expression of the operably linked coding sequence in a particular host organism. DNA sequences necessary for expression in prokaryotes include a promoter, optionally an operator sequence, a ribosome binding site and possibly other sequences. Eukaryotic cells are known to utilize promoters, polyadenylation signals and enhancers.

[0101] The term "LTR" as used herein refers to the long terminal repeat found at each end of a provirus (i.e., the integrated form of a retrovirus). The LTR contains numerous regulatory signals including transcriptional control elements, polyadenylation signals and sequences needed for replication and integration of the viral genome. The viral LTR is divided into three regions called U3, R and U5.

[0102] The U3 region contains the enhancer and promoter elements. The U5 region contains the polyadenylation signals. The R (repeat) region separates the U3 and U5 regions and transcribed sequences of the R region appear at both the 5' and 3' ends of the viral RNA.

[0103] The term "oligonucleotide" as used herein is defined as a molecule comprising two or more deoxyribonucleotides or ribonucleotides, preferably at least 5 nucleotides, more preferably at least about 10-15 nucleotides and more preferably at least about 15 to 30 nucleotides. The exact size will depend on many factors, which in turn depend on the ultimate function or use of the oligonucleotide. The oligonucleotide may be generated in any manner, including chemical synthesis, DNA replication, reverse transcription, PCR, or a combination thereof.

[0104] Because mononucleotides are reacted to make oligonucleotides in a manner such that the 5' phosphate of one mononucleotide pentose ring is attached to the 3' oxygen of its neighbor in one direction via a phosphodiester linkage, an end of an oligonucleotide is referred to as the "5' end" if its 5' phosphate is not linked to the 3' oxygen of a mononucleotide pentose ring and as the "3' end" if its 3' oxygen is not linked to a 5' phosphate of a subsequent mononucleotide pentose ring. As used herein, a nucleic acid sequence, even if internal to a larger oligonucleotide, also may be said to have 5' and 3' ends. A first region along a nucleic acid strand is said to be upstream of another region if the 3' end of the first region is before the 5' end of the second region when moving along a strand of nucleic acid in a 5' to 3' direction.

[0105] When two different, non-overlapping oligonucleotides anneal to different regions of the same linear complementary nucleic acid sequence, and the 3' end of one oligonucleotide points towards the 5' end of the other, the former may be called the "upstream" oligonucleotide and the latter the "downstream" oligonucleotide. Similarly, when two overlapping oligonucleotides are hybridized to the same linear complementary nucleic acid sequence, with the first oligonucleotide positioned such that its 5' end is upstream of the 5' end of the second oligonucleotide, and the 3' end of the first oligonucleotide is upstream of the 3' end of the second oligonucleotide, the first oligonucleotide may be called the "upstream" oligonucleotide and the second oligonucleotide may be called the "downstream" oligonucleotide.

[0106] The term "primer" refers to an oligonucleotide that is capable of acting as a point of initiation of synthesis when placed under conditions in which primer extension is initiated. An oligonucleotide "primer" may occur naturally, as in a purified restriction digest or may be produced synthetically.

[0107] A primer is selected to be "substantially" complementary to a strand of specific sequence of the template. A primer must be sufficiently complementary to hybridize with a template strand for primer elongation to occur. A primer sequence need not reflect the exact sequence of the template. For example, a non-complementary nucleotide fragment

may be attached to the 5' end of the primer, with the remainder of the primer sequence being substantially complementary to the strand. Non-complementary bases or longer sequences can be interspersed into the primer, provided that the primer sequence has sufficient complementarity with the sequence of the template to hybridize and thereby form a template primer complex for synthesis of the extension product of the primer.

[0108] The term "label" as used herein refers to any atom or molecule that can be used to provide a detectable (preferably quantifiable) signal, and that can be attached to a nucleic acid or protein. Labels may provide signals detectable by fluorescence, radioactivity, colorimetry, gravimetry, X-ray diffraction or absorption, magnetism, enzymatic activity, and the like. A label may be a charged moiety (positive or negative charge) or alternatively, may be charge neutral. Labels can include or consist of nucleic acid or protein sequence, so long as the sequence comprising the label is detectable.

[0109] The term "cleavage structure" as used herein, refers to a structure that is formed by the interaction of at least one probe oligonucleotide and a target nucleic acid, forming a structure comprising a duplex, the resulting structure being cleavable by a cleavage means, including but not limited to an enzyme. The cleavage structure is a substrate for specific cleavage by the cleavage means in contrast to a nucleic acid molecule that is a substrate for non-specific cleavage by agents such as phosphodiesterases that cleave nucleic acid molecules without regard to secondary structure (i.e., no formation of a duplexed structure is required).

[0110] The term "folded cleavage structure" as used herein, refers to a region of a single-stranded nucleic acid substrate containing secondary structure, the region being cleavable by an enzymatic cleavage means. The cleavage structure is a substrate for specific cleavage by the cleavage means in contrast to a nucleic acid molecule that is a substrate for non-specific cleavage by agents such as phosphodiesterases which cleave nucleic acid molecules without regard to secondary structure (i.e., no folding of the substrate is required).

[0111] As used herein, the term "folded target" refers to a nucleic acid strand that contains at least one region of secondary structure (i.e., at least one double stranded region and at least one single-stranded region within a single strand of the nucleic acid). A folded target may comprise regions of tertiary structure in addition to regions of secondary structure.

[0112] The term "cleavage means" or "cleavage agent" as used herein refers to any means that is capable of cleaving a cleavage structure, including but not limited to enzymes. The cleavage means may include native DNAPs having 5' nuclease activity (e.g., Taq DNA polymerase, *E. coli* DNA polymerase I) and, more specifically, modified DNAPs having 5' nuclease but lacking synthetic activity. "Structure-specific nucleases" or "structure-specific enzymes" are enzymes that recognize specific secondary structures in a nucleic molecule and cleave these structures. The cleavage means of the invention cleave a nucleic acid molecule in response to the formation of cleavage structures; it is not necessary that the cleavage means cleave the cleavage structure at any particular location within the cleavage structure.

[0113] The cleavage means is not restricted to enzymes having solely 5' nuclease activity. The cleavage means may include nuclease activity provided from a variety of sources including the Cleavase enzymes, the FEN-1 endonucleases (including RAD2 and XPG proteins), Taq DNA polymerase and *E. coli* DNA polymerase I.

[0114] The term "thermostable" when used in reference to an enzyme, such as a 5' nuclease, indicates that the enzyme is functional or active (i.e., can perform catalysis) at an elevated temperature, i.e., at about 55° C. or higher.

[0115] The term "cleavage products" as used herein, refers to products generated by the reaction of a cleavage means with a cleavage structure (i.e., the treatment of a cleavage structure with a cleavage means).

[0116] The term "target nucleic acid" refers to a nucleic acid molecule containing a sequence that has at least partial complementarity with at least a probe oligonucleotide and may also have at least partial complementarity with an INVADER oligonucleotide. The target nucleic acid may comprise single- or double-stranded DNA or RNA.

[0117] The term "probe oligonucleotide" refers to an oligonucleotide that interacts with a target nucleic acid to form a cleavage structure in the presence or absence of an INVADER oligonucleotide. When annealed to the target nucleic acid, the probe oligonucleotide and target form a cleavage structure and cleavage occurs within the probe oligonucleotide.

[0118] The term "non-target cleavage product" refers to a product of a cleavage reaction that is not derived from the target nucleic acid. As discussed above, in the methods of the present invention, cleavage of the cleavage structure generally occurs within the probe oligonucleotide. The fragments of the probe oligonucleotide generated by this target nucleic acid-dependent cleavage are "non-target cleavage products."

[0119] The term "INVADER oligonucleotide" refers to an oligonucleotide that hybridizes to a target nucleic acid at a location near the region of hybridization between a probe and the target nucleic acid, wherein the INVADER oligonucleotide comprises a portion (e.g., a chemical moiety, or nucleotide—whether complementary to that target or not) that overlaps with the region of hybridization between the probe and target. In some embodiments, the INVADER oligonucleotide contains sequences at its 3' end that are substantially the same as sequences located at the 5' end of a probe oligonucleotide.

[0120] The term "substantially single-stranded" when used in reference to a nucleic acid substrate means that the substrate molecule exists primarily as a single strand of nucleic acid in contrast to a double-stranded substrate which exists as two strands of nucleic acid which are held together by inter-strand base pairing interactions.

[0121] The term "sequence variation" as used herein refers to differences in nucleic acid sequence between two nucleic acids. For example, a wild-type structural gene and a mutant form of this wild-type structural gene may vary in sequence by the presence of single base substitutions and/or deletions or insertions of one or more nucleotides. These two forms of the structural gene are said to vary in sequence from one another. A second mutant form of the structural gene may

exist. This second mutant form is said to vary in sequence from both the wild-type gene and the first mutant form of the gene.

[0122] The term "liberating" as used herein refers to the release of a nucleic acid fragment from a larger nucleic acid fragment, such as an oligonucleotide, by the action of, for example, a 5' nuclease such that the released fragment is no longer covalently attached to the remainder of the oligonucleotide.

[0123] The term "K_m" as used herein refers to the Michaelis-Menten constant for an enzyme and is defined as the concentration of the specific substrate at which a given enzyme yields one-half its maximum velocity in an enzyme catalyzed reaction.

[0124] The term "nucleotide analog" as used herein refers to modified or non-naturally occurring nucleotides such as 7-deaza purines (i.e., 7-deaza-dATP and 7-deaza-dGTP). Nucleotide analogs include base analogs and comprise modified forms of deoxyribonucleotides as well as ribonucleotides.

[0125] The term "polymorphic locus" is a locus present in a population that shows variation between members of the population (e.g., the most common allele has a frequency of less than 0.95). In contrast, a "monomorphic locus" is a genetic locus at little or no variations seen between members of the population (generally taken to be a locus at which the most common allele exceeds a frequency of 0.95 in the gene pool of the population).

[0126] The term "microorganism" as used herein means an organism too small to be observed with the unaided eye and includes, but is not limited to bacteria, virus, protozoans, fungi, and ciliates.

[0127] The term "microbial gene sequences" refers to gene sequences derived from a microorganism.

[0128] The term "bacteria" refers to any bacterial species including eubacterial and archaebacterial species.

[0129] The term "virus" refers to obligate, ultramicroscopic, intracellular parasites incapable of autonomous replication (i.e., replication requires the use of the host cell's machinery).

[0130] The term "multi-drug resistant" or multiple-drug resistant" refers to a microorganism which is resistant to more than one of the antibiotics or antimicrobial agents used in the treatment of said microorganism.

[0131] The term "sample" in the present specification and claims is used in its broadest sense. On the one hand it is meant to include a specimen or culture (e.g., microbiological cultures). On the other hand, it is meant to include both biological and environmental samples. A sample may include a specimen of synthetic origin.

[0132] Biological samples may be animal, including human, fluid, solid (e.g., stool) or tissue, as well as liquid and solid food and feed products and ingredients such as dairy items, vegetables, meat and meat by-products, and waste. Biological samples may be obtained from all of the various families of domestic animals, as well as feral or wild animals, including, but not limited to, such animals as ungulates, bear, fish, lagamorphs, rodents, etc.

[0133] Environmental samples include environmental material such as surface matter, soil, water and industrial samples, as well as samples obtained from food and dairy processing instruments, apparatus, equipment, utensils, disposable and non-disposable items. These examples are not to be construed as limiting the sample types applicable to the present invention.

[0134] The term "source of target nucleic acid" refers to any sample that contains nucleic acids (RNA or DNA). Particularly preferred sources of target nucleic acids are biological samples including, but not limited to blood, saliva, cerebral spinal fluid, pleural fluid, milk, lymph, sputum and semen.

[0135] An oligonucleotide is said to be present in "excess" relative to another oligonucleotide (or target nucleic acid sequence) if that oligonucleotide is present at a higher molar concentration that the other oligonucleotide (or target nucleic acid sequence). When an oligonucleotide such as a probe oligonucleotide is present in a cleavage reaction in excess relative to the concentration of the complementary target nucleic acid sequence, the reaction may be used to indicate the amount of the target nucleic acid present. Typically, when present in excess, the probe oligonucleotide will be present at least a 100-fold molar excess; typically at least 1 pmole of each probe oligonucleotide would be used when the target nucleic acid sequence was present at about 10 fmoles or less.

[0136] A sample "suspected of containing" a first and a second target nucleic acid may contain either, both or neither target nucleic acid molecule.

[0137] The term "charge-balanced" oligonucleotide refers to an oligonucleotide (the input oligonucleotide in a reaction) that has been modified such that the modified oligonucleotide bears a charge, such that when the modified oligonucleotide is either cleaved (i.e., shortened) or elongated, a resulting product bears a charge different from the input oligonucleotide (the "charge-unbalanced" oligonucleotide) thereby permitting separation of the input and reacted oligonucleotides on the basis of charge. The term "charge-balanced" does not imply that the modified or balanced oligonucleotide has a net neutral charge (although this can be the case). Charge-balancing refers to the design and modification of an oligonucleotide such that a specific reaction product generated from this input oligonucleotide can be separated on the basis of charge from the input oligonucleotide.

[0138] For example, in an INVADER oligonucleotide-directed cleavage assay in which the probe oligonucleotide bears the sequence: 5' TTCTTTTCACCAGCGAGACGGG 3' (i.e., SEQ ID NO:61 without the modified bases) and cleavage of the probe occurs between the second and third residues, one possible charge-balanced version of this oligonucleotide would be: 5' Cy3-AminoT-Amino-TCTTTTCACCAGCGAGAC GGG 3'. This modified oligonucleotide bears a net negative charge. After cleavage, the following oligonucleotides are generated: 5' Cy3-AminoT-Amino-T 3'and 5' CTTTTCACCAGCGAGACGGG 3' (residues 3-22 of SEQ ID NO:61). 5' Cy3-AminoT-Amino-T 3' bears a detectable moiety (the positively-charged Cy3 dye) and two amino-modified bases. The amino-modified bases and the Cy3 dye contribute positive charges in excess of the negative charges contributed by the phosphate groups and

thus the 5' Cy3-AminoT-Amino-T 3'oligonucleotide has a net positive charge. The other, longer cleavage fragment, like the input probe, bears a net negative charge. Because the 5' Cy3-AminoT-Amino-T 3'fragment is separable on the basis of charge from the input probe (the charge-balanced oligonucleotide), it is referred to as a charge-unbalanced oligonucleotide. The longer cleavage product cannot be separated on the basis of charge from the input oligonucleotide as both oligonucleotides bear a net negative charge; thus, the longer cleavage product is not a charge-unbalanced oligonucleotide.

[0139] The term "net neutral charge" when used in reference to an oligonucleotide, including modified oligonucleotides, indicates that the sum of the charges present (i.e., R—NH3+ groups on thymidines, the N3 nitrogen of cytosine, presence or absence or phosphate groups, etc.) under the desired reaction or separation conditions is essentially zero. An oligonucleotide having a net neutral charge would not migrate in an electrical field.

[0140] The term "net positive charge" when used in reference to an oligonucleotide, including modified oligonucleotides, indicates that the sum of the charges present (i.e., R—NH3+ groups on thymidines, the N3 nitrogen of cytosine, presence or absence or phosphate groups, etc.) under the desired reaction conditions is +1 or greater. An oligonucleotide having a net positive charge would migrate toward the negative electrode in an electrical field.

[0141] The term "net negative charge" when used in reference to an oligonucleotide, including modified oligonucleotides, indicates that the sum of the charges present (i.e., R—NH3+ groups on thymidines, the N3 nitrogen of cytosine, presence or absence or phosphate groups, etc.) under the desired reaction conditions is −1 or lower. An oligonucleotide having a net negative charge would migrate toward the positive electrode in an electrical field.

[0142] The term "polymerization means" or "polymerization agent" refers to any agent capable of facilitating the addition of nucleoside triphosphates to an oligonucleotide. Preferred polymerization means comprise DNA and RNA polymerases.

[0143] The term "ligation means" or "ligation agent" refers to any agent capable of facilitating the ligation (i.e., the formation of a phosphodiester bond between a 3'-OH and a 5' P located at the termini of two strands of nucleic acid). Preferred ligation means comprise DNA ligases and RNA ligases.

[0144] The term "reactant" is used herein in its broadest sense. The reactant can comprise, for example, an enzymatic reactant, a chemical reactant or light (e.g., ultraviolet light, particularly short wavelength ultraviolet light is known to break oligonucleotide chains). Any agent capable of reacting with an oligonucleotide to either shorten (i.e., cleave) or elongate the oligonucleotide is encompassed within the term "reactant."

[0145] The term "adduct" is used herein in its broadest sense to indicate any compound or element that can be added to an oligonucleotide. An adduct may be charged (positively or negatively) or may be charge-neutral. An adduct may be added to the oligonucleotide via covalent or non-covalent linkages. Examples of adducts include, but are not limited to, indodicarbocyanine dye amidites, amino-substituted nucleotides, ethidium bromide, ethidium homodimer, (1,3-propanediamino)propidium, (diethylenetriamino)propidium, thiazole orange, (N—N'-tetramethyl-1,3-propanediamino)propyl thiazole orange, (N—N'-tetramethyl-1,2-ethanediamino)propyl thiazole orange, thiazole orange-thiazole orange homodimer (TOTO), thiazole orange-thiazole blue heterodimer (TOTAB), thiazole orange-ethidium heterodimer 1 (TOED1), thiazole orange-ethidium heterodimer 2 (TOED2) and fluorescein-ethidium heterodimer (FED), psoralens, biotin, streptavidin, avidin, etc.

[0146] Where a first oligonucleotide is complementary to a region of a target nucleic acid and a second oligonucleotide has complementary to the same region (or a portion of this region) a "region of overlap" exists along the target nucleic acid. The degree of overlap will vary depending upon the nature of the complementarity (see, e.g., region "X" in FIGS. **29** and **67** and the accompanying discussions).

[0147] As used herein, the term "purified" or "to purify" refers to the removal of contaminants from a sample. For example, recombinant Cleavase nucleases are expressed in bacterial host cells and the nucleases are purified by the removal of host cell proteins; the percent of these recombinant nucleases is thereby increased in the sample.

[0148] The term "recombinant DNA molecule" as used herein refers to a DNA molecule that comprises of segments of DNA joined together by means of molecular biological techniques.

[0149] The term "recombinant protein" or "recombinant polypeptide" as used herein refers to a protein molecule that is expressed from a recombinant DNA molecule.

[0150] As used herein the term "portion" when in reference to a protein (as in "a portion of a given protein") refers to fragments of that protein. The fragments may range in size from four amino acid residues to the entire amino acid sequence minus one amino acid (e.g., 4, 5, 6, . . . , n−1).

[0151] The term "nucleic acid sequence" as used herein refers to an oligonucleotide, nucleotide or polynucleotide, and fragments or portions thereof, and to DNA or RNA of genomic or synthetic origin that may be single or double stranded, and represent the sense or antisense strand. Similarly, "amino acid sequence" as used herein refers to peptide or protein sequence.

[0152] The term "peptide nucleic acid" ("PNA") as used herein refers to a molecule comprising bases or base analogs such as would be found in natural nucleic acid, but attached to a peptide backbone rather than the sugar-phosphate backbone typical of nucleic acids. The attachment of the bases to the peptide is such as to allow the bases to base pair with complementary bases of nucleic acid in a manner similar to that of an oligonucleotide. These small molecules, also designated anti gene agents, stop transcript elongation by binding to their complementary strand of nucleic acid (Nielsen, et al. Anticancer Drug Des. 8:53 63 [1993]).

[0153] As used herein, the terms "purified" or "substantially purified" refer to molecules, either nucleic or amino acid sequences, that are removed from their natural environment, isolated or separated, and are at least 60% free, preferably 75% free, and most preferably 90% free from other components with which they are naturally associated.

An "isolated polynucleotide" or "isolated oligonucleotide" is therefore a substantially purified polynucleotide.

[0154] An isolated oligonucleotide (or polynucleotide) encoding a *Pyrococcus woesei* (Pwo) FEN-1 endonuclease having a region capable of hybridizing to SEQ ID NO:116 is an oligonucleotide containing sequences encoding at least the amino-terminal portion of Pwo FEN-1 endonuclease. An isolated oligonucleotide (or polynucleotide) encoding a Pwo FEN-1 endonuclease having a region capable of hybridizing to SEQ ID NO:117 is an oligonucleotide containing sequences encoding at least the carboxy-terminal portion of Pwo FEN-1 endonuclease. An isolated oligonucleotide (or polynucleotide) encoding a Pwo FEN-1 endonuclease having a region capable of hybridizing to SEQ ID NOS:118 and 119 is an oligonucleotide containing sequences encoding at least portions of Pwo FEN-1 endonuclease protein located internal to either the amino or carboxy-termini of the Pwo FEN-1 endonuclease protein.

[0155] As used herein, the term "fusion protein" refers to a chimeric protein containing the protein of interest (e.g., Cleavase BN/thrombin nuclease and portions or fragments thereof) joined to an exogenous protein fragment (the fusion partner which consists of a non Cleavase BN/thrombin nuclease protein). The fusion partner may enhance solubility of recombinant chimeric protein (e.g., the Cleavase BN/thrombin nuclease) as expressed in a host cell, may provide an affinity tag (e.g., a his-tag) to allow purification of the recombinant fusion protein from the host cell or culture supernatant, or both. If desired, the fusion protein may be removed from the protein of interest (e.g., Cleavase BN/thrombin nuclease or fragments thereof) by a variety of enzymatic or chemical means known to the art.

[0156] As used herein, the terms "chimeric protein" and "chimerical protein" refer to a single protein molecule that comprises amino acid sequences portions derived from two or more parent proteins. These parent molecules may be from similar proteins from genetically distinct origins, different proteins from a single organism, or different proteins from different organisms. By way of example but not by way of limitation, a chimeric structure-specific nuclease of the present invention may contain a mixture of amino acid sequences that have been derived from FEN-1 genes from two or more of the organisms having such genes, combined to form a non-naturally occurring nuclease. The term "chimerical" as used herein is not intended to convey any particular proportion of contribution from the naturally occurring genes, nor limit the manner in which the portions are combined. Any chimeric structure-specific nuclease constructs having cleavage activity as determined by the testing methods described herein are improved cleavage agents within the scope of the present invention.

[0157] The term "continuous strand of nucleic acid" as used herein is means a strand of nucleic acid that has a continuous, covalently linked, backbone structure, without nicks or other disruptions. The disposition of the base portion of each nucleotide, whether base-paired, single-stranded or mismatched, is not an element in the definition of a continuous strand. The backbone of the continuous strand is not limited to the ribose-phosphate or deoxyribose-phosphate compositions that are found in naturally occurring, unmodified nucleic acids. A nucleic acid of the present invention may comprise modifications in the structure of the backbone, including but not limited to phosphorothioate residues, phosphonate residues, 2' substituted ribose residues (e.g., 2'-O-methyl ribose) and alternative sugar (e.g., arabinose) containing residues.

[0158] The term "continuous duplex" as used herein refers to a region of double stranded nucleic acid in which there is no disruption in the progression of basepairs within the duplex (i.e., the base pairs along the duplex are not distorted to accommodate a gap, bulge or mismatch with the confines of the region of continuous duplex). As used herein the term refers only to the arrangement of the basepairs within the duplex, without implication of continuity in the backbone portion of the nucleic acid strand. Duplex nucleic acids with uninterrupted basepairing, but with nicks in one or both strands are within the definition of a continuous duplex.

[0159] The term "duplex" refers to the state of nucleic acids in which the base portions of the nucleotides on one strand are bound through hydrogen bonding the their complementary bases arrayed on a second strand. The condition of being in a duplex form reflects on the state of the bases of a nucleic acid. By virtue of base pairing, the strands of nucleic acid also generally assume the tertiary structure of a double helix, having a major and a minor groove. The assumption of the helical form is implicit in the act of becoming duplexed.

[0160] The term "duplex dependent protein binding" refers to the binding of proteins to nucleic acid that is dependent on the nucleic acid being in a duplex, or helical form.

[0161] The term "duplex dependent protein binding sites or regions" as used herein refers to discrete regions or sequences within a nucleic acid that are bound with particular affinity by specific duplex-dependent nucleic acid binding proteins. This is in contrast to the generalized duplex-dependent binding of proteins that are not site-specific, such as the histone proteins that bind chromatin with little reference to specific sequences or sites.

[0162] The term "protein binding region" as used herein refers to a nucleic acid region identified by a sequence or structure as binding to a particular protein or class of proteins. It is within the scope of this definition to include those regions that contain sufficient genetic information to allow identifications of the region by comparison to known sequences, but which might not have the requisite structure for actual binding (e.g., a single strand of a duplex-depending nucleic acid binding protein site). As used herein "protein binding region" excludes restriction endonuclease binding regions.

[0163] The term "complete double stranded protein binding region" as used herein refers to the minimum region of continuous duplex required to allow binding or other activity of a duplex-dependent protein. This definition is intended to encompass the observation that some duplex dependent nucleic acid binding proteins can interact with full activity with regions of duplex that may be shorter than a canonical protein binding region as observed in one or the other of the two single strands. In other words, one or more nucleotides in the region may be allowed to remain unpaired without suppressing binding. As used here in, the term "complete double stranded binding region" refers to the minimum sequence that will accommodate the binding function.

Because some such regions can tolerate non-duplex sequences in multiple places, although not necessarily simultaneously, a single protein binding region might have several shorter sub-regions that, when duplexed, will be fully competent for protein binding.

[0164] The term "template" refers to a strand of nucleic acid on which a complementary copy is built from nucleoside triphosphates through the activity of a template-dependent nucleic acid polymerase. Within a duplex the template strand is, by convention, depicted and described as the "bottom" strand. Similarly, the non-template strand is often depicted and described as the "top" strand.

[0165] The term "template-dependent RNA polymerase" refers to a nucleic acid polymerase that creates new RNA strands through the copying of a template strand as described above and which does not synthesize RNA in the absence of a template. This is in contrast to the activity of the template-independent nucleic acid polymerases that synthesize or extend nucleic acids without reference to a template, such as terminal deoxynucleotidyl transferase, or Poly A polymerase.

[0166] The term "ARRESTOR molecule" refers to an agent added to or included in an invasive cleavage reaction in order to stop one or more reaction components from participating in a subsequent action or reaction. This may be done by sequestering or inactivating some reaction component (e.g., by binding or base-pairing a nucleic acid component, or by binding to a protein component). The term "ARRESTOR oligonucleotide" refers to an oligonucleotide included in an invasive cleavage reaction in order to stop or arrest one or more aspects of any reaction (e.g., the first reaction and/or any subsequent reactions or actions; it is not intended that the ARRESTOR oligonucleotide be limited to any particular reaction or reaction step). This may be done by sequestering some reaction component (e.g., base-pairing to another nucleic acid, or binding to a protein component). However, it is not intended that the term be so limited as to just situations in which a reaction component is sequestered.

[0167] As used herein, the term "kit" refers to any delivery system for delivering materials. In the context of reaction assays, such delivery systems include systems that allow for the storage, transport, or delivery of reaction reagents (e.g., oligonucleotides, enzymes, etc. in the appropriate containers) and/or supporting materials (e.g., buffers, written instructions for performing the assay etc.) from one location to another. For example, kits include one or more enclosures (e.g., boxes) containing the relevant reaction reagents and/or supporting materials. As used herein, the term "fragmented kit" refers to a delivery systems comprising two or more separate containers that each contain a subportion of the total kit components. The containers may be delivered to the intended recipient together or separately. For example, a first container may contain an enzyme for use in an assay, while a second container contains oligonucleotides. The term "fragmented kit" is intended to encompass kits containing Analyte specific reagents (ASR's) regulated under section 520(e) of the Federal Food, Drug, and Cosmetic Act, but are not limited thereto. Indeed, any delivery system comprising two or more separate containers that each contain a subportion of the total kit components are included in the term "fragmented kit." In contrast, a "combined kit" refers to a delivery system containing all of the components of a reaction assay in a single container (e.g., in a single box housing each of the desired components). The term "kit" includes both fragmented and combined kits.

[0168] As used herein, the term "functional domain" refers to a region, or a part of a region, of a protein (e.g., an enzyme) that provides one or more functional characteristic of the protein. For example, a functional domain of an enzyme may provide, directly or indirectly, one or more activities of the enzyme including, but not limited to, substrate binding capability and catalytic activity. A functional domain may be characterized through mutation of one or more amino acids within the functional domain, wherein mutation of the amino acid(s) alters the associated functionality (as measured empirically in an assay) thereby indicating the presence of a functional domain.

[0169] As used herein, the term "heterologous functional domain" refers to a protein functional domain that is not in its natural environment. For example, a heterologous functional domain includes a functional domain from one enzyme introduced into another enzyme. A heterologous functional domain also includes a functional domain native to an protein that has been altered in some way (e.g., mutated, added in multiple copies, etc.). A heterologous functional domain may comprise a plurality of contiguous amino acids or may include two or more distal amino acids are amino acids fragments (e.g., two or more amino acids or fragments with intervening, non-heterologous, sequence). Heterologous functional domains are distinguished from endogenous functional domains in that the heterologous amino acid(s) are joined to amino acid sequences that are not found naturally associated with the amino acid sequence in nature or are associated with a portion of a protein not found in nature.

[0170] As used herein, the term "altered functionality in a nucleic acid cleavage assay" refers to a characteristic of an enzyme that has been altered in some manner to differ from its natural state (e.g., to differ from how it is found in nature). Alterations include, but are not limited to, addition of a heterologous functional domain (e.g., through mutation or through creation of chimerical proteins). In some embodiments, the altered characteristic of the enzyme may be one that improves the performance of an enzyme in a nucleic acid cleavage assay. Types of improvement include, but are not limited to, improved nuclease activity (e.g., improved rate of reaction), improved substrate binding (e.g., increased or decreased binding of certain nucleic acid species [e.g., RNA or DNA] that produces a desired outcome [e.g., greater specificity, improved substrate turnover, etc.]), and improved background specificity (e.g., less undesired product is produced). The present invention is not limited by the nucleic cleavage assay used to test improved functionality. However, in some preferred embodiments of the present invention, an invasive cleavage assay is used as the nucleic acid cleavage assay. In certain particularly preferred embodiments, an invasive cleavage assay utilizing an RNA target is used as the nucleic acid cleavage assay.

[0171] As used herein, the terms "N-terminal" and "C-terminal" in reference to polypeptide sequences refer to regions of polypeptides including portions of the N-terminal and C-terminal regions of the polypeptide, respectively. A sequence that includes a portion of the N-terminal region of polypeptide includes amino acids predominantly from the

N-terminal half of the polypeptide chain, but is not limited to such sequences. For example, an N-terminal sequence may include an interior portion of the polypeptide sequence including bases from both the N-terminal and C-terminal halves of the polypeptide. The same applies to C-terminal regions. N-terminal and C-terminal regions may, but need not, include the amino acid defining the ultimate N-terminal and C-terminal ends of the polypeptide, respectively.

DESCRIPTION OF THE DRAWINGS

[0172] FIG. **1** is a comparison of the nucleotide structure of the DNAP genes isolated from *Thermus aquaticus* (SEQ ID NO:1), *Thermus flavus* (SEQ ID NO:2) and *Thermus thermophilus* (SEQ ID NO:3); the consensus sequence (SEQ ID NO:7) is shown at the top of each row.

[0173] FIG. **2** is a comparison of the amino acid sequence of the DNAP isolated from *Thermus aquaticus* (SEQ ID NO:4), *Thermus flavus* (SEQ ID NO:5), and *Thermus thermophilus* (SEQ ID NO:6); the consensus sequence (SEQ ID NO:8) is shown at the top of each row.

[0174] FIGS. **3**A-G are a set of diagrams of wild-type and synthesis-deficient DNAPTaq genes.

[0175] FIG. **4**A depicts the wild-type *Thermus flavus* polymerase gene.

[0176] FIG. **4**B depicts a synthesis-deficient *Thermus flavus* polymerase gene.

[0177] FIG. **5** depicts a structure which cannot be amplified using DNAPTaq; this Figure shows SEQ ID NO:17 (primer) and SEQ ID NO:15 (hairpin).

[0178] FIG. **6** is a ethidium bromide-stained gel demonstrating attempts to amplify a bifurcated duplex using either DNAPTaq or DNAPStf (i.e., the Stoffel fragment of DNAPTaq).

[0179] FIG. **7** is an autoradiogram of a gel analyzing the cleavage of a bifurcated duplex by DNAPTaq and lack of cleavage by DNAPStf.

[0180] FIGS. **8**A-B are a set of autoradiograms of gels analyzing cleavage or lack of cleavage upon addition of different reaction components and change of incubation temperature during attempts to cleave a bifurcated duplex with DNAPTaq.

[0181] FIGS. **9**A-B are an autoradiogram displaying timed cleavage reactions, with and without primer.

[0182] FIGS. **10**A-B are a set of autoradiograms of gels demonstrating attempts to cleave a bifurcated duplex (with and without primer) with various DNAPs.

[0183] FIG. **11**A shows the substrate and oligonucleotides (19-12 [SEQ ID NO:18] and 30-12 [SEQ ID NO:19]) used to test the specific cleavage of substrate DNAs targeted by pilot oligonucleotides.

[0184] FIG. **11**B shows an autoradiogram of a gel showing the results of cleavage reactions using the substrates and oligonucleotides shown FIG. **12**A.

[0185] FIG. **12**A shows the substrate and oligonucleotide (30-0 [SEQ ID NO:20]) used to test the specific cleavage of a substrate RNA targeted by a pilot oligonucleotide.

[0186] FIG. **12**B shows an autoradiogram of a gel showing the results of a cleavage reaction using the substrate and oligonucleotide shown in FIG. **13**A.

[0187] FIG. **13** is a diagram of vector pTTQ18.

[0188] FIG. **14** is a diagram of vector pET-3c.

[0189] FIGS. **15**A-E depicts a set of molecules which are suitable substrates for cleavage by the 5' nuclease activity of DNAPs (SEQ ID NOS:15 and 17 are depicted in FIG. **15**E).

[0190] FIG. **16** is an autoradiogram of a gel showing the results of a cleavage reaction run with synthesis-deficient DNAPs.

[0191] FIG. **17** is an autoradiogram of a PEI chromatogram resolving the products of an assay for synthetic activity in synthesis-deficient DNAPTaq clones.

[0192] FIG. **18**A depicts the substrate molecule (SEQ ID NOS:15 and 17) used to test the ability of synthesis-deficient DNAPs to cleave short hairpin structures.

[0193] FIG. **18**B shows an autoradiogram of a gel resolving the products of a cleavage reaction run using the substrate shown in FIG. **19**A.

[0194] FIG. **19** provides the complete 206-mer duplex sequence (SEQ ID NO:27) employed as a substrate for the 5' nucleases of the present invention

[0195] FIGS. **20**A and B show the cleavage of linear nucleic acid substrates (based on the 206-mer of FIG. **21**) by wild type DNAPs and 5' nucleases isolated from *Thermus aquaticus* and *Thermus flavus*.

[0196] FIG. **21**A shows the "nibbling" phenomenon detected with the DNAPs of the present invention.

[0197] FIG. **21**B shows that the "nibbling" of FIG. **25**A is 5' nucleolytic cleavage and not phosphatase cleavage.

[0198] FIG. **22** demonstrates that the "nibbling" phenomenon is duplex dependent.

[0199] FIG. **23** is a schematic showing how "nibbling" can be employed in a detection assay.

[0200] FIGS. **24**A and B demonstrates that "nibbling" can be target directed.

[0201] FIG. **25** provides a schematic drawing of a target nucleic acid with an INVADER oligonucleotide and a probe oligonucleotide annealed to the target.

[0202] FIG. **26** provides a schematic showing the S-60 hairpin oligonucleotide (SEQ ID NO:29) with the annealed P-15 oligonucleotide (SEQ ID NO:30).

[0203] FIG. **27** is an autoradiogram of a gel showing the results of a cleavage reaction run using the S-60 hairpin in the presence or absence of the P-15 oligonucleotide.

[0204] FIG. **28** provides a schematic showing three different arrangements of target-specific oligonucleotides and their hybridization to a target nucleic acid which also has a probe oligonucleotide annealed thereto (SEQ ID NOS:31-35).

[0205] FIG. **29** is the image generated by a fluorescence imager showing that the presence of an INVADER oligonucleotide causes a shift in the site of cleavage in a probe/target duplex.

[0206] FIG. **30** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run using the three target-specific oligonucleotides diagrammed in FIG. **28**.

[0207] FIG. **31** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run in the presence or absence of non-target nucleic acid molecules.

[0208] FIG. **32** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run in the presence of decreasing amounts of target nucleic acid.

[0209] FIG. **33** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run in the presence or absence of saliva extract using various thermostable 5' nucleases or DNA polymerases.

[0210] FIG. **34** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run using various 5' nucleases.

[0211] FIG. **35** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run using two target nucleic acids which differ by a single basepair at two different reaction temperatures.

[0212] FIG. **36**A provides a schematic showing the effect of elevated temperature upon the annealing and cleavage of a probe oligonucleotide along a target nucleic acid wherein the probe contains a region of noncomplementarity with the target.

[0213] FIG. **36**B provides a schematic showing the effect of adding an upstream oligonucleotide upon the annealing and cleavage of a probe oligonucleotide along a target nucleic acid wherein the probe contains a region of non-complementarity with the target.

[0214] FIG. **37** provides a schematic showing an arrangement of a target-specific INVADER oligonucleotide (SEQ ID NO:39) and a target-specific probe oligonucleotide (SEQ ID NO:38) bearing a 5' Cy3 label along a target nucleic acid (SEQ ID NO:31).

[0215] FIG. **38** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run in the presence of increasing concentrations of KCl.

[0216] FIG. **39** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run in the presence of increasing concentrations of $MnCl_2$ or $MgCl_2$.

[0217] FIG. **40** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run in the presence of increasing amounts of genomic DNA or tRNA.

[0218] FIG. **41** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run use a HCV RNA target.

[0219] FIG. **42** is the image generated by a fluorescence imager showing the products of INVADER oligonucleotide-directed cleavage assays run using a HCV RNA target and demonstrate the stability of RNA targets under INVADER oligonucleotide-directed cleavage assay conditions.

[0220] FIG. **43** is the image generated by a fluorescence imager showing the sensitivity of detection and the stability of RNA in INVADER oligonucleotide-directed cleavage assays run using a HCV RNA target.

[0221] FIG. **44** is the image generated by a fluorescence imager showing thermal degradation of oligonucleotides containing or lacking a 3' phosphate group.

[0222] FIG. **45** depicts the structure of amino-modified oligonucleotides 70 and 74.

[0223] FIG. **46** depicts the structure of amino-modified oligonucleotide 75

[0224] FIG. **47** depicts the structure of amino-modified oligonucleotide 76.

[0225] FIG. **48** is the image generated by a fluorescence imager scan of an IEF gel showing the migration of substrates 70, 70dp, 74, 74dp, 75, 75dp, 76 and 76dp.

[0226] FIG. **49**A provides a schematic showing an arrangement of a target-specific INVADER oligonucleotide (SEQ ID NO:50) and a target-specific probe oligonucleotide (SEQ ID NO:51) bearing a 5' Cy3 label along a target nucleic acid (SEQ ID NO:52).

[0227] FIG. **49**B is the image generated by a fluorescence imager showing the detection of specific cleavage products generated in an invasive cleavage assay using charge reversal (i.e., charge based separation of cleavage products).

[0228] FIG. **50** is the image generated by a fluorescence imager which depicts the sensitivity of detection of specific cleavage products generated in an invasive cleavage assay using charge reversal.

[0229] FIG. **51** depicts a first embodiment of a device for the charge-based separation of oligonucleotides.

[0230] FIG. **52** depicts a second embodiment of a device for the charge-based separation of oligonucleotides.

[0231] FIG. **53** shows an autoradiogram of a gel showing the results of cleavage reactions run in the presence or absence of a primer oligonucleotide; a sequencing ladder is shown as a size marker.

[0232] FIGS. **54**A-D depict four pairs of oligonucleotides; in each pair shown, the upper arrangement of a probe annealed to a target nucleic acid lacks an upstream oligonucleotide and the lower arrangement contains an upstream oligonucleotide (SEQ ID NOS:32 and 54-58 are shown in FIGS. **54**A-D).

[0233] FIG. **55** shows the chemical structure of several positively charged heterodimeric DNA-binding dyes.

[0234] FIG. **56** is a schematic showing alternative methods for the tailing and detection of specific cleavage products in the context of the INVADER oligonucleotide-directed cleavage assay.

[0235] FIG. **57** provides a schematic drawing of a target nucleic acid with an INVADER oligonucleotide, a mini-probe, and a stacker oligonucleotide annealed to the target.

[0236] FIG. **58** provides a space-filling model of the 3-dimensional structure of the T5 5'-exonuclease.

[0237] FIG. **59** provides an alignment of the amino acid sequences of several FEN-1 nucleases including the *Methanococcus jannaschi* FEN-1 protein (MJAFEN1.PRO), the *Pyrococcus furiosus* FEN-1 protein (PFUFEN1.PRO), the human FEN-1 protein (HUMFEN1.PRO), the mouse FEN-1 protein (MUSFEN1.PRO), the *Saccharomyces cerevisiae* YKL510 protein (YST510.PRO), the *Saccharomyces cerevisiae* RAD2 protein (YSTRAD2.PRO), the *Schizosaccharomyces pombe* RAD 13 protein (SPORAD13.PRO), the human XPG protein (HUMXPG.PRO), the mouse XPG protein (MUSXPG.PRO), the *Xenopus laevis* XPG protein (XENXPG.PRO) and the *C. elegans* RAD2 protein (CELRAD2.PRO) (SEQ ID NOS:135-145, respectively); portions of the amino acid sequence of some of these proteins were not shown in order to maximize the alignment between proteins (specifically, amino acids 122 to 765 of the YSTRAD2 sequence were deleted; amino acids 122 to 746 of the SPORAD13 sequence were deleted; amino acids 122 to 757 of the HUMXPG sequence were deleted; amino acids 122 to 770 of the MUSXPG sequence were deleted; and amino acids 122 to 790 of the XENXPG sequence were deleted). The numbers to the left of each line of sequence refers to the amino acid residue number; dashes represent gaps introduced to maximize alignment.

[0238] FIG. **60** is a schematic showing the S-33 (SEQ ID NO:84) and 11-8-0 (SEQ ID NO:85) oligonucleotides in a folded configuration; the cleavage site is indicated by the arrowhead.

[0239] FIG. **61** shows a Coomassie stained SDS-PAGE gel showing the thrombin digestion of CLEAVASE BN/thrombin.

[0240] FIG. **62** is the image generated by a fluorescence imager showing the products produced by the cleavage of the S-60 hairpin using CLEAVASE BN/thrombin (before and after thrombin digestion).

[0241] FIG. **63** is the image generated by a fluorescence imager showing the products produced by the cleavage of circular M13 DNA using CLEAVASE BN/thrombin.

[0242] FIG. **64** is an SDS-PAGE gel showing the migration of purified CLEAVASE BN nuclease, Pfu FEN-1, Pwo FEN-1 and Mja FEN-1.

[0243] FIG. **65** is the image generated by a fluorescence imager showing the products produced by the cleavage of the S-33 and 11-8-0 oligonucleotides by CLEAVASE BN and the Mja FEN-1 nucleases.

[0244] FIG. **66** is the image generated by a fluorescence imager showing the products produced by the incubation of an oligonucleotide either having or lacking a 3'-OH group with TdT.

[0245] FIG. **67** is the image generated by a fluorescence imager showing the products produced the incubation of cleavage products with TdT.

[0246] FIG. **68** is a photograph of a Universal GeneComb™ card showing the capture and detection of cleavage products on a nitrocellulose support.

[0247] FIG. **69** is the image generated by a fluorescence imager showing the products produced using the CLEAVASE A/G and Pfu FEN-1 nucleases and a fluorescein-labeled probe.

[0248] FIG. **70** is the image generated by a fluorescence imager showing the products produced using the CLEAVASE A/G and Pfu FEN-1 nucleases and a Cy3-labeled probe.

[0249] FIG. **71** is the image generated by a fluorescence imager showing the products produced using the CLEAVASE A/G and Pfu FEN-1 nucleases and a TET-labeled probe.

[0250] FIGS. **72**A and **72**B are images generated by a fluorescence imager showing the products produced using the CLEAVASE A/G and Pfu FEN-1 nucleases and probes having or lacking a 5' positive charge; the gel shown in FIG. **83**A was run in the standard direction and the gel shown in FIG. **84**B was run in the reverse direction.

[0251] FIG. **73** shows the structure of 3-nitropyrrole and 5-nitroindole.

[0252] FIG. **74** shows the sequence of oligonucleotides 109, 61 and 67 (SEQ ID NOS:97, 50 and 51) annealed into a cleavage structure as well as the sequence of oligonucleotide 67 (SEQ ID NO:51) and a composite of SEQ ID NOS:98, 99, 101 and 102.

[0253] FIG. **75**A-C show images generated by a fluorescence imager showing the products produced in an INVADER oligonucleotide-directed cleavage assay performed at various temperatures using a miniprobe which is either completely complementary to the target or contains a single mismatch with the target.

[0254] FIG. **76** shows the sequence of oligonucleotides 166 (SEQ ID NO:103), 165 (SEQ ID NO:104), 161 (SEQ ID NO:106), 162 (SEQ ID NO:105) and 164 (SEQ ID NO:107) as well as a cleavage structure.

[0255] FIG. **77** shows the image generated by a fluorescence imager showing the products produced in an INVADER oligonucleotide-directed cleavage assay performed using ras gene sequences as the target.

[0256] FIGS. **78**A-C show the sequence of the S-60 hairpin (SEQ ID NO:29) (A), and the P-15 oligonucleotide (SEQ ID NO:30) (shown annealed to the S-60 hairpin in B) and the image generated by a fluorescence imager showing the products produced by cleavage of the S-60 hairpin in the presence of various INVADER oligonucleotides.

[0257] FIG. **79** shows the structure of various 3' end substituents.

[0258] FIG. **80** is a composite graph showing the effect of probe concentration, temperature and a stacker oligonucleotide on the cleavage of miniprobes.

[0259] FIG. **81** shows the sequence of the IT-2 oligonucleotide (SEQ ID NO:115; shown in a folded configuration) as well as the sequence of the IT-1 (SEQ ID NO:116) and IT-A (SEQ ID NO:117) oligonucleotides.

[0260] FIG. **82** shows the image generated by a fluorescence imager showing the products produced by cleavage of the oligonucleotides shown in FIG. **92** by CLEAVASE A/G nuclease.

[0261] FIG. **83** shows the image generated by a fluorescence imager which provides a comparison of the rates of cleavage by the Pfu FEN-1 and Mja FEN-1 nucleases.

[0262] FIG. **84** shows the image generated by a fluorescence imager which depicts the detection of RNA targets using a miniprobe and stacker oligonucleotides.

[0263] FIGS. **85**A-C provide schematics showing particular embodiments of the present invention wherein a T7 promoter region and copy template annealed with either no oligonucleotide (A), a complete promoter oligonucleotide (B) or a complete promoter oligonucleotide with a 3' tail (C); one strand of the T7 promoter region is indicated by the hatched line.

[0264] FIGS. **86**A-D provide schematics showing particular embodiments of the present invention wherein a T7 promoter region and copy template annealed with either a cut probe (A), a partial promoter oligonucleotide (B), an uncut oligonucleotide (C) or both an uncut probe and a partial promoter oligonucleotide (D).

[0265] FIG. **87** provides a schematic illustrating one embodiment of the present invention wherein a template-dependent DNA polymerase is used to extend a cut probe to complete a T7 promoter region and thereby allow transcription.

[0266] FIG. **88** provides a schematic illustrating that an uncut probe combined with a partial promoter oligonucleotide does not permit transcription while a cut probe combined with a partial promoter oligonucleotide generates a complete (but nicked) promoter which supports transcription.

[0267] FIG. **89** shows the image generated by a fluorescence imager which shows that primer extension can be used to complete a partial promoter formed by a cut probe (lanes 1-5) and that annealing a cut probe generated in an invasive cleavage assay can complete a partial T7 promoter to permit transcription (lanes 6-9).

[0268] FIGS. **90**A-C provide schematics showing particular embodiments of the present invention which illustrate that the use of a partial promoter oligonucleotide with a paired 5' tail can be used to block transcription from a composite promoter formed by the annealing of an uncut probe.

[0269] FIG. **91** shows the image generated by a fluorescence imager which shows that transcription from a "leaky" branched T7 composite promoter can be shut down by the use of a downstream partial promoter oligonucleotide having a paired 5' tail.

[0270] FIG. **92** shows the image generated by a fluorescence imager which shows that the location of the nick site in a nicked composite T7 promoter can effect the efficiency of transcription.

[0271] FIG. **93** shows the image generated by a fluorescence imager which shows that the presence of an unpaired 3' tail on a full-length promoter oligonucleotide decreases but does not abolish transcription. Beneath the image are schematics showing the nucleic acids tested in reactions 1-4; these schematics show SEQ ID NOS:123-125.

[0272] FIG. **94** is a schematic which illustrates one embodiment of the present invention where a composite T7 promoter region is created by the binding of the cut probe oligonucleotide downstream of the partial promoter oligo.

[0273] FIGS. **95**A-D provide schematics showing particular embodiments of the present invention which show various ways in which a composite promoter can be formed wherein the nick is located in the template (or bottom) strand.

[0274] FIG. **96** is a schematic which illustrates one embodiment of the present invention where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0275] FIG. **97** is a schematic which illustrates one embodiment of the present invention where the cut probe from an initial invasive cleavage reaction is employed as an integrated INVADER-target complex in a second invasive cleavage reaction.

[0276] FIG. **98** shows the nucleotide sequence of the PR1 probe (SEQ ID NO:119), the IT3 INVADER-Target oligonucleotide (SEQ ID NO:118), the IT3-8, IT3-6, IT3-4, IT3-3 and IT3-0 oligonucleotides (SEQ ID NOS:147-151, respectively).

[0277] FIG. **99** depicts structures that may be employed to determine the ability of an enzyme to cleave a probe in the presence and the absence of an upstream oligonucleotide. FIG. **99** displays the sequence of oligonucleotide 89-15-1 (SEQ ID NO:152), oligonucleotide 81-69-5 (SEQ ID NO:156), oligonucleotide 81-69-4 (SEQ ID NO:155), oligonucleotide 81-69-3 (SEQ ID NO:154), oligonucleotide 81-69-2 (SEQ ID NO:153) and a portion of M13mp18 (SEQ ID NO:163).

[0278] FIG. **100** shows the image generated by a fluorescence imager which shows the dependence of Pfu FEN-1 on the presence of an overlapping upstream oligonucleotide for specific cleavage of the probe.

[0279] FIG. **101***a* shows the image generated by a fluorescence imager which compares the amount of product generated in a standard (i.e., a non-sequential invasive cleavage reaction) and a sequential invasive cleavage reaction.

[0280] FIG. **101***b* is a graph comparing the amount of product generated in a standard or basic (i.e., a non-sequential invasive cleavage reaction) and a sequential invasive cleavage reaction ("invader sqrd") (y axis=fluorescence units; x axis=attomoles of target).

[0281] FIG. **102** shows the image generated by a fluorescence imager which shows that the products of a completed sequential invasive cleavage reaction cannot cross contaminant a subsequent similar reaction.

[0282] FIG. **103** shows the sequence of the oligonucleotide employed in an invasive cleavage reaction for the detection of HCMV viral DNA; FIG. **103** shows the sequence of oligonucleotide 89-76 (SEQ ID NO:161), oligonucleotide 89-44 (SEQ ID NO:160) and nucleotides 3057-3110 of the HCMV genome (SEQ ID NO:162).

[0283] FIG. **104** shows the image generated by a fluorescence imager which shows the sensitive detection of HCMV viral DNA in samples containing human genomic DNA using an invasive cleavage reaction.

[0284] FIG. **105** is a schematic which illustrates one embodiment of the present invention, where the cut probe

from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction, and where an ARRESTOR oligonucleotide prevents participation of remaining uncut first probe in the cleavage of the second probe.

[0285] FIG. **106** is a schematic which illustrates one embodiment of the present invention, where the cut probe from an initial invasive cleavage reaction is employed as an integrated INVADER-target complex in a second invasive cleavage reaction, and where an ARRESTOR oligonucleotide prevents participation of remaining uncut first probe in the cleavage of the second probe.

[0286] FIG. **107** shows three images generated by a fluorescence imager showing that two different lengths of 2' O-methyl, 3' terminal amine-modified ARRESTOR oligonucleotide both reduce non-specific background cleavage of the secondary probe when included in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as an integrated INVADER-target complex in a second invasive cleavage reaction.

[0287] FIG. **108**A shows two images generated by a fluorescence imager showing the effects on nonspecific and specific cleavage signal of increasing concentrations of primary probe in the first step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0288] FIG. **108**B shows two images generated by a fluorescence imager showing the effects on nonspecific and specific cleavage signal of increasing concentrations of primary probe in the first step of a reaction, and inclusion of a 2' O-methyl, 3' terminal amine-modified ARRESTOR oligonucleotide in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0289] FIG. **108**C shows a graph generated using the spreadsheet Microsoft Excel software, comparing the effects on nonspecific and specific cleavage signal of increasing concentrations of primary probe in the first step of a reaction, in the presence or absence of a 2' O-methyl, 3' terminal amine-modified ARRESTOR oligonucleotide in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0290] FIG. **109**A shows two images generated by a fluorescence imager showing the effects on nonspecific and specific cleavage signal of including an unmodified ARRESTOR oligonucleotide in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0291] FIG. **109**B shows two images generated by a fluorescence imager showing the effects on nonspecific and specific cleavage signal of including a 3' terminal amine modified ARRESTOR, a partially 2' O-methyl substituted, 3' terminal amine modified ARRESTOR oligonucleotide, or an entirely 2' O-methyl, 3' terminal amine modified ARRESTOR oligonucleotide in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0292] FIG. **110**A shows two images generated by a fluorescence imager comparing the effects on nonspecific and specific cleavage signal of including an ARRESTOR oligonucleotides of different lengths in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction.

[0293] FIG. **110**B shows two images generated by a fluorescence imager comparing the effects on nonspecific and specific cleavage signal of including an ARRESTOR oligonucleotides of different lengths in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction, and in which a longer variant of the secondary probe used in the reactions in FIG. **110**A is tested.

[0294] FIG. **110**C shows a schematic diagram of a primary probe aligned with several ARRESTOR oligonucleotides of different lengths. The region of the primary probe that is complementary to the HBV target sequence is underlined. The ARRESTOR oligonucleotides are aligned with the probe by complementarity.

[0295] FIG. **111** shows two images generated by a fluorescence imager comparing the effects on nonspecific and specific cleavage signal of including ARRESTOR oligonucleotides of different lengths in the second step of a reaction where the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction, using secondary probes of two different lengths.

[0296] FIG. **112** A provides a schematic diagram that illustrates one embodiment of the present invention wherein the cut probe from an initial invasive cleavage reaction is employed as the INVADER oligonucleotide in a second invasive cleavage reaction using a FRET cassette. The region indicated as "N" is the overlap required for cleavage in this embodiment. **112**B diagrams how a mismatch between the probe and the target strand at position "N" disrupts the overlap, thereby suppressing cleavage of the probe.

[0297] FIG. **113**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:195), probe oligonucleotide (SEQ ID NO:197) and FRET cassette (SEQ ID NO:201) for the detection of the Apo E 112 arg allele.

[0298] FIG. **113**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:195), probe oligonucleotide (SEQ ID NO:198) and FRET cassette for the detection (SEQ ID NO:201) of the Apo E 112 cys allele.

[0299] FIG. **113**C shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:196), probe oligonucleotide (SEQ ID NO:199) and FRET cassette (SEQ ID NO:201) for the detection of the Apo E 158 arg allele.

[0300] FIG. **113**D shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:196), probe oligonucleotide (SEQ ID NO:200) and FRET cassette (SEQ ID NO:201) for the detection of the Apo E 158 cys allele.

[0301] FIG. **114**A provides a bar graph showing the detection of the arg and cys alleles at the Apo E 112 locus in 2 synthetic controls and 5 samples of human genomic DNA.

[0302] FIG. **114**B provides a bar graph showing the detection of the arg and cys alleles at the Apo E 158 locus in 2 synthetic controls and 5 samples of human genomic DNA.

[0303] FIG. **115**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:202), probe oligonucleotide (SEQ ID NO:208) and FRET cassette (SEQ ID NO: 210) for the detection of the wild-type C282 allele of the human HFE gene.

[0304] FIG. **115**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:202), probe oligonucleotide (SEQ ID NO:209) and FRET cassette (SEQ ID NO:210) for the detection of the C282Y mutant allele of the human HFE gene.

[0305] FIG. **115**C shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:203), probe oligonucleotide (SEQ ID NO:211) and FRET cassette (SEQ ID NO:206) for the detection of the wild-type H63 allele of the human HFE gene.

[0306] FIG. **115**D shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:203), probe oligonucleotide (SEQ ID NO:212) and FRET cassette (SEQ ID NO:213) for the detection of the H63D mutant allele of the human HFE gene.

[0307] FIG. **116** provides a bar graph showing the analysis of the C282Y (first set of eight tests, left to right) and H63D (second set of eight tests, left to right) mutations in the human HFE gene, each testedin 2 synthetic controls and 5 samples of human genomic DNA.

[0308] FIG. **117**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:216), probe oligonucleotide (SEQ ID NO:217) and FRET cassette (SEQ ID NO:225) for the detection of the wild-type allele at position 677 of the human MTHFR gene.

[0309] FIG. **117**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:216), probe oligonucleotide (SEQ ID NO:218) and FRET cassette (SEQ ID NO:225) for the detection of the mutant allele at position 677 of the human MTHFR gene.

[0310] FIG. **118** provides a bar graph showing the analysis of the C677T mutation in the human MTHFR gene in 3 synthetic control samples and 3 samples of human genomic DNA.

[0311] FIG. **119**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:222), probe oligonucleotide (SEQ ID NO:223) and FRET cassette (SEQ ID NO: 225) for the detection of the wild-type allele at position 20210 of the human prothrombin gene.

[0312] FIG. **119**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:222), probe oligonucleotide (SEQ ID NO:224) and FRET cassette (SEQ ID NO:225) for the detection of the mutant allele at position 20210 of the human prothrombin gene.

[0313] FIG. **120** provides a bar graph showing the analysis of the A20210G mutation in the human prothrombin gene in 2 synthetic control samples and 3 samples of human genomic DNA.

[0314] FIG. **121**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:228), probe oligonucleotide (SEQ ID NO:229) and FRET cassette (SEQ ID NO:230) for the detection of the R-2 mutant allele of the human factor V gene.

[0315] FIG. **121**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:231), probe oligonucleotide (SEQ ID NO:232) and FRET cassette (SEQ ID NO: 230) for the detection of the human α-actin gene.

[0316] FIG. **122** provides a bar graph showing the detection of the R-2 mutant (HR-2) of the human factor V gene, compared to the detection of the internal control (IC), the α-actin gene, 3 synthetic control samples and 2 samples of human genomic DNA.

[0317] FIG. **123**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:235), probe oligonucleotide (SEQ ID NO:236) and FRET cassette (SEQ ID NO:225) for the detection of the wild-type allele at position −308 in the promoter of the human TNF-α gene.

[0318] FIG. **123**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:235), probe oligonucleotide (SEQ ID NO:237) and FRET cassette (SEQ ID NO:225) for the detection of the mutant allele at position −308 in the promoter of the human TNF-α gene.

[0319] FIG. **124** provides a bar graph showing the analysis of the −308 mutation in the promoter of the human TNF-α gene in 3 synthetic control samples and 3 samples of human genomic DNA.

[0320] FIG. **125**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:240), probe oligonucleotide (SEQ ID NO:241) and FRET cassette (SEQ ID NO: 225) for the detection of the wild-type allele at codon position 506 of the human factor V gene.

[0321] FIG. **125**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:240), probe oligonucleotide (SEQ ID NO:242) and FRET cassette (SEQ ID NO:225) for the detection of the A506G mutant allele of the human factor V gene.

[0322] FIG. **126** provides a bar graph showing the analysis of the A506G mutation in the human factor V gene in 3 synthetic control samples and 6 samples of human genomic DNA.

[0323] FIG. **127**A shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:243), probe oligonucleotide (SEQ ID NO:244) and FRET cassette (SEQ ID NO:245) for the detection of the mecA gene associated with methicillin resistance in *S. aureus.*

[0324] FIG. **127**B shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:246), probe oligonucleotide (SEQ ID NO:247) and FRET cassette (SEQ ID NO:245) for the detection of the nuc gene, a species-specific gene that distinguishes *S. aureus* from *S. haemolyticus.*

[0325] FIG. **128** provides a bar graph showing the detection of the mecA gene, compared to the detection of the *S. aureus*-specific nuc gene in DNA from methicillin-sensitive *S. aureus* (MSSA), methicillin-resistant *S. aureus* (MRSA), *S. haemolyticus*, and amplified control targets for the mecA and nuc target sequences.

[0326] FIG. **129**A shows the image generated by a fluorescence imager comparing the products produced by cleav-

age of a mixture of the oligonucleotides shown in FIG. **60** by either Pfu FEN-1 (1) or Mja FEN-1 (2).

[**0327**] FIG. **129**B shows the image generated by a fluorescence imager comparing the products produced by cleavage of the oligonucleotides shown in FIG. **26** by either Pfu FEN-1 (1) or Mja FEN-1 (2).

[**0328**] FIG. **130** shows a schematic diagram of the portions of the Pfu FEN-1 and Mja FEN-1 proteins combined to create chimeric nucleases.

[**0329**] FIG. **131**A shows the image generated by a fluorescence imager comparing the products produced by cleavage of a mixture of the oligonucleotides shown in FIG. **60** by Pfu FEN-1 (1), Mja FEN-1 (2) or the chimeric nucleases diagrammed in FIG. **130**.

[**0330**] FIG. **131**B shows the image generated by a fluorescence imager comparing the products produced by cleavage of the oligonucleotides shown in FIG. **26** by Pfu FEN-1 (1), Mja FEN-1 (2) or the chimeric nucleases diagrammed in FIG. **130**.

[**0331**] FIG. **132** shows the image generated by a fluorescence imager comparing the products produced by cleavage of folded cleavage structures by Pfu FEN-1 (1), Mja FEN-1 (2) or the chimeric nucleases diagrammed in FIG. **130**.

[**0332**] FIG. **133**A-J shows the results of various assays used to determine the activity of Cleavase BN under various conditions.

[**0333**] FIGS. **134**A-B, D-F, and H-J show the results of various assays used to determine the activity of TaqDN under various conditions.

[**0334**] FIG. **135**A-B, D-F, H-J show the results of various assays used to determine the activity of TthDN under various conditions.

[**0335**] FIGS. **136**A-B, D-F, and H-J show the results of various assays used to determine the activity of Pfu FEN-1 under various conditions.

[**0336**] FIG. **137**A-J show the results of various assays used to determine the activity of Mja FEN-1 under various conditions.

[**0337**] FIGS. **138**A-B, D-F, and H-J show the results of various assays used to determine the activity of Afu FEN-1 under various conditions.

[**0338**] FIGS. **139**A-E, and G-I show the results of various assays used to determine the activity of Mth FEN-1 under various conditions.

[**0339**] FIG. **140** shows the two substrates. Panel A shows the structure and sequence of the hairpin substrate (25-65-1) (SEQ ID NO:293), while Panel B shows the structure and sequence of the INVADER (IT) substrate (25-184-5) (SEQ ID NO:294).

[**0340**] FIG. **141**A shows the structure and sequence of oligonucleotides forming an invasive cleavage structure (203-91-01, SEQ ID NO:403, and target-INVADER oligonucleotide 203-91-04, SEQ ID NO:404).

[**0341**] FIG. **141**B shows the structure and sequence of oligonucleotides forming an X-structure substrate (203-81-02, SEQ ID NO:405 and 594-09-01, SEQ ID NO:406).

[**0342**] FIG. **142** shows the activities of the indicated FEN proteins on the invasive cleavage structure diagrammed in FIG. **141**A.

[**0343**] FIG. **143** shows the activities of the indicated FEN proteins on the X-structure diagrammed in FIG. **141**B.

[**0344**] FIG. **144** shows a schematic diagram of an INVADER oligonucleotide (SEQ ID NO:407), probe oligonucleotide (SEQ ID NO:408) and FRET cassette (SEQ ID NO:409) for the detection of the polymerase gene of human cytomegalovirus.

[**0345**] FIG. **145** provides a bar graph showing the detection of different numbers of copies of human cytomegalovirus genomic DNA.

[**0346**] FIG. **146**A-J shows nucleic acid and amino acid sequences for certain FEN-1 endonucleases of the present invention.

DESCRIPTION OF THE INVENTION

[**0347**] Introduction

[**0348**] The present invention relates to methods and compositions for treating nucleic acid, and in particular, methods and compositions for detection and characterization of nucleic acid sequences and sequence changes.

[**0349**] In preferred embodiments, the present invention relates to means for cleaving a nucleic acid cleavage structure in a site-specific manner. While the present invention provides a variety of cleavage agents, in some embodiments, the present invention relates to a cleaving enzyme having 5' nuclease activity without interfering nucleic acid synthetic ability. In other embodiments, the present invention provides novel polymerases (e.g., thermostable polymerases) possessing altered polymerase and/or nucleases activities.

[**0350**] For example, in some embodiments, the present invention provides 5' nucleases derived from thermostable DNA polymerases that exhibit altered DNA synthetic activity from that of native thermostable DNA polymerases. The 5' nuclease activity of the polymerase is retained while the synthetic activity is reduced or absent. Such 5' nucleases are capable of catalyzing the structure-specific cleavage of nucleic acids in the absence of interfering synthetic activity. The lack of synthetic activity during a cleavage reaction results in nucleic acid cleavage products of uniform size.

[**0351**] The novel properties of the nucleases of the invention form the basis of a method of detecting specific nucleic acid sequences. This method relies upon the amplification of the detection molecule rather than upon the amplification of the target sequence itself as do existing methods of detecting specific target sequences.

[**0352**] DNA polymerases (DNAPs), such as those isolated from *E. coli* or from thermophilic bacteria of the genus *Thermus* as well as other organisms, are enzymes that synthesize new DNA strands. Several of the known DNAPs contain associated nuclease activities in addition to the synthetic activity of the enzyme.

[**0353**] Some DNAPs are known to remove nucleotides from the 5' and 3' ends of DNA chains (Kornberg, DNA Replication, W.H. Freeman and Co., San Francisco, pp. 127-139 [1980]). These nuclease activities are usually referred to as 5' exonuclease and 3' exonuclease activities,

respectively. For example, the 5' exonuclease activity located in the N-terminal domain of several DNAPs participates in the removal of RNA primers during lagging strand synthesis during DNA replication and the removal of damaged nucleotides during repair. Some DNAPs, such as the *E. coli* DNA polymerase (DNAPEc1), also have a 3' exonuclease activity responsible for proof-reading during DNA synthesis (Kornberg, supra).

[0354] A DNAP isolated from *Thermus aquaticus*, termed Taq DNA polymerase (DNAPTaq), has a 5' exonuclease activity, but lacks a functional 3' exonucleolytic domain (Tindall and Kunkell, Biochem., 27:6008 [1988]). Derivatives of DNAPEc1 and DNAPTaq, respectively called the Klenow and Stoffel fragments, lack 5' exonuclease domains as a result of enzymatic or genetic manipulations (Brutlag et al., Biochem. Biophys. Res. Commun., 37:982 [1969]; Erlich et al., Science 252:1643 [1991]; Setlow and Kornberg, J. Biol. Chem., 247:232 [1972]).

[0355] The 5' exonuclease activity of DNAPTaq was reported to require concurrent synthesis (Gelfand, PCR Technology—Principles and Applications for DNA Amplification, H. A. Erlich, [Ed.], Stockton Press, New York, p. 19 [1989]). Although mononucleotides predominate among the digestion products of the 5' exonucleases of DNAPTaq and DNAPEc1, short oligonucleotides (≦12 nucleotides) can also be observed implying that these so-called 5' exonucleases can function endonucleolytically (Setlow, supra; Holland et al., Proc. Natl. Acad. Sci. USA 88:7276 [1991]).

[0356] In WO 92/06200, Gelfand et al. show that the preferred substrate of the 5' exonuclease activity of the thermostable DNA polymerases is displaced single-stranded DNA. Hydrolysis of the phosphodiester bond occurs between the displaced single-stranded DNA and the double-helical DNA with the preferred exonuclease cleavage site being a phosphodiester bond in the double helical region. Thus, the 5' exonuclease activity usually associated with DNAPs is a structure-dependent single-stranded endonuclease and is more properly referred to as a 5' nuclease. Exonucleases are enzymes that cleave nucleotide molecules from the ends of the nucleic acid molecule. Endonucleases, on the other hand, are enzymes that cleave the nucleic acid molecule at internal rather than terminal sites. The nuclease activity associated with some thermostable DNA polymerases cleaves endonucleolytically but this cleavage requires contact with the 5' end of the molecule being cleaved. Therefore, these nucleases are referred to as 5' nucleases.

[0357] When a 5' nuclease activity is associated with a eubacterial Type A DNA polymerase, it is found in the one third N-terminal region of the protein as an independent functional domain. The C-terminal two-thirds of the molecule constitute the polymerization domain that is responsible for the synthesis of DNA. Some Type A DNA polymerases also have a 3' exonuclease activity associated with the two-third C-terminal region of the molecule.

[0358] The 5' exonuclease activity and the polymerization activity of DNAPs can be separated by proteolytic cleavage or genetic manipulation of the polymerase molecule. The Klenow or large proteolytic cleavage fragment of DNAPEc1 contains the polymerase and 3' exonuclease activity but lacks the 5' nuclease activity. The Stoffel fragment of DNAPTaq (DNAPStf) lacks the 5' nuclease activity due to a genetic manipulation that deleted the N-terminal 289 amino acids of the polymerase molecule (Erlich et al., Science 252:1643 [1991]). WO 92/06200 describes a thermostable DNAP with an altered level of 5' to 3' exonuclease. U.S. Pat. No. 5,108,892 describes a *Thermus aquaticus* DNAP without a 5' to 3' exonuclease. Thermostable DNA polymerases with lessened amounts of synthetic activity are available (Third Wave Technologies, Madison, Wis.) and are described in U.S. Pat. Nos. 5,541,311, 5,614,402, 5,795,763, 5,691,142, and 5,837,450, herein incorporated by reference in their entireties. The present invention provides 5' nucleases derived from thermostable Type A DNA polymerases that retain 5' nuclease activity but have reduced or absent synthetic activity. The ability to uncouple the synthetic activity of the enzyme from the 5' nuclease activity proves that the 5' nuclease activity does not require concurrent DNA synthesis as was previously reported (Gelfand, PCR Technology, supra).

[0359] In addition to the 5'-exonuclease domains of the DNA polymerase I proteins of Eubacteria, described above, 5' nucleases have been found associated with bacteriophage, eukaryotes and archaebacteria. Overall, all of the enzymes in this family display very similar substrate specificities, despite their limited level of sequence similarity. Consequently, enzymes suitable for use in the methods of the present invention may be isolated or derived from a wide array of sources.

[0360] A mammalian enzyme with functional similarity to the 5'-exonuclease domain of *E. coli* Pol I was isolated nearly 30 years ago (Lindahl, et al., Proc Natl Acad Sci USA 62(2): 597-603 [1969]). Later, additional members of this group of enzymes called flap endonucleases (FEN1) from Eukarya and Archaea were shown to possess a nearly identical structure specific activity (Harrington and Lieber. Embo J 13(5), 1235-46 [1994]; Murante et al., J Biol Chem 269(2), 1191-6 [1994]; Robins, et al., J Biol Chem 269(46), 28535-8 [1994]; Hosfield, et al., J Biol Chem 273(42), 27154-61 [1998]), despite limited sequence similarity. The substrate specificities of the FEN1 enzymes, and the eubacterial and related bacteriophage enzymes have been examined and found to be similar for all enzymes (Lyamichev, et al., Science 260(5109), 778-83 [1993], Harrington and Lieber, supra, Murante, et al., supra, Hosfield, et al, supra, Rao, et al., J Bacteriol 180(20), 5406-12 [1998], Bhagwat, et al., J. Biol Chem 272(45), 28523-30 [1997], Garforth and Sayers, Nucleic Acids Res 25(19), 3801-7 [1997]).

[0361] Using preformed substrates, many of the studies cited above determined that these nucleases leave a gap upon cleavage, leading the authors to speculate that DNA polymerase must then act to fill in that gap to generate a ligatable nick. A number of other 5' nucleases have been shown to leave a gap or overlap after cleavage of the same or similar flap substrates. It has since been determined that that all the structure-specific 5'-exonucleases leave a nick after cleavage if the substrate has an overlap between the upstream and downstream duplexes (Kaiser et al., J. Biol. Chem. 274(30):21387-21394 [1999]). While duplexes having several bases of overlapping sequence can assume several different conformations through branch migration, it was determined that cleavage occurs in the conformation where the last nucleotide at the 3' end of the upstream strand is unpaired, with the cleavage rate being essentially the same whether the end of the upstream primer is A, C, G, or T. It

was determined to be positional overlap between the 3' end of the upstream primer and downstream duplex, rather then sequence overlap, that is required for optimal cleavage. In addition to allowing these enzymes to leave a nick after cleavage, the single base of overlap causes the enzymes to cleave several orders of magnitude faster than when a substrate lacks overlap (Kaiser et al., supra).

[0362] Any of the 5' nucleases described above may find application in one or more embodiments of the methods described herein. FEN1 nucleases of particular utility in the methods of present invention include but are not limited to those of *Methanococcus jannaschi* and *Methanobacterium thermoautotrophicum*; particularly preferred FEN1 enzymes are from *Archaeoglobus fulgidus, Pyrococcus furiosus, Archaeoglobus veneficus, Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii*, and *Aeropyrum pernix*.

[0363] The detailed description of the invention is presented in the following sections:

[0364] I. Detection of Specific Nucleic Acid Sequences Using 5' Nucleases in an INVADER Directed Cleavage Assay;

[0365] II. Effect of ARRESTOR Oligonucleotides on Signal and Background in Sequential Invasive Cleavage Reactions.

[0366] III. Signal Enhancement By Incorporating The Products Of An Invasive Cleavage Reaction Into A Subsequent Invasive Cleavage Reaction;

[0367] IV. Fractionation Of Specific Nucleic Acids By Selective Charge Reversal;

[0368] V. Signal Enhancement By Tailing Of Reaction Products In The INVADER oligonucleotide-directed Cleavage Assay;

[0369] VI. Signal Enhancement By Completion Of An Activated Protein Binding Site;

[0370] VII. Generation of 5' Nucleases Derived From Thermostable DNA Polymerases;

[0371] VIII. Improved Enzymes For Use In INVADER oligonucleotide-directed Cleavage Reactions;

[0372] IX. The INVADER assay for direct detection and measurement of specific analytes.

[0373] X. Kits

I. Detection of Specific Nucleic Acid Sequences Using 5' Nucleases in an INVADER Directed Cleavage Assay

[0374] 1. INVADER Assay Reaction Design

[0375] The present invention provides means for forming a nucleic acid cleavage structure that is dependent upon the presence of a target nucleic acid and cleaving the nucleic acid cleavage structure so as to release distinctive cleavage products. 5' nuclease activity, for example, is used to cleave the target-dependent cleavage structure and the resulting cleavage products are indicative of the presence of specific target nucleic acid sequences in the sample. When two strands of nucleic acid, or oligonucleotides, both hybridize to a target nucleic acid strand such that they form an overlapping invasive cleavage structure, as described below, invasive cleavage can occur. Through the interaction of a cleavage agent (e.g., a 5' nuclease) and the upstream oligonucleotide, the cleavage agent can be made to cleave the downstream oligonucleotide at an internal site in such a way that a distinctive fragment is produced. Such embodiments have been termed the INVADER assay (Third Wave Technologies) and are described in U.S. Pat. Nos. 5,846,717, 5,985,557, 5,994,069, 6,001,567, and 6,090,543 and PCT Publications WO 97/27214 and WO 98/42873, herein incorporated by reference in their entireties.

[0376] The present invention further provides assays in which the target nucleic acid is reused or recycled during multiple rounds of hybridization with oligonucleotide probes and cleavage of the probes without the need to use temperature cycling (i.e., for periodic denaturation of target nucleic acid strands) or nucleic acid synthesis (i.e., for the polymerization-based displacement of target or probe nucleic acid strands). When a cleavage reaction is run under conditions in which the probes are continuously replaced on the target strand (e.g. through probe-probe displacement or through an equilibrium between probe/target association and disassociation, or through a combination comprising these mechanisms, [The kinetics of oligonucleotide replacement. Luis P. Reynaldo, Alexander V. Vologodskii, Bruce P. Neri and Victor I. Lyamichev. J. Mol. Biol. 97: 511-520 (2000)], multiple probes can hybridize to the same target, allowing multiple cleavages, and the generation of multiple cleavage products.

[0377] By the extent of its complementarity to a target nucleic acid strand, an oligonucleotide may be said to define a specific region of said target. In an invasive cleavage structure, the two oligonucleotides define and hybridize to regions of the target that are adjacent to one another (i.e., regions without any additional region of the target between them). Either or both oligonucleotides may comprise additional portions that are not complementary to the target strand. In addition to hybridizing adjacently, in order to form an invasive cleavage structure, the 3' end of the upstream oligonucleotide must comprise an additional moiety. When both oligonucleotides are hybridized to a target strand to form a structure and such a 3' moiety is present on the upstream oligonucleotide within the structure, the oligonucleotides may be said to overlap, and the structure may be described as an overlapping, or invasive cleavage structure.

[0378] In one embodiment, the 3' moiety of the invasive cleavage structure is a single nucleotide. In this embodiment the 3' moiety may be any nucleotide (i.e., it may be, but it need not be complementary to the target strand). In a preferred embodiment the 3' moiety is a single nucleotide that is not complementary to the target strand. In another embodiment, the 3' moiety is a nucleotide-like compound (i.e., a moiety having chemical features similar to a nucleotide, such as a nucleotide analog or an organic ring compound; See e.g., U.S. Pat. No. 5,985,557). In yet another embodiment the 3' moiety is one or more nucleotides that duplicate in sequence one or more nucleotides present at the 5' end of the hybridized region of the downstream oligonucleotide. In a further embodiment, the duplicated sequence of nucleotides of the 3' moiety is followed by a

single nucleotide that is not further duplicative of the downstream oligonucleotide sequence, and that may be any other nucleotide. In yet another embodiment, the duplicated sequence of nucleotides of the 3' moiety is followed by a nucleotide-like compound, as described above.

[0379] The downstream oligonucleotide may have, but need not have, additional moieties attached to either end of the region that hybridizes to the target nucleic acid strand. In a preferred embodiment, the downstream oligonucleotide comprises a moiety at its 5' end (i.e., a 5' moiety). In a particularly preferred embodiment, said 5' moiety is a 5' flap or arm comprising a sequence of nucleotides that is not complementary to the target nucleic acid strand.

[0380] When an overlapping cleavage structure is formed, it can be recognized and cleaved by a nuclease that is specific for this structure (i.e., a nuclease that will cleave one or more of the nucleic acids in the overlapping structure based on recognition of this structure, rather than on recognition of a nucleotide sequence of any of the nucleic acids forming the structure). Such a nuclease may be termed a "structure-specific nuclease". In some embodiments, the structure-specific nuclease is a 5' nuclease. In a preferred embodiment, the structure-specific nuclease is the 5' nuclease of a DNA polymerase. In another preferred embodiment, the DNA polymerase having the 5' nuclease is synthesis-deficient. In another preferred embodiment, the 5' nuclease is a FEN-1 endonuclease. In a particularly preferred embodiment, the 5' nuclease is thermostable.

[0381] In some embodiments, said structure-specific nuclease preferentially cleaves the downstream oligonucleotide. In a preferred embodiment, the downstream oligonucleotide is cleaved one nucleotide into the 5' end of the region that is hybridized to the target within the overlapping structure. Cleavage of the overlapping structure at any location by a structure-specific nuclease produces one or more released portions or fragments of nucleic acid, termed "cleavage products".

[0382] In some embodiments, cleavage of an overlapping structure is performed under conditions wherein one or more of the nucleic acids in the structure can disassociate (i.e. un-hybridize, or melt) from the structure. In one embodiment, full or partial disassociation of a first cleavage structure allows the target nucleic acid to participate in the formation of one or more additional overlapping cleavage structures. In a preferred embodiment, the first cleavage structure is partially disassociated. In a particularly preferred embodiment only the oligonucleotide that is cleaved disassociates from the first cleavage structure, such that it may be replaced by another copy of the same oligonucleotide. In some embodiments, said disassociation is induced by an increase in temperature, such that one or more oligonucleotides can no longer hybridize to the target strand. In other embodiments, said disassociation occurs because cleavage of an oligonucleotide produces only cleavage products that cannot bind to the target strand under the conditions of the reaction. In a preferred embodiment, conditions are selected wherein an oligonucleotide may associate with (i.e., hybridize to) and disassociate from a target strand regardless of cleavage, and wherein the oligonucleotide may be cleaved when it is hybridized to the target as part of an overlapping cleavage structure. In a particularly preferred embodiment, conditions are selected such that the number of copies of the oligonucleotide that can be cleaved when part of an overlapping structure exceeds the number of copies of the target nucleic acid strand by a sufficient amount that when the first cleavage structure disassociates, the probability that the target strand will associate with an intact copy of the oligonucleotide is greater than the probability that that it will associate with a cleaved copy of the oligonucleotide.

[0383] In some embodiments, cleavage is performed by a structure-specific nuclease that can recognize and cleave structures that do not have an overlap. In a preferred embodiment, cleavage is performed by a structure-specific nuclease having a lower rate of cleavage of nucleic acid structures that do not comprise an overlap, compared to the rate of cleavage of structures comprising an overlap. In a particularly preferred embodiment, cleavage is performed by a structure-specific nuclease having less than 1% of the rate of cleavage of nucleic acid structures that do not comprise an overlap, compared to the rate of cleavage of structures comprising an overlap.

[0384] In some embodiments it is desirable to detect the cleavage of the overlapping cleavage structure. Detection may be by analysis of cleavage products or by analysis of one or more of the remaining uncleaved nucleic acids. For convenience, the following discussion will refer to the analysis of cleavage products, but it will be appreciated by those skilled in the art that these methods may as easily be applied to analysis of the uncleaved nucleic acids in an invasive cleavage reaction. Any method known in the art for analysis of nucleic acids, nucleic acid fragments or oligonucleotides may be applied to the detection of cleavage products.

[0385] In one embodiment, the cleavage products may be identified by chemical content, e.g., the relative amounts of each atom, each particular type of reactive group or each nucleotide base (Chargaff et al., *J. Biol. Chem.* 177: 405 [1949]) they contain. In this way, a cleavage product may be distinguished from a longer nucleic acid from which it was released by cleavage, or from other nucleic acids.

[0386] In another embodiment, the cleavage products may be distinguished by a particular physical attribute, including but not limited to length, mass, charge, or charge-to-mass ratio. In yet another embodiment, the cleavage product may be distinguished by a behavior that is related to a physical attribute, including but not limited to rate of rotation in solution, rate of migration during electrophoresis, coefficient of sedimentation in centrifugation, time of flight in MALDI-TOF mass spectrometry, migration rate or other behavior in chromatography, melting temperature from a complementary nucleic acid, or precipitability from solution.

[0387] Detection of the cleavage products may be through release of a label. Such labels may include, but are not limited to one or more of any of dyes, radiolabels such as ^{32}P or ^{35}S, binding moieties such as biotin, mass tags, such as metal ions or chemical groups, charge tags, such as polyamines or charged dyes, haptens such as digoxygenin, luminogenic, phosphorescent or fluorogenic moieties, and fluorescent dyes, either alone or in combination with moieties that can suppress or shift emission spectra, such as by fluorescence resonance energy transfer (FRET) or collisional fluorescence energy transfer.

[0388] In some embodiments, analysis of cleavage products may include physical resolution or separation, for

example by electrophoresis, hybridization or by selective binding to a support, or by mass spectrometry methods such as MALDI-TOF. In other embodiments, the analysis may be performed without any physical resolution or separation, such as by detection of cleavage-induced changes in fluorescence as in FRET-based analysis, or by cleavage-induced changes in the rotation rate of a nucleic acid in solution as in fluorescence polarization analysis.

[0389] Cleavage products can be used subsequently in any reaction or read-out method that can make use of oligonucleotides. Such reactions include, but are not limited to, modification reactions, such as ligation, tailing with a template-independent nucleic acid polymerase and primer extension with a template-dependent nucleic acid polymerase. The modification of the cleavage products may be for purposes including, but not limited to, addition of one or more labels or binding moieties, alteration of mass, addition of specific sequences, or for any other purpose that would facilitate analysis of either the cleavage products or analysis of any other by-product, result or consequence of the cleavage reaction.

[0390] Analysis of the cleavage products may involve subsequent steps or reactions that do not modify the cleavage products themselves. For example, cleavage products may be used to complete a functional structure, such as a competent promoter for in vitro transcription or another protein binding site. Analysis may include the step of using the completed structure for or to perform its function. One or more cleavage products may also be used to complete an overlapping cleavage structure, thereby enabling a subsequent cleavage reaction, the products of which may be detected or used by any of the methods described herein, including the participation in further cleavage reactions.

[0391] Certain preferred embodiments of the invasive cleavage reactions are provided in the following descriptions. As exemplified by the diagram in FIG. **29**, the methods of the present invention employ at least a pair of oligonucleotides that interact with a target nucleic acid to form a cleavage structure for a structure-specific nuclease. In some embodiments, the cleavage structure comprises i) a target nucleic acid that may be either single-stranded or double-stranded (when a double-stranded target nucleic acid is employed, it may be rendered single stranded, e.g., by heating); ii) a first oligonucleotide, termed the "probe," that defines a first region of the target nucleic acid sequence by being the complement of that region (regions X and Z of the target as shown in FIG. **29**); iii) a second oligonucleotide, termed the "INVADER," the 5' part of which defines a second region of the same target nucleic acid sequence (regions Y and X in FIG. **29**), adjacent to and downstream of the first target region (regions X and Z), and the second part of which overlaps into the region defined by the first oligonucleotide (region X depicts the region of overlap). The resulting structure is diagrammed in FIG. **29**.

[0392] While not limiting the invention or the instant discussion to any particular mechanism of action, the diagram in FIG. **29** represents the effect on the site of cleavage caused by this type of arrangement of a pair of oligonucleotides. The design of such a pair of oligonucleotides is described below in detail. In FIG. **29**, the 3' ends of the nucleic acids (i.e., the target and the oligonucleotides) are indicated by the use of the arrowheads on the ends of the lines depicting the strands of the nucleic acids (and where space permits, these ends are also labeled "3'"). It is readily appreciated that the two oligonucleotides (the INVADER and the probe) are arranged in a parallel orientation relative to one another, while the target nucleic acid strand is arranged in an anti-parallel orientation relative to the two oligonucleotides. Further, it is clear that the INVADER oligonucleotide is located upstream of the probe oligonucleotide and that with respect to the target nucleic acid strand, region Z is upstream of region X and region X is upstream of region Y (that is, region Y is downstream of region X and region X is downstream of region Z). Regions of complementarity between the opposing strands are indicated by the short vertical lines. While not intended to indicate the precise location of the site(s) of cleavage, the area to which the site of cleavage within the probe oligonucleotide is shifted by the presence of the INVADER oligonucleotide in this embodiment is indicated by the solid vertical arrowhead. An alternative representation of the target/INVADER/probe cleavage structure is shown in FIG. **32***c*. Neither diagram (i.e., FIG. **29** or FIG. **32***c*) is intended to represent the actual mechanism of action or physical arrangement of the cleavage structure and further it is not intended that the method of the present invention be limited to any particular mechanism of action.

[0393] It can be considered that the binding of these oligonucleotides in this embodiment divides the target nucleic acid into three distinct regions: one region that has complementarity to only the probe (shown as "Z"); one region that has complementarity only to the INVADER oligonucleotide (shown as "Y"); and one region that has complementarity to both oligonucleotides (shown as "X"). As discussed above, in some preferred embodiments of the present invention, the overlap may comprise moieties other than overlapping complementary bases. Thus, in some embodiments, the region shown as "X" can represent a region where there is a physical, but not sequence, overlap between the INVADER and probe oligonucleotides, i.e., in these latter embodiments, there is not a region of the target nucleic acid between regions "Z" and "Y" that has complementarity to both oligonucleotides.

[0394] a) Oligonucleotide Design

[0395] Design of these oligonucleotides (i.e., the INVADER oligonucleotide and the probe) is accomplished using practices that are standard in the art. For example, sequences that have self complementarity, such that the resulting oligonucleotides would either fold upon themselves, or hybridize to each other at the expense of binding to the target nucleic acid, are generally avoided.

[0396] One consideration in choosing a length for these oligonucleotides is the complexity of the sample containing the target nucleic acid. For example, the human genome is approximately 3×10^9 basepairs in length. Any 10-nucleotide sequence will appear with a frequency of $1:4^{10}$, or 1:1048, 576 in a random string of nucleotides, which would be approximately 2,861 times in 3 billion basepairs. Clearly, an oligonucleotide of this length would have a poor chance of binding uniquely to a 10 nucleotide region within a target having a sequence the size of the human genome. If the target sequence were within a 3 kb plasmid, however, such an oligonucleotide might have a very reasonable chance of binding uniquely. By this same calculation it can be seen that

an oligonucleotide of 16 nucleotides (i.e., a 16-mer) is the minimum length of a sequence that is mathematically likely to appear once in 3×10^9 basepairs. This level of specificity may also be provided by two or more shorter oligonucleotides if they are configured to bind in a cooperative fashion (i.e., such that they can produce the intended complex only if both or all are bound to their intended target sequences), wherein the combination of the short oligonucleotides provides the desired specificity. In one such embodiment, the cooperativity between the shorter oligonucleotides is by a coaxial stacking effect that can occur when the oligonucleotides hybridize to adjacent sites on a target nucleic acid. In another embodiment, the shorter oligonucleotides are connected to one another, either directly, or by one or more spacer regions. The short oligonucleotides thus connected may bind to distal regions of the target and may be used to bridge across regions of secondary structure in a target. Examples of such bridging oligonucleotides are described in PCT Publication WO 98/50403, herein incorporated by reference in its entirety.

[0397] A second consideration in choosing oligonucleotide length is the temperature range in which the oligonucleotides will be expected to function. A 16-mer of average base content (50% G-C bases) will have a calculated T_m of about 41° C., depending on, among other things, the concentration of the oligonucleotide and its target, the salt content of the reaction and the precise order of the nucleotides. As a practical matter, longer oligonucleotides are usually chosen to enhance the specificity of hybridization. Oligonucleotides 20 to 25 nucleotides in length are often used, as they are highly likely to be specific if used in reactions conducted at temperatures which are near their T_ms (within about 5° C. of the T_m). In addition, with calculated T_ms in the range of 50 to 70° C., such oligonucleotides (i.e., 20 to 25-mers) are appropriately used in reactions catalyzed by thermostable enzymes, which often display optimal activity near this temperature range.

[0398] The maximum length of the oligonucleotide chosen is also based on the desired specificity. One must avoid choosing sequences that are so long that they are either at a high risk of binding stably to partial complements, or that they cannot easily be dislodged when desired (e.g., failure to disassociate from the target once cleavage has occurred or failure to disassociate at a reaction temperature suitable for the enzymes and other materials in the reaction).

[0399] The first step of design and selection of the oligonucleotides for the INVADER oligonucleotide-directed cleavage is in accordance with these sample general principles. Considered as sequence-specific probes individually, each oligonucleotide may be selected according to the guidelines listed above. That is to say, each oligonucleotide will generally be long enough to be reasonably expected to hybridize only to the intended target sequence within a complex sample, usually in the 20 to 40 nucleotide range. Alternatively, because the INVADER oligonucleotide-directed cleavage assay depends upon the concerted action of these oligonucleotides, the composite length of the 2 oligonucleotides which span/bind to the X, Y, Z regions may be selected to fall within this range, with each of the individual oligonucleotides being in approximately the 13 to 17 nucleotide range. Such a design might be employed if a non-thermostable cleavage means were employed in the reaction, requiring the reactions to be conducted at a lower temperature than that used when thermostable cleavage means are employed. In some embodiments, it may be desirable to have these oligonucleotides bind multiple times within a single target nucleic acid (e.g., to bind to multiple variants or multiple similar sequences within a target). It is not intended that the method of the present invention be limited to any particular size of the probe or INVADER oligonucleotide.

[0400] The second step of designing an oligonucleotide pair for this assay is to choose the degree to which the upstream "INVADER" oligonucleotide sequence will overlap into the downstream "probe" oligonucleotide sequence, and consequently, the sizes into which the probe will be cleaved. A key feature of this assay is that the probe oligonucleotide can be made to "turn over," that is to say probe can be made to depart to allow the binding and cleavage of other copies of the probe molecule, without the requirements of thermal denaturation or displacement by polymerization. While in one embodiment of this assay probe turnover may be facilitated by an exonucleolytic digestion by the cleavage agent, it is central to the present invention that the turnover does not require this exonucleolytic activity. For example, in some embodiments, a reaction temperature and reaction conditions are selected so as to create an equilibrium wherein the probe hybridizes and disassociates from the target. In other embodiments, temperature and reaction conditions are selected so that unbound probe can initiate binding to the target strand and physically displace bound probe. In still other embodiments, temperature and reaction conditions are selected such that either or both mechanisms of probe replacement may occur in any proportion. The method of the present invention is not limited to any particular mechanism of probe replacement. By any mechanism, when the probe is bound to the target to form a cleavage structure, cleavage can occur. The continuous cycling of the probe on and off of the target allows multiple probes to bind and be cleaved for each copy of a target nucleic acid.

[0401] i) Choosing the Amount of Sequence Overlap

[0402] One way of accomplishing such turnover, where the INVADER oligonucleotide and probe oligonucleotide share a region of complementarity, can be envisioned by considering the diagram in FIG. **29**. It can be seen that the T_m of each oligonucleotide will be a function of the full length of that oligonucleotide: i.e., the T_m of the INVADER oligonucleotide=T_m(Y+X), and the T_m of the probe=T_m(X+Y) for the probe. When the probe is cleaved the X region is released, leaving the Z section. If the T_m of Z is less than the reaction temperature, and the reaction temperature is less than the T_m(X+Z), then cleavage of the probe will lead to the departure of Z, thus allowing a new (X+Z) to hybridize. It can be seen from this example that the X region must be sufficiently long that the release of X will drop the T_m of the remaining probe section below the reaction temperature: a G-C rich X section may be much shorter than an A-T rich X section and still accomplish this stability shift.

[0403] In other embodiments described herein, probe turn over is not related to a change in T_m caused by cleavage of the probe, but rather is related to the association and disassociation behavior of the probe in the selected conditions, regardless of cleavage. Thus, it is not intended that the present invention be limited to the use of probes that, upon

cleavage, yield products having a T_ms below the reaction temperature, as described above.

[0404] ii) Non-Sequence Overlaps

[0405] It has been determined that the relationship between the 3' end of the upstream oligonucleotide and the desired site of cleavage on the probe should be care fully designed. It is known that the preferred site of cleavage for the types of structure-specific endonucleases employed herein is one basepair into a duplex (Lyamichev et al., supra). It was previously believed that the presence of an upstream oligonucleotide or primer allowed the cleavage site to be shifted away from this preferred site, into the single stranded region of the 5' arm (Lyamichev et al., supra and U.S. Pat. No. 5,422,253). In contrast to this previously proposed mechanism, and while not limiting the present invention to any particular mechanism, it is believed that the nucleotide immediately 5', or upstream of the cleavage site on the probe (including miniprobe and mid-range probes) should be able to basepair with the target for efficient cleavage to occur. In the case of the present invention, this would be the nucleotide in the probe sequence immediately upstream of the intended cleavage site. In addition, as described herein, it has been observed that in order to direct cleavage to that same site in the probe, the upstream oligonucleotide should have its 3' base (i.e., nt) immediately upstream of the intended cleavage site of the probe. In embodiments where the INVADER and probe oligonucleotides share a sequence overlap, this places the 3' terminal nucleotide of the upstream oligonucleotide and the base of the probe oligonucleotide 5' of the cleavage site in competition for pairing with the corresponding nucleotide of the target strand.

[0406] To examine the outcome of this competition (i.e. which base is paired during a successful cleavage event), substitutions were made in the probe and INVADER oligonucleotides such that either the probe or the INVADER oligonucleotide were mismatched with the target sequence at this position. The effects of both arrangements on the rates of cleavage were examined. When the INVADER oligonucleotide is unpaired at the 3' end, the rate of cleavage was not reduced. If this base was removed, however, the cleavage site was shifted upstream of the intended site. In contrast, if the probe oligonucleotide was not base-paired to the target just upstream of the site to which the INVADER oligonucleotide was directing cleavage, the rate of cleavage was dramatically reduced, suggesting that when a competition exists, the probe oligonucleotide was the molecule to be base-paired in this position.

[0407] It appears that the 3' end of the upstream INVADER oligonucleotide is unpaired during cleavage, and yet is important for accurate positioning of the cleavage. To examine which part(s) of the 3' terminal nucleotide are required for the positioning of cleavage, INVADER oligonucleotides were designed that terminated on this end with nucleotides that were altered in a variety of ways. Sugars examined included 2' deoxyribose with a 3' phosphate group, a dideoxyribose, 3' deoxyribose, 2' O-methyl ribose, arabinose and arabinose with a 3' phosphate. Abasic ribose, with and without 3' phosphate were tested. Synthetic "universal" bases such at 3-nitropyrrole and 5-3 nitroindole on ribose sugars were tested. Finally, a base-like aromatic ring structure, acridine, linked to the 3' end the previous nucleotide without a sugar group was tested. The results obtained support the conclusion that the aromatic ring of the base (at the 3' end of the INVADER oligonucleotide) is an important moiety for accomplishing the direction of cleavage to the desired site within the downstream probe. The 3' terminal moiety of the INVADER oligonucleotide need not be a base that is complementary to the target nucleic acid.

[0408] iii) Miniprobes and Mid-Range Probes;

[0409] As discussed above, the INVADER oligonucleotide-directed cleavage assay may be performed using INVADER and probe oligonucleotides that have a length of about 13-25 nucleotides (typically 20-25 nucleotides). It is also contemplated that the oligonucleotides may themselves be composed of shorter oligonucleotide sequences that align along a target strand but that are not covalently linked. This is to say that there is a nick in the sugar-phosphate backbone of the composite oligonucleotide, but that there is no disruption in the progression of base-paired nucleotides in the resulting duplex. When short strands of nucleic acid align contiguously along a longer strand the hybridization of each is stabilized by the hybridization of the neighboring fragments because the basepairs can stack along the helix as though the backbone was in fact uninterrupted. This cooperativity of binding can give each segment a stability of interaction in excess of what would be expected for the segment hybridizing to the longer nucleic acid alone. One application of this observation has been to assemble primers for DNA sequencing, typically about 18 nucleotides long, from sets of three hexamer oligonucleotides that are designed to hybridize in this way (Kotler et al. Proc. Natl. Acad. Sci. USA 90:4241 [1993]). The resulting doubly-nicked primer can be extended enzymatically in reactions performed at temperatures that might be expected to disrupt the hybridization of hexamers, but not of 18-mers.

[0410] The use of composite or split oligonucleotides is applied with success in the INVADER-directed cleavage assay. For example, the probe oligonucleotide may be split into two oligonucleotides that anneal in a contiguous and adjacent manner along a target oligonucleotide as diagrammed in FIG. **57**. In this Figure, the downstream oligonucleotide (analogous to the probe of FIG. **25**) is assembled from two smaller pieces: a short segment of 6-10 nts (termed the "miniprobe"), that is to be cleaved in the course of the detection reaction, and an oligonucleotide that hybridizes immediately downstream of the miniprobe (termed the "stacker"), that serves to stabilize the hybridization of the probe. To form the cleavage structure, an upstream oligonucleotide (the INVADER oligonucleotide) is provided to direct the cleavage activity to the desired region of the miniprobe. Assembly of the probe from non-linked pieces of nucleic acid (i.e., the miniprobe and the stacker) allows regions of sequences to be changed without requiring the re-synthesis of the entire proven sequence, thus improving the cost and flexibility of the detection system. In addition, the use of unlinked composite oligonucleotides makes the system more stringent in its requirement of perfectly matched hybridization to achieve signal generation, allowing this to be used as a sensitive means of detecting mutations or changes in the target nucleic acid sequences.

[0411] As illustrated in FIG. **57**, in one embodiment, the methods of the present invention employ at least three oligonucleotides that interact with a target nucleic acid to

form a cleavage structure for a structure-specific nuclease. More specifically, the cleavage structure comprises i) a target nucleic acid that may be either single-stranded or double-stranded (when a double-stranded target nucleic acid is employed, it may be rendered single-stranded, e.g., by heating); ii) a first oligonucleotide, termed the "stacker," that defines a first region of the target nucleic acid sequence by being the complement of that region (region W of the target as shown in FIG. **57**); iii) a second oligonucleotide, termed the "miniprobe," that defines a second region of the target nucleic acid sequence by being the complement of that region (regions X and Z of the target as shown in FIG. **57**); iv) a third oligonucleotide, termed the "INVADER," the 5' part of which defines a third region of the same target nucleic acid sequence (regions Y and X in FIG. **57**), adjacent to and downstream of the second target region (regions X and Z), and the second or 3' part of which overlaps into the region defined by the second oligonucleotide (region X depicts the region of overlap). The resulting structure is diagrammed in FIG. **57**. As described above for embodiments that do not employ a stacker, the region shown as "X" can represent a region where there is a physical, but not sequence, overlap between the INVADER and probe oligonucleotides.

[**0412**] While not limiting the invention or the instant discussion to any particular mechanism of action, the diagram in FIG. **57** represents the effect on the site of cleavage caused by this type of arrangement of three oligonucleotides. The design of these three oligonucleotides is described below in detail. In FIG. **57**, the 3' ends of the nucleic acids (i.e., the target and the oligonucleotides) are indicated by the use of the arrowheads on the ends of the lines depicting the strands of the nucleic acids (and where space permits, these ends are also labeled "3'"). It is readily appreciated that the three oligonucleotides (the INVADER, the miniprobe and the stacker) are arranged in a parallel orientation relative to one another, while the target nucleic acid strand is arranged in an anti-parallel orientation relative to the three oligonucleotides. Further it is clear that the INVADER oligonucleotide is located upstream of the miniprobe oligonucleotide and that the miniprobe olignucleotide is located upstream of the stacker oligonucleotide and that with respect to the target nucleic acid strand, region W is upstream of region Z, region Z is upstream of upstream of region X and region X is upstream of region Y (that is region Y is downstream of region X, region X is downstream of region Z and region Z is downstream of region W). Regions of complementarity between the opposing strands are indicated by the short vertical lines. While not intended to indicate the precise location of the site(s) of cleavage, the area to which the site of cleavage within the miniprobe oligonucleotide is shifted by the presence of the INVADER oligonucleotide is indicated by the solid vertical arrowhead. FIG. **57** is not intended to represent the actual mechanism of action or physical arrangement of the cleavage structure and further it is not intended that the method of the present invention be limited to any particular mechanism of action.

[**0413**] It can be considered that the binding of these oligonucleotides divides the target nucleic acid into four distinct regions: one region that has complementarity to only the stacker (shown as "W"); one region that has complementarity to only the miniprobe (shown as "Z"); one region that has complementarity only to the INVADER oligonucleotide (shown as "Y"); and one region that has complementarity to both the INVADER and miniprobe oligonucleotides (shown as "X"). As discussed above, the INVADER oligonucleotide may also be employed such that a physical overlap rather than a sequence overlap with the probe is provided.

[**0414**] In addition to the benefits cited above, the use of a composite design for the oligonucleotides that form the cleavage structure allows more latitude in the design of the reaction conditions for performing the INVADER-directed cleavage assay. When a longer probe (e.g., 16-25 nt), as described above, is used for detection in reactions that are performed at temperatures below the T_m of that probe, the cleavage of the probe may play a significant role in destabilizing the duplex of which it is a part, thus allowing turnover and reuse of the recognition site on the target nucleic acid. In contrast, reaction temperatures that are at or above the T_m of the probe mean that the probe molecules are hybridizing and releasing from the target quite rapidly even without cleavage of the probe. When an upstream INVADER oligonucleotide and a cleavage means are provided the probe will be specifically cleaved, but the cleavage will not be necessary to the turnover of the probe. When a long probe (e.g., 16-25 nt) is used in this way the temperatures required to achieve this state is high, around 65 to 70° C. for a 25-mer of average base composition. Requiring the use of such elevated temperatures limits the choice of cleavage agents to those that are very thermostable, and may contribute to background in the reactions, depending of the means of detection, through thermal degradation of the probe oligonucleotides. With miniprobes, this latter mechanism of probe replacement may be accomplished at a lower temperature. Thus, shorter probes are preferred for embodiments using lower reaction temperatures.

[**0415**] The miniprobe of the present invention may vary in size depending on the desired application. In one embodiment, the probe may be relatively short compared to a standard probe (e.g., 16-25 nt), in the range of 6 to 10 nucleotides. When such a short probe is used, reaction conditions can be chosen that prevent hybridization of the miniprobe in the absence of the stacker oligonucleotide. In this way a short probe can be made to assume the statistical specificity and selectivity of a longer sequence. In the event of a perturbation in the cooperative binding of the miniprobe and stacker nucleic acids, as might be caused by a mismatch within the short sequence that is otherwise complementary to the target nucleic acid or at the junction between the contiguous duplexes, this cooperativity can be lost, dramatically reducing the stability of the shorter duplex (i.e., that of the miniprobe), and thus reducing the level of cleaved product in the assay of the present invention.

[**0416**] It is also contemplated that probes of intermediate size may be used. Such probes, in the 11 to 15 nucleotide range, may blend some of the features associated with the longer probes as originally described, these features including the ability to hybridize and be cleaved absent the help of a stacker oligonucleotide. At temperatures below the expected T_m of such probes, the mechanisms of turnover may be as discussed above for probes in the 20 nt range, and be dependent on the removal of the sequence in the 'X' region for destabilization and cycling.

[**0417**] The mid-range probes may also be used at elevated temperatures, at or above their expected T_m, to allow melting rather than cleavage to promote probe turnover. In

contrast to the longer probes described above, however, the temperatures required to allow the use of such a thermally driven turnover are much lower (about 40 to 60° C.), thus preserving both the cleavage means and the nucleic acids in the reaction from thermal degradation. In this way, the mid-range probes may perform in some instances like the miniprobes described above. In a further similarity to the miniprobes, the accumulation of cleavage signal from a mid-range probe may be helped under some reaction conditions by the presence of a stacker.

[0418] To summarize, a standard long probe usually does not benefit from the presence of a stacker oligonucleotide downstream (the exception being cases where such an oligonucleotide may also disrupt structures in the target nucleic acid that interfere with the probe binding), and it may be used in conditions requiring several nucleotides to be removed to allow the oligonucleotide to release from the target efficiently. If temperature of the reaction is used to drive exchange of the probes, standard probes may require use of a temperature at which nucleic acids and enzymes are at higher risk of thermal degradation.

[0419] The miniprobe is very short and performs optimally in the presence of a downstream stacker oligonucleotide. The miniprobes are well suited to reactions conditions that use the temperature of the reaction to drive rapid exchange of the probes on the target regardless of whether any bases have been cleaved. In reactions with sufficient amount of the cleavage means, the probes that do bind will be rapidly cleaved before they melt off.

[0420] The mid-range or midiprobe combines features of these probes and can be used in reactions like those favored by long probes, with longer regions of overlap ("X" regions) to drive probe turnover at lower temperature. In a preferred embodiment, the midrange probes are used at temperatures sufficiently high that the probes are hybridizing to the target and releasing rapidly regardless of cleavage. The mid-range probe may have enhanced performance in the presence of a stacker under some circumstances.

[0421] The distinctions between the mini-, midi- (i.e., mid-range) and long probes are not contemplated to be inflexible and based only on length. The performance of any given probe may vary with its specific sequence, the choice of solution conditions, the choice of temperature and the selected cleavage means.

[0422] It is shown in Example 17 that the assemblage of oligonucleotides that comprises the cleavage structure of the present invention is sensitive to mismatches between the probe and the target. The site of the mismatch used in Ex. 17 provides one example and is not intended to be a limitation in location of a mismatch affecting cleavage. It is also contemplated that a mismatch between the INVADER oligonucleotide and the target may be used to distinguish related target sequences. In the 3-oligonucleotide system, comprising an INVADER, a probe and a stacker oligonucleotide, it is contemplated that mismatches may be located within any of the regions of duplex formed between these oligonucleotides and the target sequence. In a preferred embodiment, a mismatch to be detected is located in the probe. In a particularly preferred embodiment, the mismatch is in the probe, at the basepair immediately upstream (i.e., 5') of the site that is cleaved when the probe is not mismatched to the target.

[0423] In another preferred embodiment, a mismatch to be detected is located within the region 'Z' defined by the hybridization of a miniprobe. In a particularly preferred embodiment, the mismatch is in the miniprobe, at the basepair immediately upstream (i.e., 5') of the site that is cleaved when the miniprobe is not mismatched to the target.

[0424] b) Design of the Reaction Conditions

[0425] Target nucleic acids that may be analyzed using the methods of the present invention that employ a 5' nuclease or other appropriate cleavage agents include of both RNA and DNA. Such nucleic acids may be obtained using standard molecular biological techniques. For example, nucleic acids (RNA or DNA) may be isolated from a tissue sample (e.g., a biopsy specimen), tissue culture cells, samples containing bacteria and/or viruses (including cultures of bacteria and/or viruses), etc. The target nucleic acid may also be transcribed in vitro from a DNA template or may be chemically synthesized or amplified in by polymerase chain reaction. Furthermore, nucleic acids may be isolated from an organism, either as genomic material or as a plasmid or similar extrachromosomal DNA, or they may be a fragment of such material generated by treatment with a restriction endonuclease or other cleavage agent, or a shearing force, or it may be synthetic.

[0426] Assembly of the target, probe, and INVADER oligonucleotide nucleic acids into the cleavage reaction of the present invention uses principles commonly used in the design of oligonucleotide-based enzymatic assays, such as dideoxynucleotide sequencing and polymerase chain reaction (PCR). As is done in these assays, the oligonucleotides are provided in sufficient excess that the rate of hybridization to the target nucleic acid is very rapid. These assays are commonly performed with 50 fmoles to 2 pmoles of each oligonucleotide per microliter of reaction mixture, although they are not necessarily limited to this range In the Examples described herein, amounts of oligonucleotides ranging from 250 fmoles to 5 pmoles per microliter of reaction volume were used. These values were chosen for the purpose of ease in demonstration and are not intended to limit the performance of the present invention to these concentrations. Other (e.g., lower) oligonucleotide concentrations commonly used in other molecular biological reactions are also contemplated.

[0427] It is desirable that an INVADER oligonucleotide be immediately available to direct the cleavage of each probe oligonucleotide that hybridizes to a target nucleic acid. In some embodiments described herein, the INVADER oligonucleotide is provided in excess over the probe oligonucleotide. While this is an effective means of making the INVADER oligonucleotide immediately available in such embodiments it is not intended that the practice of the present invention be limited to conditions wherein the INVADER oligonucleotide is in excess over the probe, or to any particular ratio of INVADER-to-probe (e.g., in some preferred embodiments described herein, the probe is provided in excess over the INVADER oligonucleotide). Another means of assuring the presence of an INVADER oligonucleotide whenever a probe binds to a target nucleic acid is to design the INVADER oligonucleotide to hybridize more stably to the target, i.e., to have a higher T_m than the probe. This can be accomplished by any of the means of

increasing nucleic acid duplex stability discussed herein (e.g., by increasing the amount of complementarity to the target nucleic acid).

[0428] Buffer conditions should be chosen that will be compatible with both the oligonucleotide/target hybridization and with the activity of the cleavage agent. The optimal buffer conditions for nucleic acid modification enzymes, and particularly DNA modification enzymes, generally included enough mono- and di-valent salts to allow association of nucleic acid strands by base-pairing. If the method of the present invention is performed using an enzymatic cleavage agent other than those specifically described here, the reactions may generally be performed in any such buffer reported to be optimal for the nuclease function of the cleavage agent. In general, to test the utility of any cleavage agent in this method, test reactions are performed wherein the cleavage agent of interest is tested in the MOPS/$MnCl_2$/KCl buffer or Mg-containing buffers described herein and in whatever buffer has been reported to be suitable for use with that agent, in a manufacturer's data sheet, a journal article, or in personal communication.

[0429] The products of the INVADER oligonucleotide-directed cleavage reaction are fragments generated by structure-specific cleavage of the input oligonucleotides. The resulting cleaved and/or uncleaved oligonucleotides may be analyzed and resolved by a number of methods including, but not limited to, electrophoresis (on a variety of supports including acrylamide or agarose gels, paper, etc.), chromatography, fluorescence polarization, mass spectrometry and chip hybridization. In some Examples the invention is illustrated using electrophoretic separation for the analysis of the products of the cleavage reactions. However, it is noted that the resolution of the cleavage products is not limited to electrophoresis. Electrophoresis is chosen to illustrate the method of the invention because electrophoresis is widely practiced in the art and is easily accessible to the average practitioner. In other Examples, the invention is illustrated without electrophoresis or any other resolution of the cleavage products.

[0430] The probe and INVADER oligonucleotides may contain a label to aid in their detection following the cleavage reaction. The label may be a radioisotope (e.g., a ^{32}P or ^{35}S-labelled nucleotide) placed at either the 5' or 3' end of the oligonucleotide or alternatively, the label may be distributed throughout the oligonucleotide (i.e., a uniformly labeled oligonucleotide). The label may be a nonisotopic detectable moiety, such as a fluorophore, that can be detected directly, or a reactive group that permits specific recognition by a secondary agent. For example, biotinylated oligonucleotides may be detected by probing with a streptavidin molecule that is coupled to an indicator (e.g., alkaline phosphatase or a fluorophore) or a hapten such as digoxigenin may be detected using a specific antibody coupled to a similar indicator. The reactive group may also be a specific configuration or sequence of nucleotides that can bind or otherwise interact with a secondary agent, such as another nucleic acid, and enzyme, or an antibody.

[0431] c) Optimization of Reaction Conditions

[0432] The INVADER oligonucleotide-directed cleavage reaction is useful to detect the presence of specific nucleic acids. In addition to the considerations listed above for the selection and design of the INVADER and probe oligonucleotides, the conditions under which the reaction is to be performed may be optimized for detection of a specific target sequence.

[0433] One objective in optimizing the INVADER oligonucleotide-directed cleavage assay is to allow specific detection of the fewest copies of a target nucleic acid. To achieve this end, it is desirable that the combined elements of the reaction interact with the maximum efficiency, so that the rate of the reaction (e.g., the number of cleavage events per minute) is maximized. Elements contributing to the overall efficiency of the reaction include the rate of hybridization, the rate of cleavage, and the efficiency of the release of the cleaved probe.

[0434] The rate of cleavage will be a function of the cleavage means chosen, and may be made optimal according to the manufacturer's instructions when using commercial preparations of enzymes or as described in the examples herein. The other elements (rate of hybridization, efficiency of release) depend upon the execution of the reaction, and optimization of these elements is discussed below.

[0435] Three elements of the cleavage reaction that significantly affect the rate of nucleic acid hybridization are the concentration of the nucleic acids, the temperature at which the cleavage reaction is performed and the concentration of salts and/or other charge-shielding ions in the reaction solution.

[0436] The concentrations at which oligonucleotide probes are used in assays of this type are well known in the art, and are discussed above. One example of a common approach to optimizing an oligonucleotide concentration is to choose a starting amount of oligonucleotide for pilot tests; 0.01 to 2 μM is a concentration range used in many oligonucleotide-based assays. When initial cleavage reactions are performed, the following questions may be asked of the data: Is the reaction performed in the absence of the target nucleic acid substantially free of the cleavage product?; Is the site of cleavage specifically positioned in accordance with the design of the INVADER oligonucleotide?; Is the specific cleavage product easily detected in the presence of the uncleaved probe (or is the amount of uncut material overwhelming the chosen visualization method)?

[0437] A negative answer to any of these questions would suggest that the probe concentration is too high, and that a set of reactions using serial dilutions of the probe should be performed until the appropriate amount is identified. Once identified for a given target nucleic acid in a give sample type (e.g., purified genomic DNA, body fluid extract, lysed bacterial extract), it should not need to be re-optimized. The sample type is important because the complexity of the material present may influence the probe concentration optimum.

[0438] Conversely, if the chosen initial probe concentration is too low, the reaction may be slow, due to inefficient hybridization. Tests with increasing quantities of the probe will identify the point at which the concentration exceeds the optimum (e.g., at which it produces an undesirable effect, such as background cleavage not dependent on the target sequence, or interference with detection of the cleaved products). Since the hybridization will be facilitated by excess of probe, it is desirable, but not required, that the reaction be performed using probe concentrations just below this point.

[0439] The concentration of INVADER oligonucleotide can be chosen based on the design considerations discussed above. In some embodiments, the INVADER oligonucleotide is in excess of the probe oligonucleotide. In a preferred embodiment, the probe oligonucleotide is in excess of the INVADER oligonucleotide.

[0440] Temperature is also an important factor in the hybridization of oligonucleotides. The range of temperature tested will depend in large part on the design of the oligonucleotides, as discussed above. Where it is desired to have a reaction be run at a particular temperature (e.g., because of an enzyme requirement, for convenience, for compatibility with assay or detection apparatuses, etc.), the oligonucleotides that function in the reaction can be designed to optimally perform at the desired reaction temperature. Each INVADER reaction includes at least two target sequence-specific oligonucleotides for the primary reaction: an upstream INVADER oligonucleotide and a downstream probe oligonucleotide. In some preferred embodiments, the INVADER oligonucleotide is designed to bind stability at the reaction temperature, while the probe is designed to freely associate and disassociate with the target strand, with cleavage occurring only when an uncut probe hybridizes adjacent to an overlapping INVADER oligonucleotide. In preferred embodiments, the probe includes a 5' flap that is not complementary to the target, and this flap is released from the probe when cleavage occurs. The released flap can be detected directly or indirectly. In some preferred embodiments, as discussed in detail below, the released flap participate as in INVADER oligonucleotide in a secondary reaction.

[0441] Optimum conditions for the INVADER assay are generally those that allow specific detection of the smallest amount of a target nucleic acid. Such conditions may be characterized as those that yield the highest target-dependent signal in a given timeframe, or for a given amount of target nucleic acid, or that allow the highest rate of probe cleavage (i.e., probes cleaved per minute). To select a probe sequence that will perform optimally at a pre-selected reaction temperature, the melting temperature (T_m) of its analyte specific region (ASR, the region that is complementary to the target nucleic acid) is calculated using the nearest-neighbor model and published parameters for DNA duplex formation (SantaLucia, J., *Proc Natl Acad Sci USA* 95, 1460-5 (1998), Allawi, H. T. & SantaLucia, J., Jr. *Biochemistry* 36, 10581-94 (1997). However, there are several differences between the conditions under which the published parameters were measured and the conditions under which the INVADER assay is run in preferred embodiments. The salt concentrations are often different than the solution conditions in which the nearest-neighbor parameters were obtained (1M NaCl and no divalent metals). One can compensate for this factor by varying the value provided for the salt concentration within the melting temperature calculations. In addition to the salt concentration, the presence of and concentration of the enzyme influences the optimal reaction temperature, and an additional adjustment should be made to the calculated T_m to determine the optimal temperature at which to perform a reaction. By observing the optimal temperature for a number of INVADER reactions (i.e., the temperature at which the rate of signal accumulation is highest) it has been possible to further alter the value for salt concentration within these calculations to allow the algorithm for T_m calculation to be modified to instead provide an optimal cleavage reaction temperature for a given probe sequence. This additional adjustment is termed a "salt correction". As used herein, the term "salt correction" refers to a variation made in the value provided for a salt concentration, for the purpose of reflecting the effect on a T_m calculation for a nucleic acid duplex of a non-salt parameter or condition affecting said duplex. Variation of the values provided for the strand concentrations will also affect the outcome of these calculations. By using a value of 0.5 M NaCl [SantaLucia, J., *Proc Natl Acad Sci USA* 95, 1460-5 (1998)] and strand concentrations of about 1 μM of the probe and 1 fM target, the algorithm used for calculating probe-target melting temperature has been adapted for use in predicting optimal INVADER assay reaction temperature. For a set of about 30 probes, the average deviation between optimal assay temperatures calculated by this method and those experimentally determined was about 1.5° C.

[0442] As noted above, the concentration of the cleavage agent can affect the actual optimum temperature for a cleavage reaction. Additionally, different cleavage agents, even if used at identical concentrations, can affect reaction temperature optima differently (e.g., the difference between the calculated probe T_m and the observed optimal reaction temperature may be greater for one enzyme than for another). Determination of appropriate salt corrections for reactions using different enzymes or concentrations of enzymes, or for any other variation made in reaction conditions, involves a two step process of a) measuring reaction temperature optima under the new reaction conditions, and varying the salt concentration within the T_m algorithm to produce a calculated temperature matching or closely approximating the observed optima. Measurement of an optimum reaction temperature generally involves performing reactions at a range of temperatures selected such that the range allows observation of an increase in performance as an optimal temperature is approached (either by increasing or decreasing temperatures), and a decrease in performance when an optimal temperature has been passed, thereby allowing identification of the optimal temperature or temperature range [see, for example, V. I. Lyamichev, et al., Biochemistry 39, No. 31: 9523-9532 (2000)].

[0443] The length of the downstream probe analyte-specific region (ASR) is defined by the temperature selected for running the reaction, e.g., 63° C. in the experiments described in Examples 54 through 60. To select a probe sequence based on a desired reaction temperature, the probe sequence is selected in the following way (as illustrated for the design of a probe for the detection of a sequence difference at a particular location). Starting from the position of the variant nucleotide on the target DNA (position N, FIG. **112**); the target base that is paired to the probe nucleotide 5' of the intended cleavage site), an iterative procedure is used by which the length of the ASR is increased by one base pair until a calculated optimal reaction temperature (T_m plus salt correction to compensate for enzyme and any other reaction conditions effects) matching the desired reaction temperature is reached. The non-complementary arm of the probe is preferably selected (by a similar iterative process) to allow the secondary reaction to cycle at the same reaction temperature, and the entire probe design (ASR and 5' non-complementary arm) is screened using programs such as mfold [Zuker, M. *Science* 244, 48-52 (1989)] or Oligo 5.0 [Rychlik, W. & Rhoads, R. E. *Nucleic Acids Res* 17, 8543-51 (1989)] for the possible formation of dimer complexes or

secondary structures that could interfere with the reaction. The same principles are also followed for INVADER oligonucleotide design. The following describes design of an INVADER assay embodiment wherein the 3' end of the INVADER oligonucleotide, at position N on the target DNA, is designed to have a nucleotide not complementary to either allele suspected of being contained in the sample to be tested. The mismatch does not adversely affect cleavage [Lyamichev, V. et al. *Nature Biotechnology* 17, 292-296 (1999)], and it can enhance probe cycling, presumably by minimizing coaxial stabilization effects between the two probes. Briefly, starting from the position N, additional residues complementary to the target DNA starting from residue N−1 are then added in the upstream direction until the stability of the INVADER-target hybrid exceeds that of the probe (and therefore the planned assay reaction temperature). In preferred embodiments, the stability of the INVADER-target hybrid exceeds that of the probe by 15-20° C.

[**0444**] In some embodiments, where the released cleavage fragment from a primary reaction is to be used in a secondary reaction, one should also consider the reaction conditions of the secondary reaction in designing the oligonucleotides for the primary reaction (e.g., the sequence of the released non-complementary 5' flap of the probe in the primary reaction can be designed to optimally function in a secondary reaction). For example, as described in detail below, in some embodiments, a secondary reaction is used where the released cleavage fragment from a primary reaction hybridizes to a synthetic cassette to form a secondary cleavage reaction. In some preferred embodiments, the cassette comprises a fluorescing moiety and a quenching moiety, wherein cleavage of the secondary cleavage structure separates the fluorescing moiety from the quenching moiety, resulting in a detectable signal (e.g., FRET detection). The secondary reaction can be configured a number of different ways. For example, in some embodiments, the synthetic cassette comprises two oligonucleotides: an oligonucleotide that contains the FRET moieties and a FRET/INVADER oligonucleotide bridging oligonucleotide that allows the INVADER oligonucleotide (i.e., the released flap from the primary reaction) and the FRET oligonucleotide to hybridize thereto, such that a cleavage structure is formed. In some embodiments, the synthetic cassette is provided as a single oligonucleotide, comprising a hairpin structure (i.e., the FRET oligonucleotide is connected at its 3' end to the bridging oligonucleotide by a loop). The loop may be nucleic acid, (e.g., a string of nucleotides, such as the four T residues depicted in several Figures, including **113**A) or a non-nucleic acid spacer or linker. The linked molecules may together be described as a FRET cassette. In the secondary reaction using a FRET cassette the released flap from the primary reaction, which acts as an INVADER oligonucleotide, should be able to associate and disassociate with the FRET cassette freely, so that one released flap can direct the cleavage of multiple FRET cassettes. It is one aspect of the assay design that all of the probe sequences may be selected to allow the primary and secondary reactions to occur at the same optimal temperature, so that the reaction steps can run simultaneously. In an alternative embodiment, the probes may be designed to operate at different optimal temperatures, so that the reactions steps are not simultaneously at their temperature optima. As noted above, the same iterative process used to select the ASR of the probe can be used in the design of the portion of the primary probe that participates in a secondary reaction.

[**0445**] Another determinant of hybridization efficiency is the salt concentration of the reaction. In large part, the choice of solution conditions will depend on the requirements of the cleavage agent, and for reagents obtained commercially, the manufacturer's instructions are a resource for this information. When developing an assay utilizing any particular cleavage agent, the oligonucleotide and temperature optimizations described above should be performed in the buffer conditions best suited to that cleavage agent.

[**0446**] A "no enzyme" control allows the assessment of the stability of the labeled oligonucleotides under particular reaction conditions, or in the presence of the sample to be tested e.g., in assessing the sample for contaminating nucleases). In this manner, the substrate and oligonucleotides are placed in a tube containing all reaction components, except the enzyme and treated the same as the enzyme-containing reactions. Other controls may also be included. For example, a reaction with all of the components except the target nucleic acid will serve to confirm the dependence of the cleavage on the presence of the target sequence.

[**0447**] d) Selection of a Cleavage Agent

[**0448**] As demonstrated in a number of the Examples, some 5' nucleases do not require an upstream oligonucleotide to be active in a cleavage reaction. Although cleavage may be slower without the upstream oligonucleotide, it may still occur (Lyamichev et al., Science 260:778 [1993], Kaiser et al., J. Biol. Chem., 274:21387 [1999]). When a DNA strand is the template or target strand to which probe oligonucleotides are hybridized, the 5' nucleases derived from DNA polymerases and some flap endonucleases (FENs), such as that from *Methanococcus jannaschi*, can cleave quite well without an upstream oligonucleotide providing an overlap (Lyamichev et al., Science 260:778 [1993], Kaiser et al., J. Biol. Chem., 274:21387 [1999], and U.S. Pat. No. 5,843,669, herein incorporated by reference in its entirety). These nucleases may be selected for use in some embodiments of the INVADER assay, e.g., in embodiments wherein cleavage of the probe in the absence of an INVADER oligonucleotide gives a different cleavage product, which does not interfere with the intended analysis, or wherein both types of cleavage, INVADER oligonucleotide-directed and INVADER oligonucleotide-independent, are intended to occur.

[**0449**] In other embodiments it is preferred that cleavage of the probe be dependent on the presence of an upstream INVADER oligonucleotide, and enzyme having this requirement would be used. Other FENs, such as those from *Archeaoglobus fulgidus* (Afu) and *Pyrococcus furiosus* (Pfu), cleave an overlapped structure on a DNA target at so much greater a rate than they do a non-overlapping structure (i.e., either missing the upstream oligonucleotide or having a non-overlapping upstream oligonucleotide) that they can be viewed as having an essentially absolute requirement for the overlap (Lyamichev et al., Nat. Biotechnol., 17:292 [1999], Kaiser et al., J. Biol. Chem., 274:21387 [1999]). When an RNA target is hybridized to DNA oligonucleotide probes to form a cleavage structure, many FENs cleave the downstream DNA probe poorly, regardless of the presence of an overlap. On such an RNA-containing structure, the 5'

nucleases derived from DNA polymerases have a strong requirement for the overlap, and are essentially inactive in its absence.

[0450] e) Probing for Multiple Alleles

[0451] The INVADER oligonucleotide-directed cleavage reaction is also useful in the detection and quantification of individual variants or alleles in a mixed sample population. By way of example, such a need exists in the analysis of tumor material for mutations in genes associated with cancers. Biopsy material from a tumor can have a significant complement of normal cells, so it is desirable to detect mutations even when present in fewer than 5% of the copies of the target nucleic acid in a sample. In this case, it is also desirable to measure what fraction of the population carries the mutation. Similar analyses may also be done to examine allelic variation in other gene systems, and it is not intended that the method of the present invention by limited to the analysis of tumors.

[0452] As demonstrated below, in one embodiment, reactions can be performed under conditions that prevent the cleavage of probes bearing even a single-nucleotide difference mismatch within the region of the target nucleic acid termed "Z" in FIG. **29**, but that permit cleavage of a similar probe that is completely complementary to the target in this region. In a preferred embodiment, a mismatch is positioned at the nucleotide in the probe that is 5' of the site where cleavage occurs in the absence of the mismatch.

[0453] In other embodiments, the INVADER assay may be performed under conditions that have a tight requirement for an overlap (e.g., using the Afu FEN for DNA target detection or the 5' nuclease of DNA polymerase for RNA target detection, as described above), providing an alternative means of detecting single nucleotide or other sequence variations. In one embodiment, the probe is selected such that the target base suspected of varying is positioned at the 5' end of the target-complementary region of this probe. The upstream INVADER oligonucleotide is positioned to provide a single base of overlap. If the target and the probe oligonucleotide are complementary at the base in question, the overlap forms and cleavage can occur. This embodiment is diagrammed in FIG. **112**. However, if the target does not complement the probe at this position, that base in the probe becomes part of a non-complementary 5' arm, no overlap between the INVADER oligonucleotide and probe oligonucleotide exists, and cleavage is suppressed.

[0454] It is also contemplated that different sequences may be detected in a single reaction. Probes specific for the different sequences may be differently labeled. For example, the probes may have different dyes or other detectable moieties, different lengths, or they may have differences in net charges of the products after cleavage. When differently labeled in one of these ways, the contribution of each specific target sequence to final product can be tallied. This has application in detecting the quantities of different versions of a gene within a mixture. Different genes in a mixture to be detected and quantified may be wild type and mutant genes (e.g., as may be found in a tumor sample, such as a biopsy). In this embodiment, one might design the probes to precisely the same site, but one to match the wild-type sequence and one to match the mutant. Quantitative detection of the products of cleavage from a reaction performed for a set amount of time will reveal the ratio of the two genes in the mixture. Such analysis may also be performed on unrelated genes in a mixture. This type of analysis is not intended to be limited to two genes. Many variants within a mixture may be similarly measured.

[0455] Alternatively, different sites on a single gene may be monitored and quantified to verify the measurement of that gene. In this embodiment, the signal from each probe would be expected to be the same.

[0456] It is also contemplated that multiple probes may be used that are not differently labeled, such that the aggregate signal is measured. This may be desirable when using many probes designed to detect a single gene to boost the signal from that gene. This configuration may also be used for detecting unrelated sequences within a mix. For example, in blood banking it is desirable to know if any one of a host of infectious agents is present in a sample of blood. Because the blood is discarded regardless of which agent is present, different signals on the probes would not be required in such an application of the present invention, and may actually be undesirable for reasons of confidentiality.

[0457] Just as described for the two-oligonucleotide system, above, the specificity of the detection reaction will be influenced by the aggregate length of the target nucleic acid sequences involved in the hybridization of the complete set of the detection oligonucleotides. For example, there may be applications in which it is desirable to detect a single region within a complex genome. In such a case the set of oligonucleotides may be chosen to require accurate recognition by hybridization of a longer segment of a target nucleic acid, often in the range of 20 to 40 nucleotides. In other instances it may be desirable to have the set of oligonucleotides interact with multiple sites within a target sample. In these cases one approach would be to use a set of oligonucleotides that recognize a smaller, and thus statistically more common, segment of target nucleic acid sequence.

[0458] In one preferred embodiment, the INVADER and stacker oligonucleotides may be designed to be maximally stable, so that they will remain bound to the target sequence for extended periods during the reaction. This may be accomplished through any one of a number of measures well known to those skilled in the art, such as adding extra hybridizing sequences to the length of the oligonucleotide (up to about 50 nts in total length), or by using residues with reduced negative charge, such as phosphorothioates or peptide-nucleic acid residues, so that the complementary strands do not repel each other to degree that natural strands do. Such modifications may also serve to make these flanking oligonucleotides resistant to contaminating nucleases, thus further ensuring their continued presence on the target strand during the course of the reaction. In addition, the INVADER and stacker oligonucleotides may be covalently attached to the target (e.g., through the use of psoralen cross-linking).

II. Effect of ARRESTOR Molecules on Signal and Background in Sequential Invasive Cleavage Reactions.

[0459] As described above, and demonstrated in Example 36, the concentration of the probe that is cleaved can be used to increase the rate of signal accumulation, with higher concentrations of probe yielding higher final signal. However, the presence of large amounts of residual uncleaved probe can present problems for subsequent use of the cleaved products for detection or for further amplification. If

the subsequent step is a simple detection (e.g., by gel resolution), the excess uncut material may cause background by streaking or scattering of signal, or by overwhelming a detector (e.g., over-exposing a film in the case of radioactivity, or exceeding the quantitative detection limits of a fluorescence imager). This can be overcome by partitioning the product from the uncut probe (e.g., by using the charge reversal method described in Example 22 and discussed in detail below). In more complex detection methods, the cleaved product may be intended to interact with another entity to indicate cleavage. As noted above, the cleaved product can be used in any reaction that makes use of oligonucleotides, such as hybridization, primer extension, ligation, or the direction of invasive cleavage. In each of these cases, the fate of the residual uncut probe should be considered in the design of the reaction. In a primer extension reaction, the uncut probe can hybridize to a template for extension. If cleavage is required to reveal the correct 3' end for extension, the hybridized uncut probe will not be extended. It may, however, compete with the cleaved product for the template. If the template is in excess of the combination of cleaved and uncleaved probe, then both of the latter should be able to find a copy of template for binding. If, however, the template is limiting, any competition may reduce the portion of the cleaved probe that can find successfully bind to the available template. If a vast excess of probe was used to drive the initial reaction, the remainder may also be in vast excess over the cleavage product, and thus may provide a very effective competitor, thereby reducing the amount of the final reaction (e.g., extension) product for ultimate detection.

[**0460**] The participation of the uncut probe material in a secondary reaction can also contribute to background in these reactions. While the presentation of a cleaved probe for a subsequent reaction may represent an ideal substrate for the enzyme to be used in the next step, some enzymes may also be able to act, albeit inefficiently, on the uncut probe as well. It was shown in Example 43 that transcription can be promoted from a nicked promoter even when one side of the nick has additional unpaired nucleotides (termed a "branched promoter" in that Example). Similarly, when the subsequent reaction is to be an invasive cleavage, the uncleaved probe may bind to the elements intended to form the second cleavage structure with the cleaved probe. Two of the possible configurations are shown schematically in FIGS. **105** and **106**. The right hand structure in the second step in each Figure shows a possible configuration formed by the secondary reaction elements (e.g., secondary targets and/or probes) and the uncleaved primary probe. In each of these cases, it was found that some of the 5' nucleases described herein can catalyze some measure of cleavage of these defective structures. Even at a low level, this aberrant cleavage can be misinterpreted as positive target-specific cleavage signal.

[**0461**] With these negative effects of the surfeit of uncut probe considered, there is clearly a need for some method of preventing these interactions. As noted above, it is possible to partition the cleaved product from the uncut probe after the primary reaction by traditional methods. However, these methods are often time consuming, may be expensive (e.g., disposable columns, gels, etc.), and may increase the risk for sample mishandling or contamination. It is far preferable to configure the sequential reactions such that the original sample need not be removed to a new vessel for subsequent reaction.

[**0462**] The present invention provides a method for reducing interactions between the primary probe and other reactants. This method provides a means of specifically diverting the uncleaved probes from participation in the subsequent reactions. The diversion is accomplished by the inclusion in the next reaction step an agent designed to specifically interact with the uncleaved primary probe. While the primary probe in an invasive cleavage reaction is discussed for reasons of convenience, it is contemplated that the ARRESTOR molecules may be used at any reaction step within a chain of invasive cleavage steps, as needed or desired for the design of an assay. It is not intended that the ARRESTOR molecules of the present invention be limited to any particular step.

[**0463**] The method of diverting the residual uncut probes from a primary reaction makes use of agents that can be specifically designed or selected to bind to the uncleaved probe molecules with greater affinity than to the cleaved probes, thereby allowing the cleaved probe species to effectively compete for the elements of the subsequent reaction, even when the uncut probe is present in vast excess. These agents have been termed "ARRESTOR molecules," due to their function of stopping or arresting the primary probe from participation in the later reaction. In various Examples below, an oligonucleotide is provided as an ARRESTOR oligonucleotide in an invasive cleavage assay. It can be appreciated that any molecule or chemical that can discriminate between the full-length uncut probe and the cleaved probe, and that can bind or otherwise disable the uncleaved probe preferentially may be configured to act as an ARRESTOR molecules within the meaning of the present invention. For example, antibodies can be derived with such specificity, as can the "aptamers" that can be selected through multiple steps of in vitro amplification (e.g., "SELEX," U.S. Pat. Nos. 5,270,163 and 5,567,588; herein incorporated by reference) and specific rounds of capture or other selection means.

[**0464**] In one embodiment, the ARRESTOR molecule is an oligonucleotide. In another embodiment the ARRESTOR oligonucleotides is a composite oligonucleotide, comprising two or more short oligonucleotides that are not covalently linked, but that bind cooperatively and are stabilized by co-axial stacking. In a preferred embodiment, the oligonucleotide is modified to reduce interactions with the cleavage agents of the present invention. When an oligonucleotide is used as an ARRESTOR oligonucleotide, it is intended that it not participate in the subsequent reactive step. Consideration of the schematic diagrams in FIGS. **105** and **106**, particularly the right-most Figure in step 2b of each Figure, will show that the binding of the ARRESTOR oligonucleotide to the primary probe may, either with the participation of the secondary target, or without such participation, create a bifurcated structure that is a substrate for cleavage by the 5' nucleases used in some embodiments of the methods of the present invention. Formation of such structures would lead to some level of unintended cleavage that could contribute to background, reduce specific signal or compete for the enzyme. It is preferable to provide ARRESTOR oligonucleotides that will not create such cleavage structures. One method of doing this is to add to the

ARRESTOR oligonucleotides such modifications as have been found to reduce the activity of INVADER oligonucleotides, as the INVADER oligonucleotides occupy a similar position within a cleavage structure (i.e., the 3' end of the INVADER oligonucleotide positions the site of cleavage of an unpaired 5' arm). Modification of the 3' end of the INVADER oligonucleotides was examined for the effects on cleavage in Example 35; a number of the modifications tested were found to be significantly debilitating to the function of the INVADER oligonucleotide. Other modifications not described herein may be easily characterized by performing such a test using the cleavage enzyme to be used in the reaction for which the ARRESTOR oligonucleotide is intended.

[0465] In a preferred embodiment, the backbone of an ARRESTOR oligonucleotide is modified. This may be done to increase the resistance to degradation by nucleases or temperature, or to provide duplex structure that is a less favorable substrate for the enzyme to be used (e.g., A-form duplex vs. B-form duplex). In particularly preferred embodiment, the backbone modified oligonucleotide further comprises a 3' terminal modification. In a preferred embodiment, the modifications comprise 2' O-methyl substitution of the nucleic acid backbone, while in a particularly preferred embodiment, the 2' O-methyl modified oligonucleotide further comprises a 3' terminal amine group.

[0466] The purpose of the ARRESTOR oligonucleotide is to allow the minority population of cleaved probe to effectively compete with the uncleaved probe for binding whatever elements are to be used in the next step. While an ARRESTOR oligonucleotide that can discriminate between the two probe species absolutely (i.e., binding only to uncut and never to cut) may be of the greatest benefit in some embodiments, it is envisioned that in many applications, including the sequential INVADER assays described herein, the ARRESTOR oligonucleotide of the present invention may perform the intended function with only partial discrimination. When the ARRESTOR oligonucleotide has some interaction with the cleaved probe, it may prevent detection of some portion of these cleavage products, thereby reducing the absolute level of signal generated from a given amount of target material. If this same ARRESTOR oligonucleotide has the simultaneous effect of reducing the background of the reaction (i.e., from non-target specific cleavage) by a factor that is greater than the factor of reduction in the specific signal, then the significance of the signal (i.e., the ratio of signal to background), is increased, even with the lower amount of absolute signal. Any potential ARRESTOR molecule design may be tested in a simple fashion by comparing the levels of background and specific signals from reactions that lack ARRESTOR molecules to the levels of background and specific signal from similar reactions that include ARRESTOR oligonucleotides. Each of the reactions described in Examples 49-53 demonstrate the use of such comparisons, and these can easily be adapted by those skilled in the art to other ARRESTOR molecules and target embodiments. What constitutes an acceptable level of tradeoff of absolute signal for specificity will vary for different applications (e.g., target levels, read-out sensitivity, etc.), and can be determined by any individual user using the methods of the present invention.

III. Signal Enhancement by Incorporating the Products of an Invasive Cleavage Reaction into a Subsequent Invasive Cleavage Reaction

[0467] As noted above, the oligonucleotide product released by the invasive cleavage can be used subsequently in any reaction or read-out method that uses oligonucleotides in the size range of a cleavage product. In addition to the reactions involving primer extension and transcription, described herein, another enzymatic reaction that makes use of oligonucleotides is the invasive cleavage reaction. The present invention provide means of using the oligonucleotide released in a primary invasive cleavage reaction as a component to complete a cleavage structure to enable a secondary invasive cleavage reaction. One possible configuration of a primary cleavage reaction supplying a component for a secondary cleavage structure is diagrammed in FIG. **96**. Is not intended that the sequential use of the invasive cleavage product be limited to a single additional step. It is contemplated that many distinct invasive cleavage reactions may be performed in sequence.

[0468] The polymerase chain reaction uses a DNA replication method to create copies of a targeted segment of nucleic acid at a logarithmic rate of accumulation. This is made possible by the fact that when the strands of DNA are separated, each individual strand contains sufficient information to allow assembly of a new complementary strand. When the new strands are synthesized the number of identical molecules has doubled. Within 20 iterations of this process, the original may be copied 1 million-fold, making very rare sequences easily detectable. The mathematical power of a doubling reaction has been incorporated into a number of amplification assays, several of which are cited in Table 1.

[0469] By performing multiple, sequential invasive cleavage reactions the method of the present invention captures an exponential mathematical advantage without producing additional copies of the target analyte. In a simple invasive cleavage reaction the yield, Y, is simply the turnover rate, K, multiplied by the time of the reaction, t (i.e., $Y=(K)(t)$). If Y is used to represent the yield of a simple reaction, then the yield of a compound (i.e., a multiple, sequential reaction), assuming that each of the individual invasive cleavage steps has the same turnover rate, can be simply represented as Y^n, where n is the number of invasive cleavage reactions that have been performed in the series. If the yields of each step differ the ultimate yield can be represented as the product of the multiplication of the yields of each individual reaction in the series. For example, if a primary invasive cleavage reaction can produce one thousand products in 30 minutes, and each of those products can in turn participate in 1000 additional reactions, there will be 1000^2 copies (1000×1000) of the ultimate product in a second reaction. If a third reaction is added to the series, then the theoretical yield will be 1000^3 ($1000\times1000\times1000$). In the methods of the present invention the exponent comes from the number of invasive cleavage reactions in the cascade. This can be contrasted to the amplification methods described above (e.g., PCR) in which Y is limited to 2 by the number of strands in duplex DNA, and the exponent n is the number of cycles performed, so that many iterations are necessary to accumulate large amounts of product.

[0470] To distinguish the exponential amplifications described above from those of the present invention, the

former can be considered reciprocating reactions because the products the reaction feed back into the same reaction (e.g., event one leads to some number of events 2, and each event 2 leads back to some number of events 1). In contrast, the events of the present invention are sequential (e.g., event 1 leads to some number of events 2; each event 2 leads to some number of events 3, etc., and no event can contribute to an event earlier in the chain).

[0471] The sensitivity of the reciprocating methods is also one of the greatest weaknesses when these assays are used to determine if a target nucleic acid sequence is present or absent in a sample. Because the product of these reactions is detectable copies of the starting material, contamination of a new reaction with the products of an earlier reaction can lead to false positive results, (i.e., the apparent detection of the target nucleic acid in samples that do not actually contain any of that target analyte). Furthermore, because the concentration of the product in each positive reaction is so high, amounts of DNA sufficient to create a strong false positive signal can be communicated to new reactions very easily either by contact with contaminated instruments or by aerosol. In contrast to the reciprocating methods, the most concentrated product of the sequential reaction (i.e., the product released in the ultimate invasive cleavage event) is not capable of initiating a like reaction or cascade if carried over to a fresh test sample. This is a marked advantage over the exponential amplification methods described above because the reactions of the present invention may be performed without the costly containment arrangements (e.g., either by specialized instruments or by separate laboratory space) required by any reciprocating reaction. While the products of a penultimate event may be inadvertently transferred to produce a background of the ultimate product in the absence of the a target analyte, the contamination would need to be of much greater volume to give an equivalent risk of a false positive result.

[0472] When the term sequential is used it is not intended to limit the invention to configurations in which that one invasive cleavage reaction or assay must be completed before the initiation of a subsequent reaction for invasive cleavage of a different probe. Rather, the term refers to the order of events as would occur if only single copies of each of the oligonucleotide species were used in an assay. The primary invasive cleavage reaction refers to that which occurs first, in response to the formation of the cleavage structure on the target nucleic acid. Subsequent reactions may be referred to as secondary, tertiary and so forth, and may involve artificial "target" strands that serve only to support assembly of a cleavage structure, and which are unrelated to the nucleic acid analyte of interest. While the complete assay may, if desired, be configured with each step of invasive cleavage separated either in space (e.g., in different reaction vessels) or in time (e.g., using a shift in reaction conditions, such as temperature, enzyme identity or solution condition, to enable the later cleavage events), it is also contemplated that all of the reaction components may be mixed so that secondary reactions may be initiated as soon as product from a primary cleavage becomes available. In such a format, primary, secondary and subsequent cleavage events involving different copies of the cleavage structures may take place simultaneously.

[0473] Several levels of this sort of linear amplification can be envisioned, in which each successive round of cleavage produces an oligonucleotide that can participate in the cleavage of a different probe in subsequent rounds. The primary reaction would be specific for the analyte of interest with secondary (and tertiary, etc.) reactions being used to generate signal while still being dependent on the primary reaction for initiation.

[0474] The released product may perform in several capacities in the subsequent reactions. One of the possible variations is shown in FIG. **96**, in which the product of one invasive cleavage reaction becomes the INVADER oligonucleotide to direct the specific cleavage of another probe in a second reaction. In FIG. **96**, the first invasive cleavage structure is formed by the annealing of the INVADER oligonucleotide ("Invader") and the probe oligonucleotide ("Probe 1") to the first target nucleic acid ("Target 1"). The target nucleic acid is divided into three regions based upon which portions of the INVADER and probe oligonucleotides are capable of hybridizing to the target (as discussed above and as shown in FIG. **25**). Region 1 (region Y in FIG. **25**) of the target has complementarity to only the INVADER oligonucleotide; region 3 (region Z in FIG. **25**) of the target has complementarity to only the probe; and region 2 (region X in FIG. **25**) of the target has complementarity to both the INVADER and probe oligonucleotides. It is noted that the sequential invasive cleavage reaction diagrammed in FIG. **96** employs an INVADER and a probe oligonucleotide; the sequential cleavage reaction is not limited to the use of such a first cleavage structure. The first cleavage structure in the sequential reaction may also employ an INVADER oligonucleotide, a mini probe and a stacker oligonucleotide as discussed above. Further, as discussed above, the overlap in any or all of the cleavage structures in the sequential reactions may comprise moieties other than overlapping complementary bases, such that the region shown as "X" represents a region where there is a physical rather than sequence overlap between the INVADER and probe oligonucleotides

[0475] In FIG. **96**, cleavage of Probe 1 releases the "Cut Probe 1" (indicated by the hatched line in both the cleaved and uncleaved Probe 1 in FIG. **96**). The released Probe 1 is then used as the INVADER oligonucleotide in second cleavage. The second cleavage structure is formed by the annealing of the Cut Probe 1, a second probe oligonucleotide ("Probe 2") and a second target nucleic acid ("Target 2") In some embodiments, Probe 2 and the second target nucleic acid are covalently connected, preferably at their 3' and 5' ends, respectively, thus forming a hairpin stem and loop, termed herein a "cassette". The loop may be nucleic acid, (e.g., a string of nucleotides, such as the four T residues depicted in several Figures, including **113**A) or a non-nucleic acid spacer or linker. Inclusion of an excess of the cassette molecule allows each Cut Probe 1 to serve as an INVADER to direct the cleavage of multiple copies of the cassette.

[0476] Probe 2 may be labeled (e.g., as indicated by the star in FIG. **96**) and detection of cleavage of the second cleavage structure may be accomplished by detecting the labeled cut Probe 2; the label may a radioisotope (e.g., ^{32}P, ^{35}S), a fluorophore (e.g., fluorescein), a reactive group capable of detection by a secondary agent (e.g., biotin/streptavidin), a positively charged adduct which permits detection by selective charge reversal (as discussed in Section IV above), etc. Alternatively, the cut Probe 2 may used

in a tailing reaction, or to complete or activate a protein binding site, or may be detected or used by any of the means for detecting or using an oligonucleotide described herein.

[0477] Another possible configuration for performing a sequential invasive cleavage reaction is diagrammed in FIG. **97**. In this embodiment, probe oligonucleotides that are cleaved in the primary reaction can be designed to fold back on themselves (i.e., they contain a region of self-complementarity) to create a molecule that can serve as both the INVADER and target oligonucleotide (termed here an "IT" complex). The IT complex then enables cleavage of a different probe present in the secondary reaction. Inclusion of an excess of the secondary probe molecule ("Probe 2"), allows each IT molecule to serve as the platform for the generation of multiple copies of cleaved secondary probe. In FIG. **97**, the regions of self-complementarity contained within the 5' portion of the INVADER oligonucleotide is indicated by the hatched ovals; the arrow between these two ovals indicates that these two regions can self-pair (as shown in the "Cut Probe 1"). The target nucleic acid is divided into three regions based upon which portions of the INVADER and probe oligonucleotides are capable of hybridizing to the target (as discussed above and it is noted that the target may be divided into four regions if a stacker oligonucleotide is employed). The second cleavage structure is formed by the annealing of the second probe ("Probe 2") to the fragment of Probe 1 ("Cut Probe 1") that was released by cleavage of the first cleavage structure. The Cut Probe 1 forms a hairpin or stem/loop structure near its 3' terminus by virtue of the annealing of the regions of self-complementarity contained within Cut Probe 1 (this self-annealed Cut Probe 1 forms the IT complex). The IT complex (Cut Probe 1) is divided into three regions. Region 1 of the IT complex has complementarity to the 3' portion of Probe 2; region 2 has complementarity to both the 3' end of Cut Probe 1 and to the 5' portion of Probe 2 (analogous to the region of overlap "X" shown in FIG. **25**); and region 3 contains the region of self-complementarity (i.e., region 3 is complementary to the 3' portion of the Cut Probe 1). Note that with regard to the IT complex (i.e., Cut Probe 1), region 1 is located upstream of region 2 and region 2 is located upstream of region 3. As for other embodiments of invasive cleavage, the region shown as "2" can represent a region where there is a physical, but not sequence, overlap between the INVADER portion of the Cut Probe 1 and the Probe 2 oligonucleotide.

[0478] The cleavage products of the secondary invasive cleavage reaction (i.e., Cut Probe 2) can either be detected, or can in turn be designed to constitute yet another integrated INVADER-target complex to be used with a third probe molecule, again unrelated to the preceding targets.

[0479] The present invention is not limited to the configurations diagrammed in FIGS. **96** and **97**. It is envisioned that the oligonucleotide product of a primary cleavage reaction may fill the role of any of the oligonucleotides described herein (e.g., it may serve as a target strand without an attached INVADER oligonucleotide-like sequence, or it may serve as a stacker oligonucleotide, as described above), to enhance the turnover rate seen in the secondary reaction by stabilizing the probe hybridization through coaxial stacking.

[0480] Secondary cleavage reactions in some preferred embodiments of the present invention include the use of FRET cassettes such as those described in Examples 54 through 62. Such molecules provide both a secondary target and a FRET labeled cleavable sequence, allowing homogeneous detection (i.e., without product separation or other manipulation after the reaction) of the sequential invasive cleavage reaction. Other preferred embodiments use a secondary reaction system in which the FRET probe and synthetic target are provided as separate oligonucleotides.

[0481] In a preferred embodiment, each subsequent reaction is facilitated by (i.e., is dependent upon) the product of the previous cleavage, so that the presence of the ultimate product may serve as an indicator of the presence of the target analyte. However, cleavage in the second reaction need not be dependent upon the presence of the product of the primary cleavage reaction; the product of the primary cleavage reaction may merely measurably enhance the rate of the second cleavage reaction.

[0482] In summary, the INVADER assay cascade (i.e., sequential invasive cleavage reactions) of the present invention is a combination of two or more linear assays that allows the accumulation of the ultimate product at an exponential rate, but without significant risk of carryover contamination. It is an important to note that background that does not arise from sequential cleavage, such as thermal breakage of the secondary probe, generally increases linearly with time. In contrast, signal generation from a 2-step sequential reaction follows quadratic kinetics. Thus, collection of data as a time course, either by taking time points or through the use of an instrument that allows real-time detection during the INVADER assay reaction incubations, provides the attractive capability of discriminating between the true signal and any background solely on the basis of quadratic versus linear increases in signal over time. For example, when viewed graphically, the real signal will appear as a quadratic curve, while any accumulating background will be linear, and thus easy to distinguish, even if the absolute level of the background signal (e.g., fluorescence in a FRET detection format) is substantial.

[0483] The sequential invasive cleavage amplification of the present invention can be used as an intermediate boost to any of the detection methods (e.g., gel based analysis by either standard or by charge reversal), polymerase tailing, and incorporation into a protein binding region, described herein. When used is such combinations the increased production of a specific cleavage product in the invasive cleavage assay reduces the burdens of sensitivity and specificity on the read-out systems, thus facilitating their use.

[0484] In addition to enabling a variety of detection platforms, the cascade strategy is suitable for multiplex analysis of individual analytes (i.e., individual target nucleic acids) in a single reaction. The multiplex format can be categorized into two types. In one case, it is desirable to know the identity (and amount) of each of the analytes that can be present in a clinical sample, or the identity of each of the analytes as well as an internal control. To identify the presence of multiple individual analytes in a single sample, several distinct secondary amplification systems may be included. Each probe cleaved in response to the presence of a particular target sequence (or internal control) can be designed to trigger a different cascade coupled to different detectable moieties, such as different sequences to be extended by DNA polymerase or different dyes in an FRET format. The contribution of each specific target sequence to

final product can thereby be tallied, allowing quantitative detection of different genes or alleles in a sample containing a mixture of genes or alleles.

[0485] In the second configuration, it is desirable to determine if any of several analytes are present in a sample, but the exact identity of each does not need to be known. For example, in blood banking it is desirable to know if any one of a host of infectious agents is present in a sample of blood. Because the blood is discarded regardless of which agent is present, different signals on the probes would not be required in such an application of the present invention, and may actually be undesirable for reasons of confidentiality. In this case, the 5' arms (i.e., the 5' portion which will be released upon cleavage) of the different analyte-specific probes would be identical and would therefore trigger the same secondary signal cascade. A similar configuration would permit multiple probes complementary to a single gene to be used to boost the signal from that gene or to ensure inclusivity when there are numerous alleles of a gene to be detected.

[0486] In the primary INVADER reaction, there are two potential sources of background. The first is from INVADER-independent cleavage of probe annealed to the target, to itself, or to one of the other oligonucleotides present in the reaction. It can be seen by consideration of FIGS. **96** and **97** that the probes of the primary cleavage reactions depicted are designed to have regions of complementarity to the other oligonucleotides involved in the subsequent reactions, and, as depicted in FIG. **97**, to other regions of the same molecule. The use of an enzyme that cannot efficiently cleave a structure that lacks a primer (e.g., that cannot cleave the structures diagrammed in FIG. **16**A or **16** D) is preferred for this reason. As shown in FIGS. **99** and **100**, the enzyme Pfu FEN-1 gives no detectable cleavage in the absence of the upstream oligonucleotide or even in the presence of an upstream oligonucleotide that fails to invade the probe-target complex. This indicates that the Pfu FEN-1 endonuclease is a suitable enzyme for use in the methods of the present invention.

[0487] Other structure-specific nucleases may be suitable as a well. As discussed in the first example, some 5' nucleases can be used in conditions that significantly reduce this primer-independent cleavage. For example, it has been shown that when the 5' nuclease of DNAPTaq is used to cleave hairpins the primer-independent cleavage is markedly reduced by the inclusion of a monovalent salt in the reaction (Lyamichev, et al., [1993], supra).

[0488] Test for INVADER Oligonucleotide-Independent Cleavage

[0489] A simple test can be performed for any enzyme in combination with any reaction buffer to gauge the amount of INVADER oligonucleotide-independent cleavage to be expected from that combination. A small hairpin-like test molecule that can be used with or without a primer hybridized to a 3' arm, the S-60 molecule, is depicted in FIG. **30**. The S-60 and the oligonucleotide P15 are a convenient set of molecules for testing the suitability of an enzyme for application in the present invention and conditions for using these molecules are described in Example 11. Other similar hairpins may be used. A cleavage structure may be assembled from separate oligonucleotides as diagrammed in FIGS. **99***a-e*. Reactions using these structures to examine the activity of the Pfu FEN-1 enzyme in the presence or absence of an upstream overlapping oligonucleotide are described in Example 45 and the results are displayed in FIG. **100**. To test any particular combination of enzyme and cleavage conditions, similar reactions can be assembled. Outside of the variables of reaction conditions to be tested for any particular enzyme (e.g., salt sensitivities, divalent cation requirements) the test reactions should accommodate any known limitations of the test enzyme. For example, the test reactions should be performed at a temperature that is within the operating temperature range of the candidate enzyme, if known.

[0490] It is not necessary that multiple lengths of overlap be demonstrated for each candidate enzyme, but the activity of the enzyme in the absence of an upstream oligonucleotide (sequence or physical overlap) (as shown in FIG. **99***a*) and in the presence of an oligonucleotide that does not overlap (FIG. **99***b*) should be assessed. It is preferable that structures lacking an upstream oligonucleotide be cleaved at less than one half of the rate seen in the presence of an upstream overlapping oligonucleotide. It is more preferable that these structures be cleaved at less than about on tenth the rate of the invasive cleavage structure. It is most preferred that cleavage of these structures occur at less than one percent the rate of the invasive cleavage structure.

[0491] If the cleaved product is to serve as an upstream oligonucleotide in a subsequent cleavage reaction, as diagrammed in FIG. **96**, the most rapid reaction will be achieved if the other components of the second cleavage structure (i.e., Target 2 and Probe 2 in FIG. **96**) are provided in excess compared to the amount of first cleavage product, so that cleavage may proceed immediately after the upstream oligonucleotide (i.e., Cut Probe 1 in FIG. **96**) is made available. To provide an abundance of the second target strand or cassette (Target 2 in FIG. **96**) one may use an isolated natural nucleic acid, such as bacteriophage M13 DNA, or one may use a synthetic oligonucleotide. If a synthetic oligonucleotide is chosen as the second target sequence, the sequence employed should be examined for regions of unintended self-complementarity (similar considerations apply to short isolated natural nucleic acids such as restriction enzyme fragments or PCR products; natural nucleic acid targets whose 3' end is located ≧100 nucleotides downstream of the probe binding site on the target strand are generally long enough to obviate the design considerations discussed below). Specifically, it should be determined that the 3' end of the synthetic oligonucleotide may not hybridize to the target strand (i.e., intra-strand hybridization) upstream of the probe, triggering unintended cleavage. Simple examination of the sequence of the synthetic oligonucleotide should reveal if the 3' end has sufficient complementarity to the region of the target upstream of the probe binding site to pose a problem (i.e., it would reveal whether the synthetic oligonucleotide can form a hairpin at its 3' end which could act as an invading oligonucleotide to cause cleavage of the 2nd probe in the absence of the hybridization of the intended INVADER oligonucleotide (i.e., the cleavage product from the first invasive cleavage reaction)). If 3 or more of the last 4 to 7 nucleotides (the 3' terminal region) of the synthetic target can basepair upstream of the probe such that there is an overlap with the probe-target duplex, or such that the duplexes formed by the synthetic target strand with its own 3' terminal region and with the probe abut without a gap and the 3' terminal region

has an additional 1 or 2 nucleotides unpaired at the extreme 3' end of the synthetic target, then the sequence of the synthetic target oligonucleotide should be modified. The sequence may be changed to disrupt the interaction of the 3' terminal region or to increase the distance between the probe binding site and the regions to which the 3' terminus is binding. Alternatively, the 3' end may be modified to reduce its ability to direct cleavage (e.g., by adding a 3' phosphate during synthesis) (see Ex. 35, Table 3) or by adding several additional nucleotides that will not basepair in a self-complementary manner (i.e., they will not participate in the formation of a hairpin structure).

[0492] When the product of a first invasive cleavage reaction is designed to form a target that can fold on itself to direct cleavage of a second probe, the IT complex as diagrammed in FIG. **97**, the design of the sequence used to form the stem/loop of the IT complex should be considered. To be factored into the design of such a probe are 1) the length of the region of self-complementarity, 2) the type of overlap (i.e., what 3' moiety) and, if an overlap in sequence is selected, the length of the region of overlap (region "X" in FIG. **25**) and 3) the stability of the hairpin or stem/loop structure as predicted by both Watson-Crick base pairing and by the presence or absence of a particularly stable loop sequence (e.g., a tetraloop [Tinoco et al., supra], or a triloop [Hirao et al., supra]). It is desirable that this sequence have nucleotides that can base pair (intrastrand), so that the second round of invasive cleavage may occur, but that the structure not be so strong that its presence will prevent the cleavage of the probe in the primary reaction (i.e., Probe 1 in FIG. **96**). As shown herein, the presence of a secondary structure in the 5' arm of a cleavage structure cleaved by a structure-specific nuclease may inhibit cleavage by some structure-specific nucleases (Ex. 1).

[0493] The length of the region of self-complementarity within Probe 1 determines the length of the region of the duplex upstream of Probe 2 in the second cleavage structure (see FIG. **97**). Different enzymes have different length requirements for this duplex to effect invasive cleavage efficiently. For example, the Pfu FEN-1 and Mja FEN-1 enzymes have been tested for the effect of this duplex length using the set of target/INVADER oligonucleotide molecules depicted in FIG. **98** (i.e., SEQ ID NOS:118, 119, 147-151). The invasive cleavage reactions were performed as described in Example 38, using 1 pM IT3 (SEQ ID NO:118), 2 μM probe PR1 (SEQ ID NO:119) for 5 min, and the rates of cleavage are shown in Table 2.

TABLE 2

Length of Duplex	Pfu FEN-1 Turnover, per min.	Mja FEN-1 Turnover, per min.
0	0	0
3	1	29
4	10	57
6	44	51
8	45	46

[0494] The data shown in Table 2 demonstrate that the Pfu FEN-1 enzyme can be used with stems of 3 or 4 bases, but that the rate of cleavage is maximized when the stem is greater than 4 basepairs in length. Table 2 shows that the Mja FEN-1 enzyme can cleave efficiently using shorter stems; however, as this enzyme can also cleave a probe in the absence of an upstream oligonucleotide, Mja FEN-1 is not preferred for use in the sequential invasive cleavage methods of the present invention.

[0495] A similar test can be performed using any candidate enzyme to determine how much self-complementarity may be designed into the Probe 1. The use of a shorter stem means that the overall probe may be shorter. This is beneficial because shorter probes are less costly to synthesize, and because shorter probes will have fewer sequences that might form unintended intrastrand structures. In assessing the activity of a candidate enzyme on the structures such as those shown in FIG. **98** it is not required that the stem length chosen allow the maximum rate of cleavage to occur. For example, in considering the case of Pfu FEN-1, the advantages of using a 4 basepair stem (e.g., cost or sequence limitations), with a cleavage rate of 10 cleavages per minute, may outweigh the rate advantage of using a longer 6 basepair stem (44 cleavages/min.), in the context of a particular experiment. It is within the scope of the present invention that some elements chosen for use in the assay be sub-optimal for performance of that particular element, if the use of a sub-optimal design benefits the objectives of that particular experiment as a whole.

[0496] In designing oligonucleotides to be employed as a probe that, once cleaved, forms a stem-loop structure as diagrammed in FIG. **97** (i.e., Probe 1 in FIG. **97**), it has been found that the stability of the loop is not a factor in the efficiency of cleavage of either Probe 1 or Probe 2. Loops tested have included stable triloops, loops of 3 and 4 nucleotides that were not predicted to be particularly stable (i.e., the stability is determined by the duplex sequence and not by additional stabilizing interactions within the loop), and large loops of up to about 25 nucleotides.

IV. Fractionation of Specific Nucleic Acids by Selective Charge Reversal

[0497] Some nucleic acid-based detection assays involve the elongation and/or shortening of oligonucleotide probes. For example, as described herein, the primer-directed, primer-independent, and INVADER-directed cleavage assays, as well as the "nibbling" assay all involve the cleavage (i.e., shortening) of oligonucleotides as a means for detecting the presence of a target nucleic sequence. Examples of other detection assays that involve the shortening of an oligonucleotide probe include the "TaqMan" or nick-translation PCR assay described in U.S. Pat. No. 5,210,015 to Gelfand et al. (the disclosure of which is herein incorporated by reference), the assays described in U.S. Pat. Nos. 4,775,619 and 5,118,605 to Urdea (the disclosures of which are herein incorporated by reference), the catalytic hybridization amplification assay described in U.S. Pat. No. 5,403,711 to Walder and Walder (the disclosure of which is herein incorporated by reference), and the cycling probe assay described in U.S. Pat. Nos. 4,876,187 and 5,011,769 to Duck et al. (the disclosures of which are herein incorporated by reference). Examples of detection assays that involve the elongation of an oligonucleotide probe (or primer) include the polymerase chain reaction (PCR) described in U.S. Pat. Nos. 4,683,195 and 4,683,202 to Mullis and Mullis et al. (the disclosures of which are herein incorporated by reference) and the ligase chain reaction (LCR) described in U.S. Pat. Nos. 5,427,930 and 5,494,810

to Birkenmeyer et al. and Barany et al. (the disclosures of which are herein incorporated by reference). The above examples are intended to be illustrative of nucleic acid-based detection assays that involve the elongation and/or shortening of oligonucleotide probes and do not provide an exhaustive list.

[0498] Typically, nucleic acid-based detection assays that involve the elongation and/or shortening of oligonucleotide probes require post-reaction analysis to detect the products of the reaction. It is common that the specific reaction product(s) must be separated from the other reaction components, including the input or unreacted oligonucleotide probe. One detection technique involves the electrophoretic separation of the reacted and unreacted oligonucleotide probe. When the assay involves the cleavage or shortening of the probe, the unreacted product will be longer than the reacted or cleaved product. When the assay involves the elongation of the probe (or primer), the reaction products will be greater in length than the input. Gel-based electrophoresis of a sample containing nucleic acid molecules of different lengths separates these fragments primarily on the basis of size. This is due to the fact that in solutions having a neutral or alkaline pH, nucleic acids having widely different sizes (i.e., molecular weights) possess very similar charge-to-mass ratios and do not separate (Andrews, Electrophoresis, 2nd Edition, Oxford University Press (1986), pp. 153-[54]. The gel matrix acts as a molecular sieve and allows nucleic acids to be separated on the basis of size and shape (e.g., linear, relaxed circular or covalently closed supercoiled circles).

[0499] Unmodified nucleic acids have a net negative charge due to the presence of negatively charged phosphate groups contained within the sugar-phosphate backbone of the nucleic acid. Typically, the sample is applied to gel near the negative pole and the nucleic acid fragments migrate into the gel toward the positive pole with the smallest fragments moving fastest through the gel.

[0500] The present invention provides a novel means for fractionating nucleic acid fragments on the basis of charge. This novel separation technique is related to the observation that positively charged adducts can affect the electrophoretic behavior of small oligonucleotides because the charge of the adduct is significant relative to charge of the whole complex. In addition to the use of positively charged adducts (e.g., Cy3 and Cy5 fluorescent dyes, the positively charged heterodimeric DNA-binding dyes shown in FIG. **66**, etc.), the oligonucleotide may contain amino acids (particularly useful amino acids are the charged amino acids: lysine, arginine, asparate, glutamate), modified bases, such as amino-modified bases, and/or a phosphonate backbone (at all or a subset of the positions). In other embodiments, as discussed further below, a neutral dye or detection moiety (e.g., biotin, streptavidin, etc.) may be employed in place of a positively charged adduct, in conjunction with the use of amino-modified bases and/or a complete or partial phosphonate backbone.

[0501] This observed effect is of particular utility in assays based on the cleavage of DNA molecules. Using the assays described herein as an example, when an oligonucleotide is shortened through the action of a CLEAVASE enzyme or other cleavage agent, the positive charge can be made to not only significantly reduce the net negative charge, but to actually override it, effectively "flipping" the net charge of the labeled entity. This reversal of charge allows the products of target-specific cleavage to be partitioned from uncleaved probe by extremely simple means. For example, the products of cleavage can be made to migrate towards a negative electrode placed at any point in a reaction vessel, for focused detection without gel-based electrophoresis; Example 24 provides examples of devices suitable for focused detection without gel-based electrophoresis. When a slab gel is used, sample wells can be positioned in the center of the gel, so that the cleaved and uncleaved probes can be observed to migrate in opposite directions. Alternatively, a traditional vertical gel can be used, but with the electrodes reversed relative to usual DNA gels (i.e., the positive electrode at the top and the negative electrode at the bottom) so that the cleaved molecules enter the gel, while the uncleaved disperse into the upper reservoir of electrophoresis buffer.

[0502] An important benefit of this type of readout is the absolute nature of the partition of products from substrates (i.e., the separation is virtually 100%). This means that an abundance of uncleaved probe can be supplied to drive the hybridization step of the probe-based assay, yet the unconsumed (i.e., unreacted) probe can, in essence, be subtracted from the result to reduce background by virtue of the fact that the unreacted probe will not migrate to the same pole as the specific reaction product.

[0503] Through the use of multiple positively charged adducts, synthetic molecules can be constructed with sufficient modification that the normally negatively charged strand is made nearly neutral. When so constructed, the presence or absence of a single phosphate group can mean the difference between a net negative or a net positive charge. This observation has particular utility when one objective is to discriminate between enzymatically generated fragments of DNA, which lack a 3' phosphate, and the products of thermal degradation, which generally retain a 3' phosphate (and thus two additional negative charges). Examples 22 and 23 demonstrate the ability to separate positively charged reaction products from a net negatively charged substrate oligonucleotide. As discussed in these examples, oligonucleotides may be transformed from net negative to net positively charged compounds. In Example 23, the positively charged dye, Cy3 was incorporated at the 5' end of a 22-mer (SEQ ID NO:50) which also contained two amino-substituted residues at the 5' end of the oligonucleotide; this oligonucleotide probe carries a net negative charge. After cleavage, which occurred 2 nucleotides into the probe, the following labeled oligonucleotide was released: 5'-Cy3-AminoT-AminoT-3' (in addition to unlabeled fragment comprising the remaining 20 nucleotides of SEQ ID NO:50). This short fragment bears a net positive charge while the remainder of the cleaved oligonucleotide and the unreacted or input oligonucleotide bear net negative charges.

[0504] The present invention contemplates embodiments wherein the specific reaction product produced by any cleavage of any oligonucleotide can be designed to carry a net positive charge while the unreacted probe is charge neutral or carries a net negative charge. The present invention also contemplates embodiments where the released product may be designed to carry a net negative charge while the input nucleic acid carries a net positive charge. Depending on the length of the released product to be

detected, positively charged dyes may be incorporated at the one end of the probe and modified bases may be placed along the oligonucleotide such that upon cleavage, the released fragment containing the positively charged dye carries a net positive charge. Amino-modified bases may be used to balance the charge of the released fragment in cases where the presence of the positively charged adduct (e.g., dye) alone is not sufficient to impart a net positive charge on the released fragment. In addition, the phosphate backbone may be replaced with a phosphonate backbone at a level sufficient to impart a net positive charge (this is particularly useful when the sequence of the oligonucleotide is not amenable to the use of amino-substituted bases); FIGS. **45** and **46** show the structure of short oligonucleotides containing a phosphonate group on the second T residue). An oligonucleotide containing a fully phosphonate-substituted backbone would be charge neutral (absent the presence of modified charged residues bearing a charge or the presence of a charged adduct) due to the absence of the negatively charged phosphate groups. Phosphonate-containing nucleotides (e.g., methylphosphonate-containing nucleotides are readily available and can be incorporated at any position of an oligonucleotide during synthesis using techniques which are well known in the art.

[**0505**] In essence, the invention contemplates the use of charge-based separation to permit the separation of specific reaction products from the input oligonucleotides in nucleic acid-based detection assays. The foundation of this novel separation technique is the design and use of oligonucleotide probes (typically termed "primers" in the case of PCR) which are "charge balanced" so that upon either cleavage or elongation of the probe it becomes "charge unbalanced," and the specific reaction products may be separated from the input reactants on the basis of the net charge.

[**0506**] In the context of assays that involve the elongation of an oligonucleotide probe (i.e., a primer), such as is the case in PCR, the input primers are designed to carry a net positive charge. Elongation of the short oligonucleotide primer during polymerization will generate PCR products that now carry a net negative charge. The specific reaction products may then easily be separated and concentrated away from the input primers using the charge-based separation technique described herein (the electrodes will be reversed relative to the description in Example 23 as the product to be separated and concentrated after a PCR will carry a negative charge).

V. Signal Enhancement by Tailing of Reaction Products in the INVADER Oligonucleotide-Directed Cleavage Assay

[**0507**] It has been determined that when oligonucleotide probes are used in cleavage detection assays at elevated temperature, some fraction of the truncated probes will have been shortened by nonspecific thermal degradation, and that such breakage products can make the analysis of the target-specific cleavage data more difficult. The thermal degradation that creates a background ladder of bands when the probes of the present invention are treated at high temperature for more than a few minutes occurs as a two step process. In the first step the N-glycosyl bond breaks, leaving an abasic site in the DNA strand. At the abasic site the DNA chain is weakened and undergoes spontaneous cleavage through a beta-elimination process. It has been determined that purine bases are about 20 times more prone to breakage than pyrimidine bases (Lindahl, Nature 362:709 [1993]). This suggests that one way of reducing background in methods using oligonucleotides at elevated temperatures is to select target sequences that allow the use of pyrimidine-rich probes. It is preferable, where possible, to use oligonucleotides that are entirely composed of pyrimidine residues. If only one or a few purines are used, the background breakage will appear primarily at the corresponding sites, and these bands (due to thermal breakdown) may be mistaken for the intended cleavage products if care is not taken in the data analysis (i.e., proper controls must be run).

[**0508**] Background cleavage due to thermal breakdown of probe oligonucleotides can, when not resolved from specific cleavage products, reduce the accuracy of quantitation of target nucleic acids based on the amount of accumulated product in a set timeframe. One means of distinguishing the specific from the nonspecific products is disclosed above, and is based on partitioning the products of these reactions by differences in the net charges carried by the different molecular species in the reaction. As was noted in that discussion, the thermal breakage products usually retain 3' phosphates after breakage, while the enzyme-cleaved products do not. The two negative charges on the phosphate facilitate charge-based partition of the products.

[**0509**] The absence of a 3' phosphate on the desired subset of the probe fragments may be used to advantage in enzymatic assays as well. Nucleic acid polymerases, both non-templated (e.g., terminal deoxynucleotidyl transferase, polyA polymerase) and template-dependent (e.g., Pol I-type DNA polymerases), require an available 3' hydroxyl by which to attach further nucleotides. This enzymatic selection of 3' end structure may be used as an effective means of partitioning specific from non-specific products.

[**0510**] In addition to the benefits of the partitioning described above, the addition of nucleotides to the end of the specific product of an INVADER oligonucleotide-specific cleavage offers an opportunity to either add label to the products, to add capturable tails to facilitate solid-support based readout systems, or to do both of these things at the same time. Some possible embodiments of this concept are illustrated in FIG. **56**.

[**0511**] In FIG. **56**, an INVADER cleavage structure comprising an INVADER oligonucleotide containing a blocked or non-extendible 3' end (e.g., a 3' dideoxynucleotide) and a probe oligonucleotide containing a blocked or non-extendable 3' end (the open circle at the 3' end of the oligonucleotides represents a non-extendible nucleotide) and a target nucleic acid is shown; the probe oligonucleotide may contain a 5' end label such as a biotin or a fluorescein (indicated by the stars) label (cleavage structures which employ a 5' biotin-labeled probe or a 5' fluorescein-labeled probe are shown below the large diagram of the cleavage structure to the left and the right, respectively). Following cleavage of the probe (the site of cleavage is indicated by the large arrowhead), the cleaved biotin-labeled probe is extended using a template-independent polymerase (e.g., TdT) and fluoresceinated nucleotide triphosphates. The fluorescein tailed cleaved probe molecule is then captured by binding via its 5' biotin label to streptavidin and the fluorescence is then measured. Alternatively, following, cleavage of a 5'-fluoresceinated probe, the cleaved probe is extended using a template-independent polymerase (e.g., TdT) and dATP.

The polyadenylated (A-tailed) cleaved probe molecule is then captured by binding via the polyA tail to oligo dT attached to a solid support.

[0512] The examples described in FIG. **56** are based on the use of TdT to tail the specific products of INVADER-directed cleavage. The description of the use of this particular enzyme is presented by way of example and is not intended as a limitation (indeed, when probe oligonucleotides comprising RNA are employed, cleaved RNA probes may be extended using polyA polymerase). It is contemplated that an assay of this type can be configured to use a template-dependent polymerase, as described above. While this would require the presence of a suitable copy template distinct from the target nucleic acid, on which the truncated oligonucleotide could prime synthesis, it can be envisaged that a probe that before cleavage would be unextendible, due to either mismatch or modification of the 3' end, could be activated as a primer when cleaved by an INVADER oligonucleotide-directed cleavage. A template directed tailing reaction also has the advantage of allowing greater selection and control of the nucleotides incorporated.

[0513] The use of nontemplated tailing does not require the presence of any additional nucleic acids in the detection reaction, avoiding one step of assay development and troubleshooting. In addition, the use of non-templated synthesis eliminated the step of hybridization, potentially speeding up the assay. Furthermore, the TdT enzyme is fast, able to add at least >700 nucleotides to substrate oligonucleotides in a 15 minute reaction.

[0514] As mentioned above, the tails added can be used in a number of ways. It can be used as a straight-forward way of adding labeled moieties to the cleavage product to increase signal from each cleavage event. Such a reaction is depicted in the left side of FIG. **66**. The labeled moieties may be anything that can, when attached to a nucleotide, be added by the tailing enzyme, such as dye molecules, haptens such as digoxigenin, or other binding groups such as biotin.

[0515] In a preferred embodiment the assay includes a means of specifically capturing or partitioning the tailed INVADER oligonucleotide-directed cleavage products in the mixture. It can be seen that target nucleic acids in the mixture may be tailed during the reaction. If a label is added, it is desirable to partition the tailed INVADER oligonucleotide-directed cleavage products from these other labeled molecules to avoid background in the results. This is easily done if only the cleavage product is capable of being captured. For example, consider a cleavage assay of the present invention in which the probe used has a biotin on the 5' end and is blocked from extension on the 3' end, and in which a dye is added during tailing. Consider further that the products are to be captured onto a support via the biotin moiety, and the captured dye measured to assess the presence of the target nucleic acid. When the label is added by tailing, only the specifically cleaved probes will be labeled. The residual uncut probes can still bind in the final capture step, but they will not contribute to the signal. In the same reaction, nicks and cuts in the target nucleic acid may be tailed by the enzyme, and thus become dye labeled. In the final capture these labeled targets will not bind to the support and thus, although labeled, they will not contribute to the signal. If the final specific product is considered to consist of two portions, the probe-derived portion and the tail portion, it can be seen from this discussion that it is particularly preferred that, when the probe-derived portion is used for specific capture, whether by hybridization, biotin/streptavidin, or other method, that the label be associated with the tail portion. Conversely, if a label is attached to the probe-derived portion, then the tail portion may be made suitable for capture, as depicted on the right side of FIG. **66**. Tails may be captured in a number of ways, including hybridization, biotin incorporation with streptavidin capture, or by virtue if the fact that the longer molecules bind more predictably and efficiently to a number of nucleic acid minding matrices, such as nitrocellulose, nylon, or glass, in membrane, paper, resin, or other form. While not required for this assay, this separation of functions allows effective exclusion from signal of both unreacted probe and tailed target nucleic acid.

[0516] In addition to the supports described above, the tailed products may be captured onto any support that contains a suitable capture moiety. For example, biotinylated products are generally captured with avidin-treated surfaces. These avidin surfaces may be in microtitre plate wells, on beads, on dipsticks, to name just a few of the possibilities. Such surfaces can also be modified to contain specific oligonucleotides, allowing capture of product by hybridization. Capture surfaces as described herein are generally known to those skilled in the art and include nitrocellulose dipsticks (e.g., GENECOMB, BioRad, Hercules, Calif.).

VI. Signal Enhancement by Completion of an Activated Protein Binding Site

[0517] In addition to the DNA polymerase tailing reaction described above, the present invention also contemplates the use of the products of the invasive cleavage reaction to form activated protein binding sites, such as RNA polymerase promoter duplexes, thereby allowing the interaction of the completed site to be used as an indicator of the presence of the nucleic acid that is the target of the invasive cleavage reaction. By way of example, when an RNA polymerase promoter duplex is activated by being made complete (i.e., double-stranded over that portion of the promoter region required for polymerase binding) through the hybridization of the oligonucleotide product of the invasive cleavage reaction, the synthesis of RNA can be used as such an indicator.

[0518] It is not intended that the transcription reaction of the present invention be limited to the use of any particular RNA polymerase or RNA polymerase promoter region. Promoter sequences are well characterized for several bacteriophage, including bacteriophage SP6, T7 and T3. In addition, promoter sequences have been well characterized for a number of both eukaryotic and prokaryotic RNA polymerases. In a preferred embodiment, the promoter used enables transcription from one of the bacteriophage RNA polymerases. In a particularly preferred embodiment, the promoter used enables transcription by T7 RNA polymerase. Means of performing transcription in vitro are well known in the art and commercial kits are available for performing transcription with eukaryotic, prokaryotic or bacteriophage RNA polymerases (e.g., from Promega Corp., Madison, Wis.).

[0519] The protein binding regions of the present invention are not limited to the bacteriophage RNA polymerase promoters described above. Other promoter sequences that

are contemplated are those of prokaryotes and eukaryotes. For example, many strains of bacteria and fungi are used for the expression of heterologous proteins. The minimal promoters required for transcription by the RNA polymerases of organisms such as yeast and other fungi, eubacteria, nematodes, and cultured mammalian cells are well described in the literature and in the catalogs of commercial suppliers of DNA vectors for the expression of foreign proteins in these organisms.

[0520] The binding sites for other types of nucleic acid (e.g., DNA) binding proteins are contemplated for use in the present invention. For example, proteins involved in the regulation of genes exert their effects by binding to the DNA in the vicinity of the promoter from which the RNA from that gene is transcribed. The lac operator of *E. coli* is one example of a particularly well characterized and commonly used gene regulation system in which the lac repressor protein binds to specific sequences that overlap, and thus block, the promoter for the genes under the repressor's control (Jacob and Monod, Cold Spring Harbor Symposium on Quantitative Biol. XXVI:193-211 [1961]). Many similar systems have been described in bacteria, including the trp and AraC regulatory systems. Given the large amount of information available about bacterial promoters, the steps described below for the design of suitable partial promoters for the bacteriophage RNA polymerases can be readily adapted to the design of detection systems based on these other promoters.

[0521] As noted above, many of the bacterial promoters are under the control of a repressor or other regulatory protein. It is considered to be within the scope of the present invention to include the creation of composite binding sites for these regulatory proteins through the provision of a nucleic acid fragment (e.g., a non-target cleavage product generated in an invasive cleavage reaction). The binding of the regulatory protein to the completed protein binding region (e.g., the composite binding region) can be assessed by any one of a number of means, including slowed electrophoretic migration of either the protein or the DNA fragment, or by a conformational change in the protein or DNA upon binding. In addition, transcription from a downstream promoter can be monitored for up- or down-regulation as a result of the binding of the regulatory protein to the completed protein binding region.

[0522] In addition to the bacterial systems described above, many genes in eukaryotic systems have also been found to be under the control of specific proteins that bind to specific regions of duplex DNA. Examples include, but are not limited to, the OCT-1, OCT-2 and AP-4 proteins in mammals and the GAL4 and GCN4 proteins in yeast. Such regulatory proteins usually have a structural motif associated with duplex nucleic acid binding, such as a helix-turn-helix, a zinc finger or a leucine zipper [for review, see, *Molecular and Cellular Biology*, Wolfe (Ed.), Wadsworth Publishing Co., Belmont, Calif., pp. 694-715 [1993]).

[0523] For simplicity the test reaction described here will refer to T7 RNA polymerase, and its promoter. This is not intended to limit the invention to the use of this RNA polymerase, and those skilled in the art of molecular biology would be able to readily adapt this described test to the examination of any of the DNA binding proteins, RNA polymerases and their binding or promoter sites discussed above.

[0524] It is known in the art that active T7 promoters can be formed by the hybridization of two oligonucleotides, each comprising either the top or bottom strand of the promoter sequence, such that a complete un-nicked duplex promoter is formed (Milligan et al., Nucl. Acids Res., 15:21, 8783-8798 (1987)]. The present invention shows that one way of making the initiation of transcription dependent on the products of an invasive cleavage reaction is to design the probe for the cleavage reaction such that a portion of an RNA polymerase promoter is released as product. The remaining DNA piece or pieces required to assemble a promoter duplex may either be provided as elements in the reaction mixture, or they may be produced by other invasive cleavage events. If the oligonucleotide pieces are designed to comprise appropriate regions of complementarity they may base pair to form a complete promoter duplex composed of three or more nucleic acid fragments, as depicted in FIG. **88**B. A promoter assembled in this way will have nicks in the backbone of one or both strands. In one embodiment, these nicks may be covalently closed through the use of a DNA ligase enzyme. In a preferred embodiment, the nicks are positioned such that transcription can proceed without ligation. In selecting the site of a nick created by the assembly of the partial promoter fragment, at least one nick should be within the recognized promoter region for the RNA polymerase to be used. When a bacteriophage promoter is used, a nick should be between nucleotides −17 and −1, measured from the site of transcription initiation at +1. In a preferred embodiment, a nick will be between nucleotides −13 and −8. In a particularly preferred embodiment, a nick will be between nucleotides −12 and −10 on the non-template strand of the bacteriophage promoter.

[0525] When nicks are to be left unrepaired (i.e., not covalently closed with a DNA ligase) it is important to assess the effect of the nick location on the level of transcription from the assembled promoter. A simple test is to combine the oligonucleotides that comprise the separate portions of the promoter with an oligonucleotide that comprises one entire strand of the promoter to be assembled, thereby forming a duplex promoter with a nick in one strand. If the nick is in the top, or non-template strand of the promoter, then the oligonucleotide that comprises the complete promoter is made to include additional non-promoter sequence on its 5' end to serve as a template to be copied in the transcription. This arrangement is depicted in FIG. **88**B. Alternatively, if the nick is to be in the bottom, or template strand of the promoter, then the partial promoter oligonucleotide that covers the +1 position, the transcription start site, will include the additional template sequence. This arrangement is depicted in FIGS. **95**A-D (this Figure shows several different embodiments in which a cut probe or non-target cleavage product is used to form a composite promoter which contains one or more nicks on the template strand). In either case, the separate oligonucleotides are combined to form the complete promoter, and the assembly is used in a transcription reaction to create RNA.

[0526] To measure the effect of the nick, a substantially identical promoter fragment is created by hybridization of two oligonucleotides that each comprise one strand of the full-length promoter to create an un-nicked version of the same promoter. These two molecular assemblies are tested in parallel transcription reactions and the amount of the expected RNA that is produced in each reaction is measured for both size and yield. A preferred method of assessing the

size of the RNA is by electrophoresis with subsequent visualization. If a labeled nucleotide (e.g., ^{32}P-GTP, or fluorescein-UTP) is used in the transcription, the RNA can be detected and quantitated by autoradiography, fluorescence imaging or by transfer to support membrane with subsequent detection (e.g., by antibody or hybridization probing). Alternatively, if unlabeled RNA is produced the amounts may be determined by other methods known in the art, such as by spectrophotometry or by electrophoresis with subsequent staining and comparison to known standards.

[0527] If the size of the RNA is as predicted by the template sequence, or if it matches that produced from the control promoter, it can be presumed to have initiated transcription at the same site in the complex, and to have produced essentially the same RNA product. If the product is much shorter then transcription is either initiating at an internal site or is terminating prematurely (Schenborn and Mierendorf, Nucl. Acids Res., 13:17, 6223 [1985]; and Milligan et al., supra.). While this does not indicate that the assembly tested is completely unsuitable for the assay, the partial transcripts will reduce the gross amount of RNA created, perhaps compromising the signal from the assay, and such products would require further characterization (e.g., finger printing or sequencing) to identify the nucleotide content of the product. It is preferred that the size of the RNA produced matches that of the RNA produced in the control reaction.

[0528] The yield of the reaction is also examined. It is not necessary that the level of transcription matches that of the control reaction. In some instances (see Ex. 41, below) the nicked promoter may have an enhanced rate of transcription, while in other arrangements transcription may be reduced (relative to the rate from the un-nicked promoter assembly). It is only required that the amount of product be within the detection limits of the method to be used with the test promoter.

[0529] It is reported that transcription from a bacteriophage promoter can produce 200 to 1000 copies of each transcription template (template plus active promoter) in a reaction. These levels of transcription are not required by the present invention. Reactions in which one RNA is produced for each template are also contemplated.

[0530] The test described above will allow a promoter with a nick in any position to be assessed for utility in this assay. It is an objective of this invention to provide one or more of the oligonucleotides that comprise a partial promoter region through invasive cleavage event(s). In this embodiment, the partial promoter sequences are attached to the probe oligonucleotide in the invasive cleavage assay, and are released by cleavage at specific site, as directed by the INVADER oligonucleotide. It is also intended that transcription be very poor or nonexistent in the absence of the correctly cleaved probe. To assess the success of any oligonucleotide design at meeting these objectives, several transcription reaction tests can be performed.

[0531] For a promoter assembly that will have a nick on the non-template strand, several partial assemblies that should be tested are shown in FIGS. **86** A-D. By way of example, but not by way of limitation, this Figure depicts the tests for a nicked promoter in which the upstream, or 5' portion of the non-template strand is to be provided by the invasive cleavage assay. This fragment is seen in FIG. **86**A labeled as "cut probe". Transcription reactions incubated in the presence of the duplex shown in FIG. **86**A will test the ability of the upstream partial promoter to allow initiation of transcription when hybridized to a bottom strand, termed a "copy template." Similarly, a reaction performed in the presence of the duplex depicted in FIG. **86**B will test the ability of the partial promoter fragment nearest the initiation site (the +1 site, as indicated in FIG. **85**B) to support transcription of the copy template. It is an important feature of the present invention that neither of these partial promoter duplexes be able to support transcription at the same level as would by seen in transcription from an intact promoter as depicted in FIG. **85**B. It is preferred that neither of these partial promoters be sufficient to initiate detectable transcription in the time course of an average transcription reaction (i.e., within about an hour of incubation).

[0532] FIGS. **86**C and **86**D depict two other duplex arrangements designed to test the effect of uncut probe within the transcription reaction. FIG. **86**C depicts the duplex formed between only the uncut probe and the copy template, while FIG. **86**D includes the other portion of the promoter. The 3' region of the probe is not complementary to the promoter sequence and therefore produces an unpaired branch in the middle of the promoter. It is an important feature of the present invention that neither of these branched promoter duplexes be able to support transcription at the same level as would by seen in transcription from an intact promoter as depicted in FIG. **85**B. It is preferred that neither of these branched promoters be sufficient to initiate detectable transcription in the time course of an average transcription reaction (i.e., within about an hour of incubation).

[0533] In one embodiment of the transcription system of the present invention, the initiation of transcription from the copy template in the absence of a complete promoter, or in the presence of a branched promoter, is prevented by the judicious placement of the nick or nicks in the composite promoter. For example, as shown in the examples below, placement of a nick between the −12 and −11 nucleotides of the non-template strand of the bacteriophage T7 promoter allows transcription to take place only when the probe has been successfully cut, as in an invasive cleavage reaction. However, in some instances where the invasive cleavage reaction is to provide the upstream portion of the non-template strand of the promoter (e.g., as depicted in FIG. **88**B) it may be necessary or desirable to place the nick on that strand in a particular position for reasons other than providing an optimal composite promoter (i.e., one that is inactive in the absence of any one of the promoter pieces). It may be necessary or desirable to place the nick in such a way that the creation of a branched complete promoter (FIG. **86**D) has an undesirable level of transcription, reducing dependence of RNA production on the success of the invasive cleavage step. It is shown in the examples below that transcription from such a branched promoter can be suppressed by a modification of the downstream non-template promoter piece, shown as the "Partial Promoter Oligonucleotide" in FIGS. **86**, **88**, **90** and **95**D. As depicted in FIG. **90**, the partial promoter oligonucleotide can be provided with a 5'"tail" of nucleotides that are not complementary to the template strand of the promoter, but that are complementary to the 3' portion of the probe oligonucleotide that would be removed in the invasive cleavage reaction. When uncut probe hybridizes to the copy template with the

bound 5' tailed partial promoter oligonucleotide, the 5' tail can basepair to the 3' region of the probe, forming a three-way junction as depicted in FIG. **90**A. This can effectively shut off transcription, as shown below. When a cut probe hybridizes, as shown in FIG. **90**B, a promoter with a small branch is formed, and it is shown herein that such a branched promoter can initiate transcription. Furthermore, if care is taken in selecting the sequence of the 5' tail (i.e., if the first unpaired base is the same nucleotide at the 3' nucleotide of the cut probe, so that they compete for hybridization to the same template strand base), the resulting branched structure may also be cleaved by one of the structure specific nucleases of the present invention, creating the un-branched promoter depicted in FIG. **90**C, in some instances enhancing transcription over that seen with the FIG. **90**B promoter.

[**0534**] The promoter duplex that is intended to be created, in this embodiment, by the successful execution of the INVADER directed cleavage assay will include both the "cut probe" and the partial promoter oligonucleotide depicted in FIGS. **86**A and B, aligned on a single copy template nucleic acid. The testing of the efficiency of transcription of such a nicked promoter segment in comparison to the intact promoter is described above. All of the oligonucleotides described for these test molecules may be created using standard synthesis chemistries.

[**0535**] The set of test molecules depicted in FIG. **86** is designed to assess the transcription capabilities of the variety of structures that may be present in reactions in which the 5' portion of the non-template strand of the promoter is to be supplied by the INVADER directed cleavage. It is also envisioned that a different portion of partial promoter may be supplied by the invasive cleavage reaction (e.g., the downstream segment of the non-template strand of the promoter), as is shown in FIG. **94**. Portions of the template strand of the promoter may also be provided by the cut probe, as shown in FIGS. **95**A-D. An analogous set of test molecules, including "cut" and uncut versions of the probe to be used in the invasive cleavage assay may be created to test any alternative design, whether the nick is to be located on the template or non template strand of the promoter.

[**0536**] The transcription-based visualization methods of the present invention may also be used in a multiplex fashion. Reactions can be constructed such that the presence of one particular target leads to transcription from one type of promoter, while the presence of a different target sequence (e.g., a mutant or variant) or another target suspected of being present, may lead to transcription from a different (i.e., a second) type of promoter. In such an embodiment, the identity of the promoter from which transcription was initiated could be deduced from the type or size of the RNA produced.

[**0537**] By way of example, but not by way of limitation, the bacteriophage promoters can be compared with such an application in view. The promoters for the phage T7, T3 and SP6 are quite similar, each being about 15 to 20 basepairs long, and sharing about 45% identity between −17 and −1 nucleotides, relative to the start of transcription. Despite these similarities, the RNA polymerases from these phage are highly specific for their cognate promoters, such that the other promoters may be present in a reaction, but will not be transcribed (Chamberlin and Ryan, Enzymes XV:87-108 [1982]). Because these promoters are similar in size and in the way in which they are recognized by their polymerases (Li et al., Biochem. 35:3722 [1996]) similar nicked versions of the promoters may be designed for use in the methods of the present invention by analogy to the examples described herein which employ the T7 promoter. Because of the high degree of specificity of the RNA polymerases, these nicked promoters may be used together to detect multiple targets in a single reaction. There are many instances in which it would be highly desirable to detect multiple nucleic acid targets in a single sample, including cases in which multiple infectious agents may be present, or in which variants of a single type of target may need to be identified. Alternatively, it is often desirable to use a combination of probes to detect both a target sequence and an internal control sequence, to gauge the effects of sample contaminants on the output of the assay. The use of multiple promoters allows the reaction to be assessed for both the efficiency of the invasive cleavage and the robustness of the transcription.

[**0538**] As stated above, the phage promoters were described in detail as an example of suitable protein binding regions (e.g., which can be used to generate a composite promoter) for use in the methods of the present invention. The invention is not limited to the use of phage RNA polymerase promoter regions, in particular, and RNA polymerase promoter regions, in general. Suitably specific, well characterized promoters are also found in both prokaryotic and eukaryotic systems.

[**0539**] The RNA that is produced in a manner that is dependent of the successful detection of the target nucleic acid in the invasive cleavage reaction may be detected in any of several ways. If a labeled nucleotide is incorporated into the RNA during transcription, the RNA may be detected directly after fractionation (e.g., by electrophoresis or chromatography). The labeled RNA may also be captured onto a solid support, such as a microtitre plate, a bead or a dipstick (e.g., by hybridization, antibody capture, or through an affinity interaction such as that between biotin and avidin). Capture may facilitate the measuring of incorporated label, or it may be an intermediate step before probe hybridization or similar detection means. If the maximum amount of label is desired to be incorporated into each transcript, it is preferred that the copy template be very long, around 3 to 10 kilobases, so that each RNA molecule will carry many labels. Alternatively, it may be desired that a single site or a limited number of sites within the transcript be specifically labeled. In this case, it may be desirable to have a short copy template with only one or a few residues that would allow incorporation of the labeled nucleotide.

[**0540**] The copy template may also be selected to produce RNAs that perform specified functions. In a simple case, if an duplex-dependent intercalating fluorophore is to be used to detect the RNA product, it may be desirable to transcribe an RNA that is known to form duplexed secondary structures, such as a ribosomal RNA or a tRNA. In another embodiment, the RNA may be designed to interact specifically, or with particular affinity, with a different substance. It has been shown that a process of alternating steps of selection (e.g., by binding to a target substance) and in vitro amplification (e.g., by PCR) can be used to identify nucleic acid ligands with novel and useful properties (Tuerk and Gold, Science 249:505 [1990]). This system has been used to identify RNAs, termed ligands or aptamers, that bind

tightly and specifically to proteins and to other types of molecules, such as antibiotics (Wang et al., Biochem. 35:12338 [1996]) and hormones. RNAs can even be selected to bind to other RNAs through non-Watson-Crick interactions (Schmidt et al., Ann. N.Y. Acad. Sci. 782:526 [1996]). A ligand RNA may be used to either inactivate or enhance the activity of a molecule to which it binds. Any RNA segment identified through such a process may also be produced by the methods of the present invention, so that the observation of the activity of the RNA ligand may be used as a specific sign of the presence of the target material in the invasive cleavage reaction. The ligand binding to its specific partner may also be used as another way of capturing a readout signal to a solid support.

[**0541**] The product RNA might also be designed to have a catalytic function (e.g., to act as a ribozyme), allowing cleavage another molecule to be indicative of the success of the primary invasive cleavage reaction (Uhlenbeck, Nature 328:596 [1987]). In yet another embodiment, the RNA may be made to encode a peptide sequence. When coupled to an in vitro translation system (e.g., the S-30 system derived from *E. coli* [Lesley, Methods Mol. Biol., 37:265 (1985)], or a rabbit reticulocyte lysate system [Dasso and Jackson, Nucleic Acids Res. 17:3129 (1989)], available from Promega), the production of the appropriate protein may be detected. In a preferred embodiment, the proteins produced include those that allow either colorimetric or luminescent detection, such as beta-galactosidase (lac-Z) or luciferase, respectively.

[**0542**] The above discussion focused on the use of the present transcription visualization methods in the context of the INVADER-directed cleavage assay (i.e., the non-target cleavage products produced in the INVADER assay were used to complete and activate a protein binding region, such as a promoter region). However, the transcription visualization methods are not limited to this context. Any assay that produces an oligonucleotide product having relatively discrete ends can be used in conjunction with the present transcription visualization methods. For example, the homogenous assay described in U.S. Pat. No. 5,210,015, particularly when conducted under conditions where polymerization cannot occur, produces short oligonucleotide fragments as the result of cleavage of a probe. If this assay is conducted under conditions where polymerization occurs, the site of cleavage of the probe may be focused through the use of nucleotide analogs that have uncleavable linkages at particular positions within the probe. These short oligonucleotides can be employed in a manner analogous to the cut probe or non-target cleavage products produced in the invasive cleavage reactions of the present invention. Additional assays that generate suitable oligonucleotide products are known to the art. For example, the non-target cleavage products produced in assays such as the "Cycling Probe Reaction" (Duck et al., BioTech., 9:142 [1990] and U.S. Pat. Nos. 4,876,187 and 5,011,769, herein incorporated by reference), in which shorter oligonucleotides are released from longer oligonucleotides after hybridization to a target sequence would be suitable, as would short restriction fragments released in assays where a probe is designed to be cleaved when successfully hybridized to an appropriate restriction recognition sequence (U.S. Pat. No. 4,683,194, herein incorporated by reference).

[**0543**] Assays that generate short oligonucleotides having "ragged" (i.e., not discrete) 3' ends can also be employed with success in the transcription reactions of the present invention when the oligonucleotide provided by this non-transcription reaction are used to provide a portion of the promoter region located downstream of the other oligonucleotide(s) that are required to complete the promoter region (that is a 3' tail or unpaired extension can be tolerated when the oligonucleotide is being used as the "Cut Probe" is in FIGS. **94** and **95**A).

VII. Generation of 5' Nucleases Derived from Thermostable DNA Polymerases

[**0544**] The 5' nucleases of the invention form the basis of a novel detection assay for the identification of specific nucleic acid sequences. FIG. **1**A provides a schematic of one embodiment of the detection method of the present invention. The target sequence is recognized by two distinct oligonucleotides in the triggering or trigger reaction. In a preferred embodiment, one of these oligonucleotides is provided on a solid support. The other can be provided free in solution. In FIG. **1**A the free oligonucleotide is indicated as a "primer" and the other oligonucleotide is shown attached to a bead designated as type 1. The target nucleic acid aligns the two oligonucleotides for specific cleavage of the 5' arm (of the oligonucleotide on bead 1) by the 5' nucleases of the present invention (not shown in FIG. **1**A). The site of cleavage (indicated by a large solid arrowhead) is controlled by the position of the 3' end of the "primer" relative to the downstream fork of the oligonucleotide on bead 1.

[**0545**] Successful cleavage releases a single copy of what is referred to as the alpha signal oligonucleotide. This oligonucleotide may contain a detectable moiety (e.g., fluorescein). On the other hand, it may be unlabeled.

[**0546**] In one embodiment of the detection method, two more oligonucleotides are provided on solid supports. The oligonucleotide shown in FIG. **1**A on bead 2 has a region that is complementary to the alpha signal oligonucleotide (indicated as alpha prime) allowing for hybridization. This structure can be cleaved by the 5' nucleases of the present invention to release the beta signal oligonucleotide. The beta signal oligonucleotide can then hybridize to type 3 beads having an oligonucleotide with a complementary region (indicated as beta prime). Again, this structure can be cleaved by the 5' nucleases of the present invention to release a new alpha oligonucleotide.

[**0547**] Up to this point, the amplification has been linear. To increase the power of the method, it is desired that the alpha signal oligonucleotide hybridized to bead type 2 be liberated after release of the beta oligonucleotide so that it may go on to hybridize with other oligonucleotides on type 2 beads. Similarly, after release of an alpha oligonucleotide from type 3 beads, it is desired that the beta oligonucleotide be liberated.

[**0548**] With the liberation of signal oligonucleotides by such techniques, each cleavage results in a doubling of the number of signal oligonucleotides. In this manner, detectable signal can quickly be achieved.

[**0549**] FIG. **1**B provides a schematic of a second embodiment of the detection method of the present invention. Again, the target sequence is recognized by two distinct

oligonucleotides in the triggering or trigger reaction and the target nucleic acid aligns the two oligonucleotides for specific cleavage of the 5' arm by the DNAPs of the present invention (not shown in FIG. 1B). In this specific example, the first oligonucleotide is completely complementary to a portion of the target sequence. The second oligonucleotide is partially complementary to the target sequence; the 3' end of the second oligonucleotide is fully complementary to the target sequence while the 5' end is non-complementary and forms a single-stranded arm. The non-complementary end of the second oligonucleotide may be a generic sequence that can be used with a set of standard hairpin structures (described below). The detection of different target sequences would require unique portions of two oligonucleotides: the entire first oligonucleotide and the 3' end of the second oligonucleotide. The 5' arm of the second oligonucleotide can be invariant or generic in sequence.

[0550] The second part of the detection method allows the annealing of the fragment of the second oligonucleotide liberated by the cleavage of the first cleavage structure formed in the triggering reaction (called the third or trigger oligonucleotide) to a first hairpin structure. This first hairpin structure has a single-stranded 5' arm and a single-stranded 3' arm. The third oligonucleotide triggers the cleavage of this first hairpin structure by annealing to the 3' arm of the hairpin thereby forming a substrate for cleavage by the 5' nuclease of the present invention. The cleavage of this first hairpin structure generates two reaction products: 1) the cleaved 5' arm of the hairpin called the fourth oligonucleotide, and 2) the cleaved hairpin structure that now lacks the 5' arm and is smaller in size than the uncleaved hairpin. This cleaved first hairpin may be used as a detection molecule to indicate that cleavage directed by the trigger or third oligonucleotide occurred. Thus, this indicates that the first two oligonucleotides found and annealed to the target sequence thereby indicating the presence of the target sequence in the sample.

[0551] The detection products may be amplified by having the fourth oligonucleotide anneal to a second hairpin structure. This hairpin structure has a 5' single-stranded arm and a 3' single-stranded arm. The fourth oligonucleotide generated by cleavage of the first hairpin structure anneals to the 3' arm of the second hairpin structure thereby creating a third cleavage structure recognized by the 5' nuclease. The cleavage of this second hairpin structure also generates two reaction products: 1) the cleaved 5' arm of the hairpin called the fifth oligonucleotide, and 2) the cleaved second hairpin structure which now lacks the 5' arm and is smaller in size than the uncleaved hairpin. In one embodiment, the fifth oligonucleotide is similar or identical in sequence to the third nucleotide. The cleaved second hairpin may be viewed as a detection molecule that amplifies the signal generated by the cleavage of the first hairpin structure. Simultaneously with the annealing of the forth oligonucleotide, the third oligonucleotide is dissociated from the cleaved first hairpin molecule so that it is free to anneal to a new copy of the first hairpin structure. The disassociation of the oligonucleotides from the hairpin structures may be accomplished by heating or other means suitable to disrupt base-pairing interactions. As described above, conditions may be selected that allow the association and disassociation of hybridized oligonucleotides without temperature cycling.

[0552] If fifth oligonucleotide is similar or identical in sequence to the third oligonucleotide, further amplification of the detection signal is achieved by annealing the fifth oligonucleotide to another molecule of the first hairpin structure. Cleavage is then performed and the oligonucleotide that is liberated then is annealed to another molecule of the second hairpin structure. Successive rounds of annealing and cleavage of the first and second hairpin structures, provided in excess, are performed to generate a sufficient amount of cleaved hairpin products to be detected.

[0553] As discussed above for other embodiments of detection using structure-specific nuclease cleavage, any method known in the art for analysis of nucleic acids, nucleic acid fragments or oligonucleotides may be applied to the detection of these cleavage products.

[0554] The hairpin structures may be attached to a solid support, such as an agarose, styrene or magnetic bead, via the 3' end of the hairpin. A spacer molecule may be placed between the 3' end of the hairpin and the bead, if so desired. The advantage of attaching the hairpin structures to a solid support is that this prevents the hybridization of the two hairpin structures to one another over regions which are complementary. If the hairpin structures anneal to one another, this would reduce the amount of hairpins available for hybridization to the primers released during the cleavage reactions. If the hairpin structures are attached to a solid support, then additional methods of detection of the products of the cleavage reaction may be employed. These methods include, but are not limited to, the measurement of the released single-stranded 5' arm when the 5' arm contains a label at the 5' terminus. This label may be radioactive, fluorescent, biotinylated, etc. If the hairpin structure is not cleaved, the 5' label will remain attached to the solid support. If cleavage occurs, the 5' label will be released from the solid support.

[0555] The 3' end of the hairpin molecule may be blocked through the use of dideoxynucleotides. A 3' terminus containing a dideoxynucleotide is unavailable to participate in reactions with certain DNA modifying enzymes, such as terminal transferase. Cleavage of the hairpin having a 3' terminal dideoxynucleotide generates a new, unblocked 3' terminus at the site of cleavage. This new 3' end has a free hydroxyl group that can interact with terminal transferase thus providing another means of detecting the cleavage products.

[0556] The hairpin structures are designed so that their self-complementary regions are very short (generally in the range of 3-8 base pairs). Thus, the hairpin structures are not stable at the high temperatures at which this reaction is performed (generally in the range of 50-75° C.) unless the hairpin is stabilized by the presence of the annealed oligonucleotide on the 3' arm of the hairpin. This instability prevents the polymerase from cleaving the hairpin structure in the absence of an associated primer thereby preventing false positive results due to non-oligonucleotide directed cleavage.

VIII. Improved Enzymes for Use in INVADER Oligonucleotide-Directed Cleavage Reactions

[0557] A cleavage structure is defined herein as a structure that is formed by the interaction of a probe oligonucleotide and a target nucleic acid to form a duplex, the resulting

structure being cleavable by a cleavage agent, including but not limited to an enzyme. The cleavage structure is further defined as a substrate for specific cleavage by the cleavage means in contrast to a nucleic acid molecule that is a substrate for nonspecific cleavage by agents such as phosphodiesterases. Examples of some possible cleavage structures are shown in FIG. **15**. In considering improvements to enzymatic cleavage agents, one may consider the action of said enzymes on any of these structures, and on any other structures that fall within the definition of a cleavage structure. The cleavage sites indicated on the structures in FIG. **15** are presented by way of example. Specific cleavage at any site within such a structure is contemplated.

[**0558**] Improvements in an enzyme may be an increased or decreased rate of cleavage of one or more types of structures. Improvements may also result in more or fewer sites of cleavage on one or more of said cleavage structures. In developing a library of new structure-specific nucleases for use in nucleic acid cleavage assays, improvements may have many different embodiments, each related to the specific substrate structure used in a particular assay.

[**0559**] As an example, one embodiment of the INVADER oligonucleotide-directed cleavage assay of the present invention may be considered. In the INVADER oligonucleotide-directed cleavage assay, the accumulation of cleaved material is influenced by several features of the enzyme behavior. Not surprisingly, the turnover rate, or the number of structures that can be cleaved by a single enzyme molecule in a set amount of time, is very important in determining the amount of material processed during the course of an assay reaction. If an enzyme takes a long time to recognize a substrate (e.g., if it is presented with a less-than-optimal structure), or if it takes a long time to execute cleavage, the rate of product accumulation is lower than if these steps proceeded quickly. If these steps are quick, yet the enzyme "holds on" to the cleaved structure, and does not immediately proceed to another uncut structure, the rate will be negatively affected.

[**0560**] Enzyme turnover is not the only way in which enzyme behavior can negatively affect the rate of accumulation of product. When the means used to visualize or measure product is specific for a precisely defined product, products that deviate from that definition may escape detection, and thus the rate of product accumulation may appear to be lower than it is. For example, if one had a sensitive detector for trinucleotides that could not see di- or tetranucleotides, or any sized oligonucleotide other that 3 residues, in the INVADER-directed cleavage assay of the present invention any errant cleavage would reduce the detectable signal proportionally. It can be seen from the cleavage data presented here that, while there is usually one site within a probe that is favored for cleavage, there are often products that arise from cleavage one or more nucleotides away from the primary cleavage site. These are products that are target-dependent, and are thus not non-specific background. Nevertheless, if a subsequent visualization system can detect only the primary product, these represent a loss of signal. One example of such a selective visualization system is the charge reversal readout presented herein, in which the balance of positive and negative charges determines the behavior of the products. In such a system the presence of an extra nucleotide or the absence of an expected nucleotide can excluded a legitimate cleavage product from ultimate detection by leaving that product with the wrong balance of charge. It can be easily seen that any assay that can sensitively distinguish the nucleotide content of an oligonucleotide, such as standard stringent hybridization, suffers in sensitivity when some fraction of the legitimate product is not eligible for successful detection by that assay.

[**0561**] These discussions suggest two highly desirable traits in any enzyme to be used in the method of the present invention. First, the more rapidly the enzyme executes an entire cleavage reaction, including recognition, cleavage and release, the more signal it may potentially created in the INVADER oligonucleotide-directed cleavage assay. Second, the more successful an enzyme is at focusing on a single cleavage site within a structure, the more of the cleavage product can be successfully detected in a selective read-out.

[**0562**] The rationale cited above for making improvements in enzymes to be used in the INVADER oligonucleotide-directed cleavage assay are meant to serve as an example of one direction in which improvements might be sought, but not as a limit on either the nature or the applications of improved enzyme activities. As another direction of activity change that would be appropriately considered improvement, the DNAP-associated 5' nucleases may be used as an example. In creating some of the polymerase-deficient 5' nucleases described herein it was found that the those that were created by deletion of substantial portions of the polymerase domain, as depicted in FIG. **4**, assumed activities that were weak or absent in the parent proteins. These activities included the ability to cleave the non-forked structure shown in FIG. **15**D, a greatly enhanced ability to exonucleolytically remove nucleotides from the 5' ends of duplexed strands, and a nascent ability to cleave circular molecules without benefit of a free 5' end.

[**0563**] In addition to the 5' nucleases derived from DNA polymerases, the present invention also contemplates the use of structure-specific nucleases that are not derived from DNA polymerases. For example, a class of eukaryotic and archaebacterial endonucleases have been identified which have a similar substrate specificity to 5' nucleases of Pol I-type DNA polymerases. These are the FEN1 (Flap Endo-Nuclease), RAD2, and XPG (Xeroderma Pigmentosa-complementation group G) proteins. These proteins are involved in DNA repair, and have been shown to favor the cleavage of structures that resemble a 5' arm that has been displaced by an extending primer during polymerization, similar to the model depicted in FIG. **15**B. Similar DNA repair enzymes have been isolated from single cell and higher eukaryotes and from archaea, and there are related DNA repair proteins in eubacteria. Similar 5' nucleases have also been associated with bacteriophage such as T5 and T7.

[**0564**] Recently, the 3-dimensional structures of DNAPTaq and T5 phage 5'-exonuclease (FIG. **58**) were determined by X-ray diffraction (Kim et al., Nature 376:612 [1995]; and Ceska et al., Nature 382:90 [1995]). The two enzymes have very similar 3-dimensional structures despite limited amino acid sequence similarity. The most striking feature of the T5 5'-exonuclease structure is the existence of a triangular hole formed by the active site of the protein and two alpha helices (FIG. **58**). This same region of DNAPTaq is disordered in the crystal structure, indicating that this region is flexible, and thus is not shown in the published 3-dimensional structure. However, the 5' nuclease domain of

DNAPTaq is likely to have the same structure, based its overall 3-dimensional similarity to T5 5'-exonuclease, and that the amino acids in the disordered region of the DNAPTaq protein are those associated with alpha helix formation. The existence of such a hole or groove in the 5' nuclease domain of DNAPTaq was predicted based on its substrate specificity (Lyamichev et al., supra).

[0565] It has been suggested that the 5' arm of a cleavage structure must thread through the helical arch described above to position said structure correctly for cleavage (Ceska et al., supra). One of the modifications of 5' nucleases described herein opened up the helical arch portion of the protein to allow improved cleavage of structures that cut poorly or not at all (e.g., structures on circular DNA targets that would preclude such threading of a 5' arm). The gene construct that was chosen as a model to test this approach was the one called CLEAVASE BN, which was derived from DNAPTaq but does not contain the polymerase domain (Ex. 2). It comprises the entire 5' nuclease domain of DNAP Taq, and thus should be very close in structure to the T5 5' exonuclease. This 5' nuclease was chosen to demonstrate the principle of such a physical modification on proteins of this type. The arch-opening modification of the present invention is not intended to be limited to the 5' nuclease domains of DNA polymerases, and is contemplated for use on any structure-specific nuclease that includes such an aperture as a limitation on cleavage activity. The present invention contemplates the insertion of a thrombin cleavage site into the helical arch of DNAPs derived from the genus *Thermus* as well as 5' nucleases derived from DNAPs derived from the genus *Thermus*. The specific example shown herein using the CLEAVASE BN/thrombin nuclease merely illustrates the concept of opening the helical arch located within a nuclease domain. As the amino acid sequence of DNAPs derived from the genus *Thermus* are highly conserved, the teachings of the present invention enable the insertion of a thrombin site into the helical arch present in these DNAPs and 5' nucleases derived from these DNAPs.

[0566] The opening of the helical arch was accomplished by insertion of a protease site in the arch. This allowed post-translational digestion of the expressed protein with the appropriate protease to open the arch at its apex. Proteases of this type recognize short stretches of specific amino acid sequence. Such proteases include thrombin and factor Xa. Cleavage of a protein with such a protease depends on both the presence of that site in the amino acid sequence of the protein and the accessibility of that site on the folded intact protein. Even with a crystal structure it can be difficult to predict the susceptibility of any particular region of a protein to protease cleavage. Absent a crystal structure it must be determined empirically.

[0567] In selecting a protease for a site-specific cleavage of a protein that has been modified to contain a protease cleavage site, a first step is to test the unmodified protein for cleavage at alternative sites. For example, DNAPTaq and CLEAVASE BN nuclease were both incubated under protease cleavage conditions with factor Xa and thrombin proteases. Both nuclease proteins were cut with factor Xa within the 5' nuclease domain, but neither nuclease was digested with large amounts of thrombin. Thus, thrombin was chosen for initial tests on opening the arch of the CLEAVASE BN enzyme.

[0568] In the protease/CLEAVASE modifications described herein the factor Xa protease cleaved strongly in an unacceptable position in the unmodified nuclease protein, in a region likely to compromise the activity of the end product. Other unmodified nucleases contemplated herein may not be sensitive to the factor Xa, but may be sensitive to thrombin or other such proteases. Alternatively, they may be sensitive to these or other such proteases at sites that are immaterial to the function of the nuclease sought to be modified. In approaching any protein for modification by addition of a protease cleavage site, the unmodified protein should be tested with the proteases under consideration to determine which proteases give acceptable levels of cleavage in other regions.

[0569] Working with the cloned segment of DNAPTaq from which the CLEAVASE BN protein is expressed, nucleotides encoding a thrombin cleavage site were introduced in-frame near the sequence encoding amino acid 90 of the nuclease gene. This position was determined to be at or near the apex of the helical arch by reference to both the 3-dimensional structure of DNAPTaq, and the structure of T5 5' exonuclease. The encoded amino acid sequence, LVPRGS, was inserted into the apex of the helical arch by site-directed mutagenesis of the nuclease gene. The proline (P) in the thrombin cleavage site was positioned to replace a proline normally in this position in CLEAVASE BN because proline is an alpha helix-breaking amino acid, and may be important for the 3-dimensional structure of this arch. This construct was expressed, purified and then digested with thrombin. The digested enzyme was tested for its ability to cleave a target nucleic acid, bacteriophage M13 genomic DNA, that does not provide free 5' ends to facilitate cleavage by the threading model.

[0570] While the helical arch in this nuclease was opened by protease cleavage, it is contemplated that a number of other techniques could be used to achieve the same end. For example, the nucleotide sequence could be rearranged such that, upon expression, the resulting protein would be configured so that the top of the helical arch (amino acid 90) would be at the amino terminus of the protein, the natural carboxyl and amino termini of the protein sequence would be joined, and the new carboxyl terminus would lie at natural amino acid 89. This approach has the benefit that no foreign sequences are introduced and the enzyme is a single amino acid chain, and thus may be more stable that the cleaved 5' nuclease. In the crystal structure of DNAPTaq, the amino and carboxyl termini of the 5'-exonuclease domain lie in close proximity to each other, which suggests that the ends may be directly joined without the use of a flexible linker peptide sequence as is sometimes necessary. Such a rearrangement of the gene, with subsequent cloning and expression could be accomplished by standard PCR recombination and cloning techniques known to those skilled in the art.

[0571] The present invention also contemplates the use of nucleases isolated from organisms that grow under a variety of conditions. The genes for the FEN-1/XPG class of enzymes are found in organisms ranging from bacteriophage to humans to the extreme thermophiles of Kingdom Archaea. For assays in which high temperature is to be used, it is contemplated that enzymes isolated from extreme thermophiles may exhibit the thermostability required of such an assay. For assays in which it might be desirable to

have peak enzyme activity at moderate temperature or in which it might be desirable to destroy the enzyme with elevated temperature, those enzymes from organisms that favor moderate temperatures for growth may be of particular value.

[0572] An alignment of a collection of FEN-1 proteins sequenced by others is shown in FIGS. **59**A-E (SEQ ID NOS:135-145). It can be seen from this alignment that there are some regions of conservation in this class of proteins, suggesting that they are related in function, and possibly in structure. Regions of similarity at the amino acid sequence level can be used to design primers for in vitro amplification (PCR) by a process of back translating the amino acid sequence to the possible nucleic acid sequences, then choosing primers with the fewest possible variations within the sequences. These can be used in low stringency PCR to search for related DNA sequences. This approach permits the amplification of DNA encoding a FEN-1 nuclease without advance knowledge of the actual DNA sequence.

[0573] It can also be seen from this alignment that there are regions in the sequences that are not completely conserved. The degree of difference observed suggests that the proteins may have subtle or distinct differences in substrate specificity. In other words, they may have different levels of cleavage activity on the cleavage structures of the present invention. When a particular structure is cleaved at a higher rate than the others, this is referred to a preferred substrate, while a structure that is cleaved slowly is considered a less preferred substrate. The designation of preferred or less preferred substrates in this context is not intended to be a limitation of the present invention. It is contemplated that some embodiments the present invention will make use of the interactions of an enzyme with a less preferred substrate. Candidate enzymes are tested for suitability in the cleavage assays of the present invention using the assays described below.

[0574] 1. Structure Specific Nuclease Assay

[0575] Testing candidate nucleases for structure-specific activities in these assays is done in much the same way as described for testing modified DNA polymerases in Example 2, but with the use of a different library of model structures. In addition to assessing the enzyme performance in primer-independent and primer-directed cleavage, a set of synthetic hairpins are used to examine the length of duplex downstream of the cleavage site preferred by the enzyme.

[0576] The FEN-1 and XPG 5' nucleases used in the present invention should be tested for activity in the assays in which they are intended to be used, including but not limited to the INVADER-directed cleavage detection assay of the present invention and the CFLP method of characterizing nucleic acids (the CFLP method is described in U.S. Pat. Nos. 5,843,654, 5,843,669, 5,719,028, and 5,888,780 and PCT Publication WO 96/15267; the disclosures of which are incorporated herein by reference). The INVADER assay uses a mode of cleavage that has been termed "primer directed" of "primer dependent" to reflect the influence of the an oligonucleotide hybridized to the target nucleic acid upstream of the cleavage site. In contrast, the CFLP reaction is based on the cleavage of folded structure, or hairpins, within the target nucleic acid, in the absence of any hybridized oligonucleotide. The tests described herein are not intended to be limited to the analysis of nucleases with any particular site of cleavage or mode of recognition of substrate structures. It is contemplated that enzymes may be described as 3' nucleases, utilizing the 3' end as a reference point to recognize structures, or may have a yet a different mode of recognition. Further, the use of the term 5' nucleases is not intended to limit consideration to enzymes that cleave the cleavage structures at any particular site. It refers to a general class of enzymes that require some reference or access to a 5' end to effect cleavage of a structure.

[0577] A set of model cleavage structures has been created to allow the cleavage ability of unknown enzymes on such structures to be assessed. Each of the model structures is constructed of one or more synthetic oligonucleotides made by standard DNA synthesis chemistry. Examples of such synthetic model substrate structures are shown in FIGS. **26** and **60**. These are intended only to represent the general folded configuration desirable is such test structures. While a sequence that would assume such a structure is indicated in the Figures, there are numerous other sequence arrangements of nucleotides that would be expected to fold in such ways. The essential features to be designed into a set of oligonucleotides to perform the tests described herein are the presence or absence of a sufficiently long 3' arm to allow hybridization of an additional nucleic acid to test cleavage in a "primer-directed" mode, and the length of the duplex region. In the set depicted in FIG. **60**, the duplex lengths of the S-33 and the 11-8-0 structures are 12 and 8 basepairs, respectively. This difference in length in the test molecules facilitates detection of discrimination by the candidate nuclease between longer and shorter duplexes. Additions to this series expanding the range of duplex molecules presented to the enzymes, both shorter and longer, may be used. The use of a stabilizing DNA tetraloop (Antao et al., Nucl. Acids Res., 19:5901 [1991]) or triloop (Hiraro et al., Nuc. Acids Res., 22:576 [1994]) at the closed end of the duplex helps ensure formation of the expected structure by the oligonucleotide.

[0578] The model substrate for testing primer directed cleavage, the "S-60 hairpin" (SEQ ID NO:40) is described in Example 11. In the absence of a primer this hairpin is usually cleaved to release 5' arm fragments of 18 and 19 nucleotides length. An oligonucleotide, termed P-14 (5'-CGAGAGACCACGCT-3'; SEQ ID NO:108), that extends to the base of the duplex when hybridized to the 3' arm of the S-60 hairpin gives cleavage products of the same size, but at a higher rate of cleavage.

[0579] To test invasive cleavage a different primer is used, termed P-15 (5'-CGAGAGACCACGCTG-3'; SEQ ID NO:30). In a successful invasive cleavage the presence of this primer shifts the site of cleavage of S-60 into the duplex region, usually releasing products of 21 and 22 nucleotides length.

[0580] The S-60 hairpin may also be used to test the effects of modifications of the cleavage structure on either primer-directed or invasive cleavage. Such modifications include, but are not limited to, use of mismatches or base analogs in the hairpin duplex at one, a few or all positions, similar disruptions or modifications in the duplex between the primer and the 3' arm of the S-60, chemical or other modifications to one or both ends of the primer sequence, or attachment of moieties to, or other modifications of the 5' arm of the structure. In all of the analyses using the S-60 or

a similar hairpin described herein, activity with and without a primer may be compared using the same hairpin structure.

[0581] The assembly of these test reactions, including appropriate amounts of hairpin, primer and candidate nuclease is described in Example 2. As cited therein, the presence of cleavage products is indicated by the presence of molecules that migrate at a lower molecular weight than does the uncleaved test structure. When the reversal of charge of a label is used the products will carry a different net charge than the uncleaved material. Any of these cleavage products indicate that the candidate nuclease has the desired structure-specific nuclease activity. By "desired structure-specific nuclease activity" it is meant only that the candidate nuclease cleaves one or more test molecules. It is not necessary that the candidate nuclease cleave at any particular rate or site of cleavage to be considered successful cleavage.

[0582] 2. Enzyme Chimeras and Variants

[0583] The present invention further provides chimerical structure-specific nucleases. Chimerical structure-specific nucleases comprise one or more portions of any of the enzymes described herein in combination with another sequence. In preferred embodiments, the chimerical structure-specific nucleases comprise a functional domain (e.g., a region of the enzyme containing an arch region or sequence physically associated therewith) from a 5'-nuclease in combination with domains from other enzymes (e.g., from other 5'-nucleases). In some preferred embodiments, a given functional domain comprises sequence from two or more enzymes. For example, the amino acid sequence of a functional domain of a first structure-specific nuclease may be altered at one or more amino acid positions to convert the functional domain, or a portion thereof, to the sequence of a second structure-specific nuclease, thereby imparting characteristics of the second nuclease on the first. Such characteristics include, but are not limited to catalytic activity, specificity, and stability (e.g., thermostability).

[0584] In one embodiment, the present invention provides chimerical enzymes comprising amino acid portions derived from the enzymes selected from the group of DNA polymerases and FEN-1, XPG and RAD endonucleases. In a preferred embodiment, the chimerical enzymes comprise amino acid portions derived from the FEN-1 endonucleases selected from the group of *Pyrococcus furiosus, Methanococcus jannaschi, Pyrococcus woesei, Archaeoglobus fulgidus, Methanobacterium thermoautotrophicum, Sulfolobus solfataricus, Pyrobaculum aerophilum, Thermococcus litoralis, Archaeaglobus veneficus, Archaeaglobus profundus, Acidianus brierlyi, Acidianus ambivalens, Desulfurococcus amylolyticus, Desulfurococcus mobilis, Pyrodictium brockii, Thermococcus gorgonarius, Thermococcus zilligii, Methanopyrus kandleri, Methanococcus igneus, Pyrococcus horikoshii*, and *Aeropyrum pernix*.

[0585] Some embodiments of the present invention provide mutant or variant forms of enzymes described herein. It is possible to modify the structure of a peptide having an activity of the enzymes described herein for such purposes as enhancing cleavage rate, substrate specificity, stability, and the like. For example, a modified peptide can be produced in which the amino acid sequence has been altered, such as by amino acid substitution, deletion, or addition. For example, it is contemplated that an isolated replacement of a leucine with an isoleucine or valine, an aspartate with a glutamate, a threonine with a serine, or a similar replacement of an amino acid with a structurally related amino acid (i.e., conservative mutations) will not have a major effect on the biological activity of the resulting molecule. Accordingly, some embodiments of the present invention provide variants of enzymes described herein containing conservative replacements. Conservative replacements are those that take place within a family of amino acids that are related in their side chains. Genetically encoded amino acids can be divided into four families: (1) acidic (aspartate, glutamate); (2) basic (lysine, arginine, histidine); (3) nonpolar (alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan); and (4) uncharged polar (glycine, asparagine, glutamine, cysteine, serine, threonine, tyrosine). Phenylalanine, tryptophan, and tyrosine are sometimes classified jointly as aromatic amino acids. In similar fashion, the amino acid repertoire can be grouped as (1) acidic (aspartate, glutamate); (2) basic (lysine, arginine histidine), (3) aliphatic (glycine, alanine, valine, leucine, isoleucine, serine, threonine), with serine and threonine optionally be grouped separately as aliphatic-hydroxyl; (4) aromatic (phenylalanine, tyrosine, tryptophan); (5) amide (asparagine, glutamine); and (6) sulfur-containing (cysteine and methionine) (See e.g., Stryer (ed.), *Biochemistry,* 2nd ed, WH Freeman and Co. [1981]). Whether a change in the amino acid sequence of a peptide results in a functional homolog can be readily determined by assessing the ability of the variant peptide to produce a response in a fashion similar to the wild-type protein using the assays described herein. Peptides in which more than one replacement has taken place can readily be tested in the same manner.

[0586] It is contemplated that the nucleic acids encoding the enzymes can be utilized as starting nucleic acids for directed evolution. These techniques can be utilized to develop enzyme variants having desirable properties. In some embodiments, artificial evolution is performed by random mutagenesis (e.g., by utilizing error-prone PCR to introduce random mutations into a given coding sequence). This method requires that the frequency of mutation be finely tuned. As a general rule, beneficial mutations are rare, while deleterious mutations are common. This is because the combination of a deleterious mutation and a beneficial mutation often results in an inactive enzyme. The ideal number of base substitutions for targeted gene is usually between 1.5 and 5 (Moore and Arnold, Nat. Biotech., 14, 458-67 [1996]; Leung et al., Technique, 1:11-15 [1989]; Eckert and Kunkel, PCR Methods Appl., 1:17-24 [1991]; Caldwell and Joyce, PCR Methods Appl., 2:28-33 (1992); and Zhao and Arnold, Nuc. Acids. Res., 25:1307-08 [1997]). After mutagenesis, the resulting clones are selected for desirable activity (e.g., ability to cleave a cleavage structure such as those described in Example 66). Successive rounds of mutagenesis and selection are often necessary to develop enzymes with desirable properties. It should be noted that only the useful mutations are carried over to the next round of mutagenesis.

[0587] In other embodiments of the present invention, the polynucleotides of the present invention are used in gene shuffling or sexual PCR procedures (e.g., Smith, Nature, 370:324-25 [1994]; U.S. Pat. Nos. 5,837,458; 5,830,721; 5,811,238; 5,733,731; all of which are herein incorporated by reference). Gene shuffling involves random fragmentation of several mutant DNAs followed by their reassembly

by PCR into full length molecules. Examples of various gene shuffling procedures include, but are not limited to, assembly following DNase treatment, the staggered extension process (STEP), and random priming in vitro recombination. In the DNase mediated method, DNA segments isolated from a pool of positive mutants are cleaved into random fragments with DNaseI and subjected to multiple rounds of PCR with no added primer. The lengths of random fragments approach that of the uncleaved segment as the PCR cycles proceed, resulting in mutations in different clones becoming mixed and accumulating in some of the resulting sequences. Multiple cycles of selection and shuffling have led to the functional enhancement of a number of enzymes (Stemmer, Nature, 370:398-91 [1994]; Stemmer, Proc. Natl. Acad. Sci. USA, 91, 10747-51 [1994]; Crameri et al., Nat. Biotech., 14:315-19 [1996]; Zhang et al., Proc. Natl. Acad. Sci. USA, 94:4504-09 [1997]; and Crameri et al., Nat. Biotech., 15:436-38 [1997]).

IX. The INVADER Assay for Direct Detection and Measurement of Specific Analytes.

[0588] The following description provides illustrative examples of target sequence detection through the use of the compositions and methods of the present invention. These example include the detection of human cytomegalovirus viral DNA, single nucleotide polymorphisms in the human apolipoprotein E gene, mutations in the human hemochromatosis gene, mutations in the human MTHFR, prothrombin 20210GA polymorphism, the HR-2 mutation in the human Factor V gene, single nucleotide polymorphisms in the human TNF-α Gene, and Leiden mutation in the human Factor V gene. Included in these descriptions are novel nucleic acid compositions for use in the detection of such sequence. Examples 54-61 below provide details on the design and execution of these illustrative embodiments.

[0589] A. Detection of Human Cytomegalovirus Viral DNA by Invasive Cleavage

[0590] Human cytomegalovirus (HCMV) causes, or is associated with, a wide variety of diseases in humans (Table 3). More than 90% of bone marrow or kidney transplant recipients (immunocompromised hosts) develop HCMV infections, most of which are due to reactivation of latent virus by immunosuppressive drugs, as well as transmission of virus by latently infected donor tissue or blood (Ackerman et al., Transplant. Proc., 20(S1):468 [1988]; and Peterson et al., Medicine 59:283 [1980]).

TABLE 3

Diseases Caused By Human Cytomegalovirus
cytomegalic inclusion
heterophil-negative disease in neonates
mononucleosis
interstitial pneumonia
pneumonitis
retinitis
hepatitis
pancreatitis
meningoencephalitis
gastrointestinal disease
disseminated infection

[0591] There are instances in which rapid, sensitive, and specific diagnosis of HCMV disease is imperative. In recent years, the number of patients undergoing organ and tissue transplantations has increased markedly. HCMV is the most frequent cause of death in immunocompromised transplant recipients, thereby confirming the need for rapid and reliable laboratory diagnosis. Lymphocytes, monocytes, and possibly arterial endothelial or smooth muscle cells, are sites of HCMV latency. Therefore, prevention of HCMV infections in immunocompromised individuals (e.g., transplant recipients) includes use of HCMV-negative blood products and organs. Additionally, HCMV can be spread transplacentally, and to newborns by contact with infected cervical secretions during birth. Thus, a rapid, sensitive, and specific assay for detecting HCMV in body fluids or secretions may be desirable as a means to monitor infection, and consequently, determine the necessity of cesarean section.

[0592] Diagnosis of HCMV infection may be performed by conventional cell culture using human fibroblasts; shell vial centrifugation culture utilizing monoclonal antibodies and immunofluorescent staining techniques; serological methods; the HCMV antigenemia assay which employs a monoclonal antibody to detect HCMV antigen in peripheral blood leukocytes (PBLs); or by nucleic acid hybridization assays. These various methods have their advantages and limitations. Conventional cell culture is sensitive but slow, as cytopathic effect (CPE) may take 30 or more days to develop. Shell vial centrifugation is more rapid but still requires 24-48 hours for initial results. Both culture methods are affected by antiviral therapy. In immunocompromised patients, the ability to mount IgG and/or IgM antibody responses to HCMV infection are impaired, and serological methods are thus not reliable in this setting. Alternatively, IgM antibodies may be persistent for months after infection is resolved, and thus their presence may not be indicative of active infection. The HCMV antigenemia assay is labor intensive and is not applicable to specimens other than PBLs.

[0593] Recent advances in molecular biology have spurred the use of DNA probes in attempts to provide a more rapid, sensitive and specific assay for detecting HCMV in clinical specimens. For example, radiolabeled DNA probes have been used to hybridize to tissue cultures infected with or by HCMV, or in clinical samples suspected of containing HCMV ("hybridization assays"). However, probing of tissue cultures requires at least 18-24 hours for growth to amplify the antigen (HCMV) to be detected, if present, and additional time for development of autoradiographic detection systems. Using hybridization assays for assaying clinical specimens for HCMV may lack sensitivity, depending upon the titer of virus and the clinical sample assayed. Detection of HCMV in clinical samples has been reported using the polymerase chain reaction (PCR) to enzymatically amplify HCMV DNA. Methods using PCR compare favorably with virus isolation, in situ hybridization assays, and Southern blotting; See, e.g., Bamborschke et al., J. Neurol., 239:205 [1992]; Drouet et al., J. Virol. Meth., 45:259 [1993]; Einsele et al., Blood 77:1104-1110 [1991]; Einsele et al., Lancet 338:1170 [1991]; Lee et al., Aust. NZ J. Med., 22:249 [1992]; Miller et al., J. Clin. Microbiol., 32:5 [1994]; Rowley et al., Transplant. 51:1028 [1991]; Spector et al. J. Clin. Microbiol., 30:2359 [1992]; and Stanier et al., Mol. Cell. Probes 8:51 [1992]). Others, comparing the HCMV antigenemia assay with PCR methods, have found PCR methods as efficient or slightly more efficient in the detection of HCMV (van Dorp et al. (1992) Transplant. 54:661; Gerna

et al. (1991) J. Infect. Dis. 164:488; Vleiger et al. (1992) Bone Marrow Transplant. 9:247; Zipeto et al. (1992) J. Clin. Microbiol. 30:527]. In addition, PCR methods have exhibited great sensitivity when specimens other than PBLs are assayed (Natori et al., Kansenshogaku Zasshi 67:1011 [1993]; Peterson et al., Medicine 59:283 [1980]; Prosch et al., J. Med. Virol., 38:246 [1992]; Ratnamohan et al., J. Med. Virol. 38:252 [1992]). However, because of the dangers of false positive reactions, these PCR-based procedures require rigid controls to prevent contamination and carry over (Ehrlich et al., in *PCR-Based Diagnostics in Infectious Diseases*, Ehrlich and Greenberg (eds), Blackwell Scientific Publications, [1994], pp. 3-18). Therefore, there exists a need for a rapid, sensitive, and specific assay for HCMV that has a reduced risk of false positive result due to contamination by reaction product carried over from other samples.

[0594] As shown herein, the INVADER-directed cleavage assay is rapid, sensitive and specific. Because the accumulated products do not contribute to the further accumulation of signal, reaction products carried over from one standard (i.e., non-sequential) INVADER-directed cleavage assay to another cannot promote false positive results. The use of multiple sequential INVADER-directed cleavage assays will further boost the sensitivity of HCMV detection without sacrifice of these advantages.

[0595] B. Detection of Single Nucleotide Polymorphisms in the Human Apolipoprotein E Gene

[0596] Apolipoprotein E (ApoE) performs various functions as a protein constituent of plasma lipoproteins, including its role in cholesterol metabolism. It was first identified as a constituent of liver-synthesized very low density lipoproteins which function in the transport of triglycerides from the liver to peripheral tissues. There are three major isoforms of ApoE, referred to as ApoE2, ApoE3 and ApoE4 which are products of three alleles at a single gene locus. Three homozygous phenotypes (Apo-E2/2, E3/3, and E4/4) and three heterozygous phenotypes (ApoE3/2, E4/3 and E4/2) arise from the expression of any two of the three alleles. The most common phenotype is ApoE3/3 and the most common allele is E3. See Mahley, R. W., Science 240:622-630 (1988).

[0597] The amino acid sequences of the three types differ only slightly. ApoE4 differs from ApoE3 in that in ApoE4 arginine is substituted for the normally occurring cysteine at amino acid residue 112. The most common form of ApoE2 differs from ApoE3 at residue 158, where cysteine is substituted for the normally occurring arginine. See Mahley, Science, supra.

[0598] The frequency of the apoE4 allele has been shown to be markedly increased in sporadic Alzheimer's Disease (AD) (Poirier, J. et al., 1993, Apolipoprotein E phenotype and Alzheimer's Disease, Lancet, 342:697-699; Noguchi, S. et al., 1993, Lancet (letter), 342:737) and late onset familial Alzheimer's disease (AD) (Corder, E. H. et al., 1993, Science, 261:921-923; Payami, H. et al., 1993, Lancet (letter), 342:738). This gene dosage effect was observed in both sporadic and familial cases (i.e., as age of onset increases, E4 allele copy number decreases). Women, who are generally at a greater risk of developing Alzheimer's disease, show increased E4 allele frequency when compared to age matched men.

[0599] C. Detection of Mutations in the Human Hemochromatosis Gene

[0600] Hereditary hemochromatosis (HH) is an inherited disorder of iron metabolism wherein the body accumulates excess iron. In symptomatic individuals, this excess iron leads to deleterious effects by being deposited in a variety of organs leading to their failure, and resulting in cirrhosis, diabetes, sterility, and other serious illnesses.

[0601] HH is inherited as a recessive trait; heterozygotes are asymptomatic and only homozygotes are affected by the disease. It is estimated that approximately 10% of individuals of Western European descent carry an HH gene mutation and that there are about one million homozygotes in the United States. Although ultimately HH produces debilitating symptoms, the majority of homozygotes have not been diagnosed. Indeed, it has been estimated that no more than 10,000 people in the United States have been diagnosed with this condition. The symptoms are often confused with those of other conditions, and the severe effects of the disease often do not appear immediately. It would be desirable to provide a method to identify persons who are ultimately destined to become symptomatic in order to intervene in time to prevent excessive tissue damage. One reason for the lack of early diagnosis is the inadequacy of presently available diagnostic methods to ascertain which individuals are at risk.

[0602] Although blood iron parameters can be used as a screening tool, a confirmed diagnosis often employs HLA typing, which is tedious, nonspecific, and expensive and/or liver biopsy which is undesirably invasive and costly. Accordingly, others have attempted to develop inexpensive and noninvasive diagnostics both for detection of homozygotes having existing disease, in that presymptomatic detection would guide intervention to prevent organ damage, and for identification of carriers. The need for such diagnostics is documented for example, in Finch, C. A. West J Med (1990) 153:323-325; McCusick, V. et al. Mendelian Inheritance in Man 11th ed., Johns Hopkins University Press (Baltimore, 1994) pp. 1882-1887; Report of the Joint World Health Organization/HH Foundation/French HH Association Meeting, 1993.

[0603] D. Detection of Mutations in the Human MTHFR

[0604] Folic acid derivatives are coenzymes for several critical single-carbon transfer reactions, including reactions in the biosynthesis of purines, thymidylate and methionine. Methylenetetrahydrofolate reductase (MTHFR; EC 1.5.1.20) catalyzes the NADPH-linked reduction of 5,10-methylenetetrahydrofolate to 5-methyltetrahydrofolate, a co-substrate for methylation of homocysteine to methionine. The porcine liver enzyme, a flavoprotein, has been purified to homogeneity; it is a homodimer of 77-kDa subunits. Partial proteolysis of the porcine peptide has revealed two spatially distinct domains: an N-terminal domain of 40 kDa and a C-terminal domain of 37 kDa. The latter domain contains the binding site for the allosteric regulator S-adenosylmethionine.

[0605] Hereditary deficiency of MTHFR, an autosomal recessive disorder, is the most common inborn error of folic acid metabolism. A block in the production of methyltetrahydrofolate leads to elevated homocysteine with low to normal levels of methionine. Patients with severe deficien-

cies of MTHFR (0-20% activity in fibroblasts) can have variable phenotypes. Developmental delay, mental retardation, motor and gait abnormalities, peripheral neuropathy, seizures and psychiatric disturbances have been reported in this group, although at least one patient with severe MTHFR deficiency was asymptomatic. Pathologic changes in the severe form include the vascular changes that have been found in other conditions with elevated homocysteine, as well as reduced neurotransmitter and methionine levels in the CNS. A milder deficiency of MTHFR (35-50% activity) has been described in patients with coronary artery disease. Genetic heterogeneity is likely, considering the diverse clinical features, the variable levels of enzyme activity, and the differential heat inactivation profiles of the reductase in patients' cells. Methods to detect the MTHFR mutation include: AS-PCR (Hessner, et al. *Br J Haematol* 106, 237-9 (1999)) and PCR-RFLP (Nature Genetics, Frosst et al. 1995:10; 111-113).

[0606] E. Detection of Prothrombin 20210GA Polymorphism and the Factor V Leiden Polymorphism

[0607] The coagulation cascade is a complex series of zymogen activations, inactivations and feed back loops involving numerous enzymes and their cofactors. The entire cascade, from tissue injury or venous trauma to clotting has been well described (refs). The cascade culminates in the conversion of prothrombin (Factor II) to thrombin. This is catalyzed by the activated form of factor X, factor Xa and its cofactor, activated factor V, factor Va. Thrombin then converts fibrinogen to fibrin and promotes fibrin cross-linking and clot formation by activating factor XIII. In addition to the above stated functions, thrombin a serine protease, can also activate factor V in a positive feed-back loop. Factor Va is a pro-coagulant cofactor in the clotting cascade, and when clot formation is sufficient, is inactivated by activated protein C (APC).

[0608] Venous thrombosis is the obstruction of the circulation by clots that have been formed in the veins or have been released from a thrombus formed elsewhere. The most frequent sites of clot formation are the deep veins of the legs, but it also may occur in veins in the brain, retina, liver and mesentery. Factors other than heritable defects that can play a role in the development of thrombosis include recent surgery, malignant disorders, pregnancy and labor and long term immobilization.

[0609] Studies of hereditary thrombophilia, defined as an increased tendency towards venous thrombotic disease in relatively young adults, have provided insights into the genetic factors that regulate thrombosis. In 1993, Dahlback et al. (Proc Natl Acad Sci USA 1993; 90:1004-1008) described an insensitivity to APC, a critical anti-coagulant in the clotting cascade, in three unrelated families with hereditary thrombophilia. The anticoagulant property of APC resides in its capacity to inactivate the activated cofactors Va and VIIIa by limited proteolysis (ref 3). This inactivation of cofactors Va and VIIIa results in reduction of the rate of formation of thrombin, the end product of the cascade. This observation was confirmed by other investigators (ref) and the term "APC resistance" was coined to describe this particular phenotype in thrombophilic patients. In a subsequent study of 20 families with thrombophilia and APC resistance, an autosomal dominant pattern of inheritance was observed (17). Bertina et al (Nature, 1994, May 5; 369 (6475):64-7) then demonstrated that the phenotype of APC resistance is associated with heterozygosity or homozygosity for a single point mutation at nucleotide 1691 in exon 10 of the factor V gene. This single base change, a guanine to adenine substitution, yields a mutant factor V molecule wherein the arginine at position 506 is replaced with glutamine. This form of the factor V molecule, characterized at Leiden University, (Bertenia et al) is known as the FV Q506 or FV Leiden mutation, and is inactivated less efficiently by APC than the wild type protein. It has been postulated that the prolonged circulation of activated factor V promotes a hypercoagulable state and increases the risk of thrombosis. Subsequent analysis of various patient groups exhibiting symptoms of venous thrombosis indicate that the factor V Leiden mutation is the single most common heritable factor contributing to an increased risk of venous thrombosis.

[0610] In 1996, studies by Poort et al. (Blood. 1996:88; 3698-703) revealed the second most common heritable factor contributing to increase thrombotic risk. In studying the sequence of the prothrombin gene in selected patients with a documented familial history of venous thrombophilia, the Poort group identified a single point mutation in the 3' untranslated region. This G to A transition at position 20210 is strongly correlated with elevated plasma prothrombin levels, and was also shown to be associated with an almost threefold increased risk of venous thrombosis (abstract, Howard)

[0611] The first reported case of a thrombophilia patient genetically homozygous for the G to A polymorphism in the 3' untranslated region was by Howard, et al (*Blood Coagulation Fibrinolysis* 1997 *July;* 8(5):316-9). The patient, a healthy young Mexican male presented with a myocardial infarction, venous thrombosis and embolism. The patient was found to be homozygous for the prothrombin mutation and heterozygous for the Factor V Leiden mutation, supporting the doublehit theory for thrombophilia in young patients.

[0612] Studies by Hessner et al. show that the prothrombin 20210 GA genotype was nearly 5 times as prevalent in the symptomatic FVL carriers than in a random Caucasian control group (*British Journal of Haematology,* 1999, 106), and that allele frequencies for the prothrombin and Factor V mutants vary among different ethnic backgrounds (*Thromb Haemostat* 1999; 81:733-8). The above discussion confirms that early detection of the factor V Leiden mutation and the factor II prothrombin mutation are paramount in hereditary thrombotic risk assessment. The nature of these two mutations, that is, a single base change in the nucleic acid sequence, make them amenable to a variety of nucleic acid detection methods known to the art, though the demand for faster, more reliable, cost-effective and user-friendly tests for the detection of specific nucleic acid sequences continues to grow. The most common methods to test for these mutations include PCR/RFLP, AS-PCR and functional, coagulation assay.

[0613] F. Detection of the HR-2 Mutation in the Human Factor V Gene

[0614] The R-2 polymorphism is located in exon 13 of the factor V gene, and is the result of an A to G transition at base 4070, replacing the wild-type amino acid histine with the mutant argenine in the mature protein. The R-2 polymor-

phism is one of a set of mutations termed collectively HR-2. The HR-2 haplotype is defined by 6 nucleotide base substitutions in exons 13 and 16 of the factor V gene. The haplotype is associated with an increased functional resistance to activated protein C both in normal subjects and in thrombophilic patients. When present as a compound heterozygote in conjunction with the factor V Leiden mutation, clinical symptoms are comparable to those seen in patients homozygous for the factor V Leiden mutation, and include increased risk of deep vein thrombosis.

[0615] G. Detection of Single Nucleotide Polymorphisms in the Human TNF-α Gene

[0616] The human cytokine tumor necrosis factor alpha (TNF-alpha) has been shown to be a major factor in graft rejection; the more TNF-alpha present in the system, the greater the rejection response to transplanted tissue. Mutations in TNF-alpha have also been correlated with cerebral malaria (Nature 1994; 371:508-510), fulminas purpura (J Infect Dis. 1996; 174:878-880), and mucocutaneous leishmaniasis (J Exp Med. 1995; 182:1259-1264). The mutation detected in this example is located in the promoter region of the TNF-alpha gene at position minus 308. The wild-type guanine (G) is replaced with a mutant adenine (A). This result of this promoter mutation is the enhancement of transcription of TNF-alpha by 6-7 fold. Methods to detect mutations in TNF-alpha include sequencing, denaturing gradient gel electrophoresis, PCR methods, and methods involving both PCR and post-PCR hybridization with specific oligos.

[0617] H. Detection of Methicillin Resistant *Staphylococcus aureus*

[0618] *Staphylococcus aureus* is recognized as one of the major causes of infections in humans occurring in both in the hospital and in the community at large. One of the most serious concerns in treating any bacterial infection is the increasing resistance to antibiotics. The growing incidence of methicillin-resistant *S. aureus* (MRSA) infections worldwide has underscored the importance of both early detection of the infective agent, and defining a resistance profile such that proper treatment can be given. The primary mechanism for resistance to methicillin involves the production of a protein called PBP2a, encoded by the mecA gene. The mecA gene not specific to *Staphylococcus aureus*, but is of extraspecies origin. The mecA gene is however, indicative of methicillin resistance and is used as a marker for the detection of resistant bacteria. So, to identify methicillin resistant *S. aureus* via nucleic acid techniques, both the mecA gene and at least one species specific gene must be targeted. A particular species specific gene, the nuclease or nuc gene is used in the following example. Methods used to detect MRSA include time consuming and laborious culturing and coagulation assays and growth assays on antibiotic media. Molecular approaches include a Cycling Probe™ assay, the Velogene™ Kit from Alexon-Trend (Ramsey, Minn. cat #818-48), anti-body test which bind the PBP2a protein, bDNA Assay (Chiron, Emeryville, Calif.), all of which tests only for the presence of the mecA gene and are not *Staph. aureus* specific.

X. Kits

[0619] In some embodiments, the present invention provides kits comprising one or more of the components necessary for practicing the present invention. For example, the present invention provides kits for storing or delivering the enzymes of the present invention and/or the reaction components necessary to practice a cleavage assay (e.g., the INVADER assay). The kit may include any and all components necessary or desired for the enzymes or assays including, but not limited to, the reagents themselves, buffers, control reagents (e.g., tissue samples, positive and negative control target oligonucleotides, etc.), solid supports, labels, written and/or pictorial instructions and product information, inhibitors, labeling and/or detection reagents, package environmental controls (e.g., ice, desiccants, etc.), and the like. In some embodiments, the kits provide a sub-set of the required components, wherein it is expected that the user will supply the remaining components. In some embodiments, the kits comprise two or more separate containers wherein each container houses a subset of the components to be delivered. For example, a first container (e.g., box) may contain an enzyme (e.g., structure specific cleavage enzyme in a suitable storage buffer and container), while a second box may contain oligonucleotides (e.g., INVADER oligonucleotides, probe oligonucleotides, control target oligonucleotides, etc.).

[0620] Additionally, in some embodiments, the present invention provides methods of delivering kits or reagents to customers for use in the methods of the present invention. The methods of the present invention are not limited to a particular group of customers. Indeed, the methods of the present invention find use in the providing of kits or reagents to customers in many sectors of the biological and medical community, including, but not limited to customers in academic research labs, customers in the biotechnology and medical industries, and customers in governmental labs. The methods of the present invention provide for all aspects of providing the kits or reagents to the customers, including, but not limited to, marketing, sales, delivery, and technical support.

[0621] In some embodiments of the present invention, quality control (QC) and/or quality assurance (QA) experiments are conducted prior to delivery of the kits or reagents to customers. Such QC and QA techniques typically involve testing the reagents in experiments similar to the intended commercial uses (e.g., using assays similar to those described herein). Testing may include experiments to determine shelf life of products and their ability to withstand a wide range of solution and/or reaction conditions (e.g., temperature, pH, light, etc.).

[0622] In some embodiments of the present invention, the compositions and/or methods of the present invention are disclosed and/or demonstrated to customers prior to sale (e.g., through printed or web-based advertising, demonstrations, etc.) indicating the use or functionality of the present invention or components of the present invention. However, in some embodiments, customers are not informed of the presence or use of one or more components in the product being sold. In such embodiments, sales are developed, for example, through the improved and/or desired function of the product (e.g., kit) rather than through knowledge of why or how it works (i.e., the user need not know the components of kits or reaction mixtures). Thus, the present invention contemplates making kits, reagents, or assays available to users, whether or not the user has knowledge of the components or workings of the system.

[0623] Accordingly, in some embodiments, sales and marketing efforts present information about the novel and/or

improved properties of the methods and compositions of the present invention. In other embodiments, such mechanistic information is withheld from marketing materials. In some embodiments, customers are surveyed to obtain information about the type of assay components or delivery systems that most suits their needs. Such information is useful in the design of the components of the kit and the design of marketing efforts.

EXAMPLES

[0624] The following examples serve to illustrate certain preferred embodiments and aspects of the present invention and are not to be construed as limiting the scope thereof.

[0625] In the disclosure which follows, the following abbreviations apply: Afu (*Archaeoglobus fulgidus*); Mth (*Methanobacterium thermoautotrophicum*); Mja (*Methanococcus jannaschi*); Pfu (*Pyrococcus furiosus*); Pwo (*Pyrococcus woesei*); Taq (*Thermus aquaticus*); Taq DNAP, DNAPTaq, and Taq Pol I (*T. aquaticus* DNA polymerase I); DNAPStf (the Stoffel fragment of DNAPTaq); DNAPEc1 (*E. coli* DNA polymerase I); Tth (*Thermus thermophilus*); Ex. (Example); FIG. (Figure); ° C. (degrees Centigrade); g (gravitational field); hr (hour); min (minute); olio (oligonucleotide); r×n (reaction); vol (volume); w/v (weight to volume); v/v (volume to volume); BSA (bovine serum albumin); CTAB (cetyltrimethylammonium bromide); HPLC (high pressure liquid chromatography); DNA (deoxyribonucleic acid); p (plasmid); μl (microliters); ml (milliliters); μg (micrograms); mg (milligrams); M (molar); mM (milliMolar); μM (microMolar); pmoles (picomoles); amoles (attomoles); zmoles (zeptomoles); nm (nanometers); kdal (kilodaltons); OD (optical density); EDTA (ethylene diamine tetra-acetic acid); FITC (fluorescein isothiocyanate); SDS (sodium dodecyl sulfate); $NaPO_4$ (sodium phosphate); NP-40 (Nonidet P-40); Tris(tris(hydroxymethyl)-aminomethane); PMSF (phenylmethylsulfonylfluoride); TBE (Tris-Borate-EDTA, i.e., Tris buffer titrated with boric acid rather than HCl and containing EDTA); PBS (phosphate buffered saline); PPBS (phosphate buffered saline containing 1 mM PMSF); PAGE (polyacrylamide gel electrophoresis); Tween (polyoxyethylene-sorbitan); ATCC (American Type Culture Collection, Rockville, Md.); Coriell (Coriell Cell Repositories, Camden, N.J.); DSMZ (Deutsche Sammlung von Mikroorganismen und Zellculturen, Braunschweig, Germany); Ambion (Ambion, Inc., Austin, Tex.); Boehringer (Boehringer Mannheim Biochemical, Indianapolis, Ind.); MJ Research (MJ Research, Watertown, Mass.; Sigma (Sigma Chemical Company, St. Louis, Mo.); Dynal (Dynal A.S., Oslo, Norway); Gull (Gull Laboratories, Salt Lake City, Utah); Epicentre (Epicentre Technologies, Madison, Wis.); Lampire (Biological Labs., Inc., Coopersberg, Pa.); MJ Research (MJ Research, Watertown, Mass.); National Biosciences (National Biosciences, Plymouth, Minn.); NEB (New England Biolabs, Beverly, Mass.); Novagen (Novagen, Inc., Madison, Wis.); Promega (Promega, Corp., Madison, Wis.); Stratagene (Stratagene Cloning Systems, La Jolla, Calif.); Clonetech (Clonetech, Palo Alto, Calif.) Pharmacia (Pharmacia, Piscataway, N.J.); Milton Roy (Milton Roy, Rochester, N.Y.); Amersham (Amersham International, Chicago, Ill.); and USB (U.S. Biochemical, Cleveland, Ohio). Glen Research (Glen Research, Sterling, Va.); Coriell (Coriell Cell Repositories, Camden, N.J.); Gentra (Gentra, Minneapolis, Minn.); Third Wave Technologies (Third Wave Technologies, Madison, Wis.); PerSeptive Biosystems (PerSeptive Biosystems, Framington, Mass.); Microsoft (Microsoft, Redmond, Wash.); Qiagen (Qiagen, Valencia, Calif.); Molecular Probes (Molecular Probes, Eugene, Oreg.); VWR (VWR Scientific); Advanced Biotechnologies (Advanced Biotechnologies, INC., Columbia, Md.); and Perkin Elmer (also known as PE Biosytems and Applied Biosystems, Foster City, Calif.).

Example 1

Characteristics of Native Thermostable DNA Polymerases

[0626] A. 5' Nuclease Activity of DNAPTaq

[0627] During the polymerase chain reaction (PCR) (Saiki et al., Science 239:487 [1988]; Mullis and Faloona, Meth. Enzymol., 155:335 [1987]), DNAPTaq is able to amplify many, but not all, DNA sequences. One sequence that cannot be amplified using DNAPTaq is shown in FIG. **5** (Hairpin structure is SEQ ID NO:15, FIG. **5** also shows a primer: SEQ ID NO: 17) This DNA sequence has the distinguishing characteristic of being able to fold on itself to form a hairpin with two single-stranded arms, which correspond to the primers used in PCR.

[0628] To test whether this failure to amplify is due to the 5' nuclease activity of the enzyme, the abilities of DNAPTaq and DNAPStf to amplify this DNA sequence during 30 cycles of PCR were compared. Synthetic oligonucleotides were obtained from The Biotechnology Center at the University of Wisconsin-Madison. The DNAPTaq and DNAPStf were from Perkin Elmer (i.e., AMPLITAQ DNA polymerase and the Stoffel fragment of AMPLITAQ DNA polymerase). The substrate DNA comprised the hairpin structure shown in FIG. **6** cloned in a double-stranded form into pUC19. The primers used in the amplification are listed as SEQ ID NOS:16-17. Primer SEQ ID NO:17 is shown annealed to the 3' arm of the hairpin structure in FIG. **5**. Primer SEQ ID NO:16 is shown as the first 20 nucleotides in bold on the 5' arm of the hairpin in FIG. **5**.

[0629] Polymerase chain reactions comprised 1 ng of supercoiled plasmid target DNA, 5 pmoles of each primer, 40 μM each dNTP, and 2.5 units of DNAPTaq or DNAPStf, in a 50 μl solution of 10 mM Tris.Cl pH 8.3. The DNAPTaq reactions included 50 mM KCl and 1.5 mM $MgCl_2$. The temperature profile was 95° C. for 30 sec., 55° C. for 1 min. and 72° C. for 1 min., through 30 cycles. Ten percent of each reaction was analyzed by gel electrophoresis through 6% polyacrylamide (cross-linked 29:1) in a buffer of 45 mM Tris.Borate, pH 8.3, 1.4 mM EDTA.

[0630] The results are shown in FIG. **6**. The expected product was made by DNAPStf (indicated simply as "S") but not by DNAPTaq (indicated as "T"). It was concluded that the 5' nuclease activity of DNAPTaq is responsible for the lack of amplification of this DNA sequence.

[0631] To test whether the 5' unpaired nucleotides in the substrate region of this structured DNA are removed by DNAPTaq, the fate of the end-labeled 5' arm during four cycles of PCR was compared using the same two polymerases (FIG. **7**). The hairpin templates, such as the one described in FIG. **5**, were made using DNAPStf and a ^{32}P-5'-end-labeled primer. The 5'-end of the DNA was

released as a few large fragments by DNAPTaq but not by DNAPStf. The sizes of these fragments (based on their mobilities) show that they contain most or all of the unpaired 5' arm of the DNA. Thus, cleavage occurs at or near the base of the bifurcated duplex. These released fragments terminate with 3' OH groups, as evidenced by direct sequence analysis, and the abilities of the fragments to be extended by terminal deoxynucleotidyl transferase.

[0632] FIGS. **8-10** show the results of experiments designed to characterize the cleavage reaction catalyzed by DNAPTaq. Unless otherwise specified, the cleavage reactions comprised 0.01 pmoles of heat-denatured, end-labeled hairpin DNA (with the unlabeled complementary strand also present), 1 pmole primer (complementary to the 3' arm) and 0.5 units of DNAPTaq (estimated to be 0.026 pmoles) in a total volume of 10 μl of 10 mM Tris-Cl, ph 8.5, 50 mM KCl and 1.5 mM $MgCl_2$. As indicated, some reactions had different concentrations of KCl, and the precise times and temperatures used in each experiment are indicated in the individual Figures. The reactions that included a primer used the one shown in FIG. **5** (SEQ ID NO:17). In some instances, the primer was extended to the junction site by providing polymerase and selected nucleotides.

[0633] Reactions were initiated at the final reaction temperature by the addition of either the $MgCl_2$ or enzyme. Reactions were stopped at their incubation temperatures by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. The T_m calculations listed were made using the Oligo™ primer analysis software from National Biosciences, Inc. These were determined using 0.25 μM as the DNA concentration, at either 15 or 65 mM total salt (the 1.5 mM $MgCl_2$ in all reactions was given the value of 15 mM salt for these calculations).

[0634] FIG. **8** is an autoradiogram containing the results of a set of experiments and conditions on the cleavage site. FIG. **8**A is a determination of reaction components that enable cleavage. Incubation of 5'-end-labeled hairpin DNA was for 30 minutes at 55° C., with the indicated components. The products were resolved by denaturing polyacrylamide gel electrophoresis and the lengths of the products, in nucleotides, are indicated. FIG. **8**B describes the effect of temperature on the site of cleavage in the absence of added primer. Reactions were incubated in the absence of KCl for 10 minutes at the indicated temperatures. The lengths of the products, in nucleotides, are indicated.

[0635] Surprisingly, cleavage by DNAPTaq requires neither a primer nor dNTPs (See FIG. **8**A). Thus, the 5' nuclease activity can be uncoupled from polymerization. Nuclease activity requires magnesium ions, though manganese ions can be substituted, albeit with potential changes in specificity and activity. Neither zinc nor calcium ions support the cleavage reaction. The reaction occurs over a broad temperature range, from 25° C. to 85° C., with the rate of cleavage increasing at higher temperatures.

[0636] Still referring to FIG. **8**, the primer is not elongated in the absence of added dNTPs. However, the primer influences both the site and the rate of cleavage of the hairpin. The change in the site of cleavage (FIG. **8**A) apparently results from disruption of a short duplex formed between the arms of the DNA substrate. In the absence of primer, the sequences indicated by underlining in FIG. **5** could pair, forming an extended duplex. Cleavage at the end of the extended duplex would release the 11 nucleotide fragment seen on the FIG. **8**A lanes with no added primer. Addition of excess primer (FIG. **8**A, lanes 3 and 4) or incubation at an elevated temperature (FIG. **8**B) disrupts the short extension of the duplex and results in a longer 5' arm and, hence, longer cleavage products.

[0637] The location of the 3' end of the primer can influence the precise site of cleavage. Electrophoretic analysis revealed that in the absence of primer (FIG. **8**B), cleavage occurs at the end of the substrate duplex (either the extended or shortened form, depending on the temperature) between the first and second base pairs. When the primer extends up to the base of the duplex, cleavage also occurs one nucleotide into the duplex. However, when a gap of four or six nucleotides exists between the 3' end of the primer and the substrate duplex, the cleavage site is shifted four to six nucleotides in the 5' direction.

[0638] FIG. **9** describes the kinetics of cleavage in the presence (FIG. **9**A) or absence (FIG. **9**B) of a primer oligonucleotide. The reactions were run at 55° C. with either 50 mM KCl (FIG. **9**A) or 20 mM KCl (FIG. **9**B). The reaction products were resolved by denaturing polyacrylamide gel electrophoresis and the lengths of the products, in nucleotides, are indicated. "M", indicating a marker, is a 5' end-labeled 19-nt oligonucleotide. Under these salt conditions, FIGS. **9**A and **9**B indicate that the reaction appears to be about twenty times faster in the presence of primer than in the absence of primer. This effect on the efficiency may be attributable to proper alignment and stabilization of the enzyme on the substrate.

[0639] The relative influence of primer on cleavage rates becomes much greater when both reactions are run in 50 mM KCl. In the presence of primer, the rate of cleavage increases with KCl concentration, up to about 50 mM. However, inhibition of this reaction in the presence of primer is apparent at 100 mM and is complete at 150 mM KCl. In contrast, in the absence of primer the rate is enhanced by concentration of KCl up to 20 mM, but it is reduced at concentrations above 30 mM. At 50 mM KCl, the reaction is almost completely inhibited. The inhibition of cleavage by KCl in the absence of primer is affected by temperature, being more pronounced at lower temperatures.

[0640] Recognition of the 5' end of the arm to be cut appears to be an important feature of substrate recognition. Substrates that lack a free 5' end, such as circular M13 DNA, cannot be cleaved under any conditions tested. Even with substrates having defined 5' arms, the rate of cleavage by DNAPTaq is influenced by the length of the arm. In the presence of primer and 50 mM KCl, cleavage of a 5' extension that is 27 nucleotides long is essentially complete within 2 minutes at 55° C. In contrast, cleavages of molecules with 5' arms of 84 and 188 nucleotides are only about 90% and 40% complete after 20 minutes. Incubation at higher temperatures reduces the inhibitory effects of long extensions indicating that secondary structure in the 5' arm or a heat-labile structure in the enzyme may inhibit the reaction. A mixing experiment, run under conditions of substrate excess, shows that the molecules with long arms do not preferentially tie up the available enzyme in non-productive complexes. These results may indicate that the 5' nuclease domain gains access to the cleavage site at the end of the bifurcated duplex by moving down the 5' arm from

one end to the other. Longer 5' arms would be expected to have more adventitious secondary structures (particularly when KCl concentrations are high), which would be likely to impede this movement.

[0641] Cleavage does not appear to be inhibited by long 3' arms of either the substrate strand target molecule or pilot nucleic acid, at least up to 2 kilobases. At the other extreme, 3' arms of the pilot nucleic acid as short as one nucleotide can support cleavage in a primer-independent reaction, albeit inefficiently. Fully paired oligonucleotides do not elicit cleavage of DNA templates during primer extension.

[0642] The ability of DNAPTaq to cleave molecules even when the complementary strand contains only one unpaired 3' nucleotide may be useful in optimizing allele-specific PCR. PCR primers that have unpaired 3' ends could act as pilot oligonucleotides to direct selective cleavage of unwanted templates during preincubation of potential template-primer complexes with DNAPTaq in the absence of nucleoside triphosphates.

[0643] B. 5' Nuclease Activities of Other DNAPs

[0644] To determine whether other 5' nucleases in other DNAPs would be suitable for the present invention, an array of enzymes, several of which were reported in the literature to be free of apparent 5' nuclease activity, were examined. The ability of these other enzymes to cleave nucleic acids in a structure-specific manner was tested using the hairpin substrate shown in FIG. **5** under conditions reported to be optimal for synthesis by each enzyme.

[0645] DNAPEc1 and DNAP Klenow were obtained from Promega; the DNAP of *Pyrococcus furious* ("Pfu", Bargseid et al., Strategies 4:34 [1991]) was from Stratagene; the DNAP of *Thermococcus litoralis* ("Tli", Vent™(exo-), Perler et al., Proc. Natl. Acad. Sci. USA 89:5577 [1992] was from New England Biolabs; the DNAP of *Thermus flavus* ("Tfl", Kaledin et al., Biokhimiya 46:1576 [1981] was from Epicentre Technologies; and the DNAP of *Thermus thermophilus* ("Tth", Carballeira et al., Biotechn., 9:276 [1990]; Myers et al., Biochem., 30:7661 (1991)] was from U.S. Biochemicals.

[0646] 0.5 units of each DNA polymerase was assayed in a 20 μl reaction, using either the buffers supplied by the manufacturers for the primer-dependent reactions, or 10 mM Tris.Cl, pH 8.5, 1.5 mM $MgCl_2$, and 20 mM KCl. Reaction mixtures were at held 72° C. before the addition of enzyme.

[0647] FIG. **10** is an autoradiogram recording the results of these tests. FIG. **10**A demonstrates reactions of endonucleases of DNAPs of several thermophilic bacteria. The reactions were incubated at 55° C. for 10 minutes in the presence of primer or at 72° C. for 30 minutes in the absence of primer, and the products were resolved by denaturing polyacrylamide gel electrophoresis. The lengths of the products, in nucleotides, are indicated. FIG. **10**B demonstrates endonucleolytic cleavage by the 5' nuclease of DNAPEc1. The DNAPEc1 and DNAP Klenow reactions were incubated for 5 minutes at 37° C. Note the light band of cleavage products of 25 and 11 nucleotides in the DNAPEc1 lanes (made in the presence and absence of primer, respectively). FIG. **8**A also demonstrates DNAPTaq reactions in the presence (+) or absence (−) of primer. These reactions were run in 50 mM and 20 mM KCl, respectively, and were incubated at 55° C. for 10 minutes.

[0648] Referring to FIG. **10**A, DNAPs from the eubacteria *Thermus thermophilus* and *Thermus flavus* cleave the substrate at the same place as DNAPTaq, both in the presence and absence of primer. In contrast, DNAPs from the archaebacteria *Pyrococcus furiosus* and *Thermococcus litoralis* are unable to cleave the substrates endonucleolytically. The DNAPs from *Pyrococcus furious* and *Thermococcus litoralis* share little sequence homology with eubacterial enzymes (Ito et al., *Nucl. Acids Res.* 19:4045 (1991); Mathur et al., *Nucl. Acids. Res.* 19:6952 (1991); see also Perler et al.). Referring to FIG. **10**B, DNAPEc1 also cleaves the substrate, but the resulting cleavage products are difficult to detect unless the 3' exonuclease is inhibited. The amino acid sequences of the 5' nuclease domains of DNAPEc1 and DNAPTaq are about 38% homologous (Gelfand, supra).

[0649] The 5' nuclease domain of DNAPTaq also shares about 19% homology with the 5' exonuclease encoded by gene 6 of bacteriophage T7 (Dunn et al., J. Mol. Biol., 166:477 [1983]). This nuclease, which is not covalently attached to a DNAP polymerization domain, is also able to cleave DNA endonucleolytically, at a site similar or identical to the site that is cut by the 5' nucleases described above, in the absence of added primers.

[0650] C. Transcleavage

[0651] The ability of a 5' nuclease to be directed to cleave efficiently at any specific sequence was demonstrated in the following experiment. A partially complementary oligonucleotide termed a "pilot oligonucleotide" was hybridized to sequences at the desired point of cleavage. The non-complementary part of the pilot oligonucleotide provided a structure analogous to the 3' arm of the template (see FIG. **5**), whereas the 5' region of the substrate strand became the 5' arm. A primer was provided by designing the 3' region of the pilot so that it would fold on itself creating a short hairpin with a stabilizing tetra-loop (Antao et al., *Nucl. Acids Res.* 19:5901 [1991]). Two pilot oligonucleotides are shown in FIG. **11**A. Oligonucleotides 19-12 (SEQ ID NO:18), 30-12 (SEQ ID NO:19) and 30-0 (SEQ ID NO:20) are 31, 42 or 30 nucleotides long, respectively. However, oligonucleotides 19-12 (SEQ ID NO:18) and 34-19 (SEQ ID NO:19) have only 19 and 30 nucleotides, respectively, that are complementary to different sequences in the substrate strand. The pilot oligonucleotides are calculated to melt off their complements at about 50° C. (19-12) and about 75° C. (30-12). Both pilots have 12 nucleotides at their 3' ends, which act as 3' arms with base-paired primers attached.

[0652] To demonstrate that cleavage could be directed by a pilot oligonucleotide, a single-stranded target DNA with DNAPTaq was incubated in the presence of two potential pilot oligonucleotides. The transcleavage reactions, where the target and pilot nucleic acids are not covalently linked, includes 0.01 pmoles of single end-labeled substrate DNA, 1 unit of DNAPTaq and 5 pmoles of pilot oligonucleotide in a volume of 20 μl of the same buffers. These components were combined during a one minute incubation at 95° C., to denature the PCR-generated double-stranded substrate DNA, and the temperatures of the reactions were then reduced to their final incubation temperatures. Oligonucleotides 30-12 and 19-12 can hybridize to regions of the substrate DNAs that are 85 and 27 nucleotides from the 5' end of the targeted strand.

[0653] FIG. **19** shows the complete 206-mer sequence (SEQ ID NO:27). The 206-mer was generated by PCR. The

M13/pUC 24-mer reverse sequencing (−48) primer and the M13/pUC sequencing (−47) primer from NEB (catalogue nos. 1233 and 1224 respectively) were used (50 pmoles each) with the pGEM3z(f+) plasmid vector (Promega) as template (10 ng) containing the target sequences. The conditions for PCR were as follows: 50 μM of each dNTP and 2.5 units of Taq DNA polymerase in 100 μl of 20 mM Tris-Cl, pH 8.3, 1.5 mM $MgCl_2$, 50 mM KCl with 0.05% Tween-20 and 0.05% NP-40. Reactions were cycled 35 times through 95° C. for 45 seconds, 63° C. for 45 seconds, then 72° C. for 75 seconds. After cycling, reactions were finished off with an incubation at 72° C. for 5 minutes. The resulting fragment was purified by electrophoresis through a 6% polyacrylamide gel (29:1 cross link) in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA, visualized by ethidium bromide staining or autoradiography, excised from the gel, eluted by passive diffusion, and concentrated by ethanol precipitation.

[0654] Cleavage of the substrate DNA occurred in the presence of the pilot oligonucleotide 19-12 at 50° C. (FIG. **11**B, lanes 1 and 7) but not at 75° C. (lanes 4 and 10). In the presence of oligonucleotide 30-12 cleavage was observed at both temperatures. Cleavage did not occur in the absence of added oligonucleotides (lanes 3, 6 and 12) or at about 80° C. even though at 50° C. adventitious structures in the substrate allowed primer-independent cleavage in the absence of KCl (FIG. **11**B, lane 9). A non-specific oligonucleotide with no complementarity to the substrate DNA did not direct cleavage at 50° C., either in the absence or presence of 50 mM KCl (lanes 13 and 14). Thus, the specificity of the cleavage reactions can be controlled by the extent of complementarity to the substrate and by the conditions of incubation.

[0655] D. Cleavage of RNA

[0656] A shortened RNA version of the sequence used in the transcleavage experiments discussed above was tested for its ability to serve as a substrate in the reaction. The RNA is cleaved at the expected place, in a reaction that is dependent upon the presence of the pilot oligonucleotide. The RNA substrate, made by T7 RNA polymerase in the presence of (α-^{32}P)UTP, corresponds to a truncated version of the DNA substrate used in FIG. **11**B. Reaction conditions were similar to those in used for the DNA substrates described above, with 50 mM KCl; incubation was for 40 minutes at 55° C. The pilot oligonucleotide used is termed 30-0 (SEQ ID NO:20) and is shown in FIG. **12**A.

[0657] The results of the cleavage reaction is shown in FIG. **13**B. The reaction was run either in the presence or absence of DNAPTaq or pilot oligonucleotide as indicated in FIG. **12**B.

[0658] Strikingly, in the case of RNA cleavage, a 3' arm is not required for the pilot oligonucleotide. It is very unlikely that this cleavage is due to previously described RNaseH, which would be expected to cut the RNA in several places along the 30 base-pair long RNA-DNA duplex. The 5' nuclease of DNAPTaq is a structure-specific RNaseH that cleaves the RNA at a single site near the 5' end of the heteroduplexed region.

[0659] It is surprising that an oligonucleotide lacking a 3' arm is able to act as a pilot in directing efficient cleavage of an RNA target because such oligonucleotides are unable to direct efficient cleavage of DNA targets using native DNAPs. However, some 5' nucleases of the present invention (for example, clones E, F and G of FIG. **4**) can cleave DNA in the absence of a 3' arm. In other words, a non-extendable cleavage structure is not required for specific cleavage with some 5' nucleases of the present invention derived from thermostable DNA polymerases.

[0660] Tests were then conducted to determine whether cleavage of an RNA template by DNAPTaq in the presence of a fully complementary primer could help explain why DNAPTaq is unable to extend a DNA oligonucleotide on an RNA template, in a reaction resembling that of reverse transcriptase. Another thermophilic DNAP, DNAPTth, is able to use RNA as a template, but only in the presence of Mn++, so it was predicted that this enzyme would not cleave RNA in the presence of this cation. Accordingly, an RNA molecule was incubated with an appropriate pilot oligonucleotide in the presence of DNAPTaq or DNAPTth, in buffer containing either Mg++ or Mn++. As expected, both enzymes cleaved the RNA in the presence of Mg++. However, DNAPTaq, but not DNAPTth, degraded the RNA in the presence of Mn++. It was concluded that the 5' nuclease activities of many DNAPs may contribute to their inability to use RNA as templates.

Example 2

Generation of 5' Nucleases from Thermostable DNA Polymerases

[0661] Thermostable DNA polymerases were generated which have reduced synthetic activity, an activity that is an undesirable side-reaction during DNA cleavage in the detection assay of the invention, yet have maintained thermostable nuclease activity. The result is a thermostable polymerase which cleaves nucleic acids DNA with extreme specificity.

[0662] Type A DNA polymerases from eubacteria of the genus *Thermus* share extensive protein sequence identity (90% in the polymerization domain, using the Lipman-Pearson method in the DNA analysis software from DNASTar, WI) and behave similarly in both polymerization and nuclease assays. Therefore, the genes for the DNA polymerase of *Thermus aquaticus* (DNAPTaq) and *Thermus flavus* (DNAPTfl) are used as representatives of this class. Polymerase genes from other eubacterial organisms, such as *Thermus thermophilus, Thermus* sp., *Thermotoga maritima, Thermosipho africanus* and *Bacillus stearothermophilus* are equally suitable. The DNA polymerases from these thermophilic organisms are capable of surviving and performing at elevated temperatures, and can thus be used in reactions in which temperature is used as a selection against non-specific hybridization of nucleic acid strands.

[0663] The restriction sites used for deletion mutagenesis, described below, were chosen for convenience. Different sites situated with similar convenience are available in the *Thermus thermophilus* gene and can be used to make similar constructs with other Type A polymerase genes from related organisms.

[0664] A. Creation of 5' Nuclease Constructs

[0665] 1. Modified DNAPTaq Genes

[0666] The first step was to place a modified gene for the Taq DNA polymerase on a plasmid under control of an

inducible promoter. The modified Taq polymerase gene was isolated as follows: The Taq DNA polymerase gene was amplified by polymerase chain reaction from genomic DNA from *Thermus aquaticus*, strain YT-1 (Lawyer et al., supra), using as primers the oligonucleotides described in SEQ ID NOS:13-14. The resulting fragment of DNA has a recognition sequence for the restriction endonuclease EcoRI at the 5' end of the coding sequence and a BglII sequence at the 3' end. Cleavage with BglII leaves a 5' overhang or "sticky end" that is compatible with the end generated by BamHI. The PCR-amplified DNA was digested with EcoRI and BamHI. The 2512 bp fragment containing the coding region for the polymerase gene was gel purified and then ligated into a plasmid which contains an inducible promoter.

[0667] In one embodiment of the invention, the PTTQ18 vector, which contains the hybrid trp-lac (tac) promoter, was used (Stark, *Gene* 5:255 [1987]) and shown in FIG. **13**. The tac promoter is under the control of the *E. coli* lac repressor. Repression allows the synthesis of the gene product to be suppressed until the desired level of bacterial growth has been achieved, at which point repression is removed by addition of a specific inducer, isopropyl-β-D-thiogalactopyranoside (IPTG). Such a system allows the expression of foreign proteins that may slow or prevent growth of transformants.

[0668] Bacterial promoters, such as tac, may not be adequately suppressed when they are present on a multiple copy plasmid. If a highly toxic protein is placed under control of such a promoter, the small amount of expression leaking through can be harmful to the bacteria. In another embodiment of the invention, another option for repressing synthesis of a cloned gene product was used. The non-bacterial promoter, from bacteriophage T7, found in the plasmid vector series pET-3 was used to express the cloned mutant Taq polymerase genes (FIG. **15**; Studier and Moffatt, J. Mol. Biol., 189:113 [1986]). This promoter initiates transcription only by T7 RNA polymerase. In a suitable strain, such as BL21(DE3)pLYS, the gene for this RNA polymerase is carried on the bacterial genome under control of the lac operator. This arrangement has the advantage that expression of the multiple copy gene (on the plasmid) is completely dependent on the expression of T7 RNA polymerase, which is easily suppressed because it is present in a single copy.

[0669] For ligation into the pTTQ18 vector (FIG. **13**), the PCR product DNA containing the Taq polymerase coding region (mutTaq, clone 4B, SEQ ID NO:21) was digested with EcoRI and BglII and this fragment was ligated under standard "sticky end" conditions (Sambrook et al. Molecular Cloning, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, pp. 1.63-1.69 [1989]) into the EcoRI and BamHI sites of the plasmid vector pTTQ18. Expression of this construct yields a translational fusion product in which the first two residues of the native protein (Met-Arg) are replaced by three from the vector (Met-Asn-Ser), but the remainder of the natural protein would not change. The construct was transformed into the JM109 strain of *E. coli* and the transformants were plated under incompletely repressing conditions that do not permit growth of bacteria expressing the native protein. These plating conditions allow the isolation of genes containing pre-existing mutations, such as those that result from the infidelity of Taq polymerase during the amplification process.

[0670] Using this amplification/selection protocol, a clone (depicted in FIG. **3**B) containing a mutated Taq polymerase gene (mutTaq, clone 3B) was isolated. The mutant was first detected by its phenotype, in which temperature-stable 5' nuclease activity in a crude cell extract was normal, but polymerization activity was almost absent (approximately less than 1% of wild type Taq polymerase activity).

[0671] DNA sequence analysis of the recombinant gene showed that it had changes in the polymerase domain resulting in two amino acid substitutions: an A to G change at nucleotide position 1394 causes a Glu to Gly change at amino acid position 465 (numbered according to the natural nucleic and amino acid sequences, SEQ ID NOS:1 and 4) and another A to G change at nucleotide position 2260 causes a Gln to Arg change at amino acid position 754. Because the Gln to Gly mutation is at a nonconserved position and because the Glu to Arg mutation alters an amino acid that is conserved in virtually all of the known Type A polymerases, this latter mutation is most likely the one responsible for curtailing the synthesis activity of this protein. The nucleotide sequence for the FIG. **3**B construct is given in SEQ ID NO:21. The enzyme encoded by this sequence is referred to as Cleavase® A/G.

[0672] Subsequent derivatives of DNAPTaq constructs were made from the mutTaq gene, thus, they all bear these amino acid substitutions in addition to their other alterations, unless these particular regions were deleted. These mutated sites are indicated by black boxes at these locations in the diagrams in FIG. **3**. In FIG. **3**, the designation "3'Exo" is used to indicate the location of the 3' exonuclease activity associated with Type A polymerases which is not present in DNAPTaq. All constructs except the genes shown in FIGS. **3**E, F and G were made in the pTTQ18 vector.

[0673] The cloning vector used for the genes in FIGS. **3**E and F was from the commercially available pET-3 series, described above. Though this vector series has only a BamHI site for cloning downstream of the T7 promoter, the series contains variants that allow cloning into any of the three reading frames. For cloning of the PCR product described above, the variant called pET-3c was used (FIG. **14**). The vector was digested with BamHI, dephosphorylated with calf intestinal phosphatase, and the sticky ends were filled in using the Klenow fragment of DNAPEc1 and dNTPs. The gene for the mutant Taq DNAP shown in FIG. **3**B (mutTaq, clone 3B) was released from pTTQ18 by digestion with EcoRI and SalI, and the "sticky ends" were filled in as was done with the vector. The fragment was ligated to the vector under standard blunt-end conditions (Sambrook et al., Molecular Cloning, supra), the construct was transformed into the BL21(DE3)pLYS strain of *E. coli*, and isolates were screened to identify those that were ligated with the gene in the proper orientation relative to the promoter. This construction yields another translational fusion product, in which the first two amino acids of DNAPTaq (Met-Arg) are replaced by 13 from the vector plus two from the PCR primer (Met-Ala-Ser-Met-Thr-Gly-Gly-Gln-Gln-Met-Gly-Arg-Ile-Asn-Ser) (SEQ ID NO:24).

[0674] In these experiments, the goal was to generate enzymes that lacked the ability to synthesize DNA, but retained the ability to cleave nucleic acids with a 5' nuclease activity. The act of primed, templated synthesis of DNA is actually a coordinated series of events, so it is possible to

disable DNA synthesis by disrupting one event while not affecting the others. These steps include, but are not limited to, primer recognition and binding, dNTP binding and catalysis of the inter-nucleotide phosphodiester bond. Some of the amino acids in the polymerization domain of DNAPEc1 have been linked to these functions, but the precise mechanisms are as yet poorly defined.

[0675] One way of destroying the polymerizing ability of a DNA polymerase is to delete all or part of the gene segment that encodes that domain for the protein, or to otherwise render the gene incapable of making a complete polymerization domain. Individual mutant enzymes may differ from each other in stability and solubility both inside and outside cells. For instance, in contrast to the 5' nuclease domain of DNAPEc1, which can be released in an active form from the polymerization domain by gentle proteolysis (Setlow and Kornberg, J. Biol. Chem., 247:232 [1972]), the *Thermus* nuclease domain, when treated similarly, becomes less soluble and the cleavage activity is often lost.

[0676] Using the mutant gene shown in FIG. **3**B as starting material, several deletion constructs were created. All cloning technologies were standard (Sambrook et al., supra) and are summarized briefly, as follows:

[0677] FIG. **3**C: The mutTaq construct was digested with PstI, which cuts once within the polymerase coding region, as indicated, and cuts immediately downstream of the gene in the multiple cloning site of the vector. After release of the fragment between these two sites, the vector was re-ligated, creating an 894-nucleotide deletion, and bringing into frame a stop codon 40 nucleotides downstream of the junction. The nucleotide sequence of this 5' nuclease (clone 4C) is given in SEQ ID NO:9.

[0678] FIG. **3**D: The mutTaq construct was digested with NheI, which cuts once in the gene at position 2047. The resulting four-nucleotide 5' overhanging ends were filled in, as described above, and the blunt ends were re-ligated. The resulting four-nucleotide insertion changes the reading frame and causes termination of translation ten amino acids downstream of the mutation. The nucleotide sequence of this 5' nuclease (clone 3D) is given in SEQ ID NO:10.

[0679] FIG. **3**E: The entire mutTaq gene was cut from pTTQ18 using EcoRI and SalI and cloned into pET-3c, as described above. This clone was digested with BstXI and XcmI, at unique sites that are situated as shown in FIG. **3**E. The DNA was treated with the Klenow fragment of DNAPEc1 and dNTPs, which resulted in the 3' overhangs of both sites being trimmed to blunt ends. These blunt ends were ligated together, resulting in an out-of-frame deletion of 1540 nucleotides. An in-frame termination codon occurs 18 triplets past the junction site. The nucleotide sequence of this 5' nuclease (clone 3E) is given in SEQ ID NO:11, with the appropriate leader sequence given in SEQ ID NO:25. It is also referred to as Cleavase® BX.

[0680] FIG. **3**F: The entire mutTaq gene was cut from pTTQ18 using EcoRI and SalI and cloned into pET-3c, as described above. This clone was digested with BstXI and BamHI, at unique sites that are situated as shown in the diagram. The DNA was treated with the Klenow fragment of DNAPEc1 and dNTPs, which resulted in the 3' overhang of the BstXI site being trimmed to a blunt end, while the 5' overhang of the BamHI site was filled in to make a blunt end. These ends were ligated together, resulting in an in-frame deletion of 903 nucleotides. The nucleotide sequence of the 5' nuclease (clone 3F) is given in SEQ ID NO:12. It is also referred to as Cleavase® BB.

[0681] FIG. **3**G: This polymerase is a variant of that shown in FIG. **4**E. It was cloned in the plasmid vector pET-21 (Novagen). The non-bacterial promoter from bacteriophage T7, found in this vector, initiates transcription only by T7 RNA polymerase. See Studier and Moffatt, supra. In a suitable strain, such as (DES)pLYS, the gene for this RNA polymerase is carried on the bacterial genome under control of the lac operator. This arrangement has the advantage that expression of the multiple copy gene (on the plasmid) is completely dependent on the expression of T7 RNA polymerase, which is easily suppressed because it is present in a single copy. Because the expression of these mutant genes is under this tightly controlled promoter, potential problems of toxicity of the expressed proteins to the host cells are less of a concern.

[0682] The pET-21 vector also features a "His*Tag", a stretch of six consecutive histidine residues that are added on the carboxy terminus of the expressed proteins. The resulting proteins can then be purified in a single step by metal chelation chromatography, using a commercially available (Novagen) column resin with immobilized Ni^{++} ions. The 2.5 ml columns are reusable, and can bind up to 20 mg of the target protein under native or denaturing (guanidine*HCl or urea) conditions.

[0683] *E. coli* (DES)pLYS cells are transformed with the constructs described above using standard transformation techniques, and used to inoculate a standard growth medium (e.g., Luria-Bertani broth). Production of T7 RNA polymerase is induced during log phase growth by addition of IPTG and incubated for a further 12 to 17 hours. Aliquots of culture are removed both before and after induction and the proteins are examined by SDS-PAGE. Staining with Coomassie Blue allows visualization of the foreign proteins if they account for about 3-5% of the cellular protein and do not co-migrate with any of the major protein bands. Proteins that co-migrate with major host protein must be expressed as more than 10% of the total protein to be seen at this stage of analysis.

[0684] Some mutant proteins are sequestered by the cells into inclusion bodies. These are granules that form in the cytoplasm when bacteria are made to express high levels of a foreign protein, and they can be purified from a crude lysate, and analyzed by SDS-PAGE to determine their protein content. If the cloned protein is found in the inclusion bodies, it must be released to assay the cleavage and polymerase activities. Different methods of solubilization may be appropriate for different proteins, and a variety of methods are known (See e.g., Builder & Ogez, U.S. Pat. No. 4,511,502 (1985); Olson, U.S. Pat. No. 4,518,526 (1985); Olson & Pai, U.S. Pat. No. 4,511,503 (1985); and Jones et al., U.S. Pat. No. 4,512,922 (1985), all of which are hereby incorporated by reference).

[0685] The solubilized protein is then purified on the Ni^{++}column as described above, following the manufacturers instructions (Novagen). The washed proteins are eluted from the column by a combination of imidazole competitor (1 M) and high salt (0.5 M NaCl), and dialyzed to exchange the buffer and to allow denature proteins to refold. Typical

recoveries result in approximately 20 μg of specific protein per ml of starting culture. The DNAP mutant is referred to as the CLEAVASE BN nuclease and the sequence is given in SEQ ID NO:26 (the amino acid sequence of the CLEAVASE BN nuclease is obtained by translating the DNA sequence of SEQ ID NO:26).

[0686] 2. Modified DNAPTfl Gene

[0687] The DNA polymerase gene of *Thermus flavus* was isolated from the "*T. flavus*" AT-62 strain obtained from the American Type Tissue Collection (ATCC 33923). This strain has a different restriction map then does the *T. flavus* strain used to generate the sequence published by Akhmetzjanov and Vakhitov, supra. The published sequence is listed as SEQ ID NO:2. No sequence data has been published for the DNA polymerase gene from the AT-62 strain of *T. flavus*.

[0688] Genomic DNA from *T. flavus* was amplified using the same primers used to amplify the *T. aquaticus* DNA polymerase gene (SEQ ID NOS:13-14). The approximately 2500 base pair PCR fragment was digested with EcoRI and BamHI. The over-hanging ends were made blunt with the Klenow fragment of DNAPEc1 and dNTPs. The resulting approximately 1800 base pair fragment containing the coding region for the N-terminus was ligated into pET-3c, as described above. This construct, clone 4B, is depicted in FIG. **4**B. The wild type *T. flavus* DNA polymerase gene is depicted in FIG. **4**A. The 4B clone has the same leader amino acids as do the DNAPTaq clones 4E and F which were cloned into pET-3c; it is not known precisely where translation termination occurs, but the vector has a strong transcription termination signal immediately downstream of the cloning site.

[0689] B. Growth and Induction of Transformed Cells

[0690] Bacterial cells were transformed with the constructs described above using standard transformation techniques and used to inoculate 2 mls of a standard growth medium (e.g., Luria-Bertani broth). The resulting cultures were incubated as appropriate for the particular strain used, and induced if required for a particular expression system. For all of the constructs depicted in FIGS. **3** and **4**, the cultures were grown to an optical density (at 600 nm wavelength) of 0.5 OD.

[0691] To induce expression of the cloned genes, the cultures were brought to a final concentration of 0.4 mM IPTG and the incubations were continued for 12 to 17 hours. Then, 50 μl aliquots of each culture were removed both before and after induction and were combined with 20 μl of a standard gel loading buffer for sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). Subsequent staining with Coomassie Blue (Sambrook et al., supra) allows visualization of the foreign proteins if they account for about 3-5% of the cellular protein and do not co-migrate with any of the major *E. coli* protein bands. Proteins that do co-migrate with a major host protein must be expressed as more than 10% of the total protein to be seen at this stage of analysis.

[0692] C. Heat Lysis and Fractionation

[0693] Expressed thermostable proteins (i.e., the 5' nucleases), were isolated by heating crude bacterial cell extracts to cause denaturation and precipitation of the less stable *E. coli* proteins. The precipitated *E. coli* proteins were then, along with other cell debris, removed by centrifugation. Then, 1.7 mls of the culture were pelleted by microcentrifugation at 12,000 to 14,000 rpm for 30 to 60 seconds. After removal of the supernatant, the cells were resuspended in 400 μl of buffer A (50 mM Tris-HCl, pH 7.9, 50 mM dextrose, 1 mM EDTA), re-centrifuged, then resuspended in 80 μl of buffer A with 4 mg/ml lysozyme. The cells were incubated at room temperature for 15 minutes, then combined with 80 μl of buffer B (10 mM Tris-HCl, pH 7.9, 50 mM KCl, 1 mM EDTA, 1 mM PMSF, 0.5% Tween-20, 0.5% Nonidet-P40).

[0694] This mixture was incubated at 75° C. for 1 hour to denature and precipitate the host proteins. This cell extract was centrifuged at 14,000 rpm for 15 minutes at 4° C., and the supernatant was transferred to a fresh tube. An aliquot of 0.5 to 1 μl of this supernatant was used directly in each test reaction, and the protein content of the extract was determined by subjecting 7 μl to electrophoretic analysis, as above. The native recombinant Taq DNA polymerase (Engelke, Anal. Biochem., 191:396 [1990]), and the double point mutation protein shown in FIG. **3**B are both soluble and active at this point.

[0695] The foreign protein may not be detected after the heat treatments due to sequestration of the foreign protein by the cells into inclusion bodies. These are granules that form in the cytoplasm when bacteria are made to express high levels of a foreign protein, and they can be purified from a crude lysate, and analyzed SDS PAGE to determine their protein content. Many methods have been described in the literature, and one approach is described below.

[0696] D. Isolation and Solubilization of Inclusion Bodies

[0697] A small culture was grown and induced as described above. A 1.7 ml aliquot was pelleted by brief centrifugation, and the bacterial cells were resuspended in 100 μl of Lysis buffer (50 mM Tris-HCl, pH 8.0, 1 mM EDTA, 100 mM NaCl). Then, 2.5 μl of 20 mM PMSF were added for a final concentration of 0.5 mM, and lysozyme was added to a concentration of 1.0 mg/ml. The cells were incubated at room temperature for 20 minutes, deoxycholic acid was added to 1 mg/ml (1 μl of 100 mg/ml solution), and the mixture was further incubated at 37° C. for about 15 minutes or until viscous. DNAse I was added to 10 μg/ml and the mixture was incubated at room temperature for about 30 minutes or until it was no longer viscous.

[0698] From this mixture the inclusion bodies were collected by centrifugation at 14,000 rpm for 15 minutes at 4° C., and the supernatant was discarded. The pellet was resuspended in 100 μl of lysis buffer with 10 mM EDTA (pH 8.0) and 0.5% Triton X-100. After 5 minutes at room temperature, the inclusion bodies were pelleted as before, and the supernatant was saved for later analysis. The inclusion bodies were resuspended in 50 μl of distilled water, and 5 μl was combined with SDS gel loading buffer (which dissolves the inclusion bodies) and analyzed electrophoretically, along with an aliquot of the supernatant.

[0699] If the cloned protein is found in the inclusion bodies, it may be released to assay the cleavage and polymerase activities and the method of solubilization must be compatible with the particular activity. Different methods of solubilization may be appropriate for different proteins, and a variety of methods are discussed in *Molecular Cloning*

(Sambrook et al., supra). The following is an adaptation used for several of the isolates used in the development of the present invention.

[0700] Twenty μl of the inclusion body-water suspension were pelleted by centrifugation at 14,000 rpm for 4 minutes at room temperature, and the supernatant was discarded. To further wash the inclusion bodies, the pellet was resuspended in 20 μl of lysis buffer with 2M urea, and incubated at room temperature for one hour. The washed inclusion bodies were then resuspended in 2 μl of lysis buffer with 8 M urea; the solution clarified visibly as the inclusion bodies dissolved. Undissolved debris was removed by centrifugation at 14,000 rpm for 4 minutes at room temperature, and the extract supernatant was transferred to a fresh tube.

[0701] To reduce the urea concentration, the extract was diluted into KH_2PO_4. A fresh tube was prepared containing 180 μl of 50 mM KH_2PO_4, pH 9.5, 1 mM EDTA and 50 mM NaCl. A 2 μl aliquot of the extract was added and vortexed briefly to mix. This step was repeated until all of the extract had been added for a total of 10 additions. The mixture was allowed to sit at room temperature for 15 minutes, during which time some precipitate often forms. Precipitates were removed by centrifugation at 14,000 rpm, for 15 minutes at room temperature, and the supernatant was transferred to a fresh tube. To the 200 μl of protein in the KH_2PO_4 solution, 140-200 μl of saturated $(NH_4)_2SO_4$ were added, so that the resulting mixture was about 41% to 50% saturated $(NH_4)_2SO_4$. The mixture was chilled on ice for 30 minutes to allow the protein to precipitate, and the protein was then collected by centrifugation at 14,000 rpm, for 4 minutes at room temperature. The supernatant was discarded, and the pellet was dissolved in 20 μl Buffer C (20 mM HEPES, pH 7.9, 1 mM EDTA, 0.5% PMSF, 25 mM KCl and 0.5% each of Tween-20 and Nonidet P 40). The protein solution was centrifuged again for 4 minutes to pellet insoluble materials, and the supernatant was removed to a fresh tube. The protein contents of extracts prepared in this manner were visualized by resolving 1-4 μl by SDS-PAGE; 0.5 to 1 μl of extract was tested in the cleavage and polymerization assays as described.

[0702] E. Protein Analysis for Presence of Nuclease and Synthetic Activity

[0703] The 5' nucleases described above and shown in FIGS. **3** and **4** were analyzed by the following methods.

[0704] 1. Structure Specific Nuclease Assay

[0705] A candidate modified polymerase is tested for 5' nuclease activity by examining its ability to catalyze structure-specific cleavages. By the term "cleavage structure" as used herein, is meant a nucleic acid structure which is a substrate for cleavage by the 5' nuclease activity of a DNAP.

[0706] The polymerase is exposed to test complexes that have the structures shown in FIG. **15**. Testing for 5' nuclease activity involves three reactions: 1) a primer-directed cleavage (FIG. **15**B) is performed because it is relatively insensitive to variations in the salt concentration of the reaction and can, therefore, be performed in whatever solute conditions the modified enzyme requires for activity; this is generally the same conditions preferred by unmodified polymerases; 2) a similar primer-directed cleavage is performed in a buffer which permits primer-independent cleavage (i.e., a low salt buffer), to demonstrate that the enzyme is viable under these conditions; and 3) a primer-independent cleavage (FIG. **15**A) is performed in the same low salt buffer.

[0707] The bifurcated duplex is formed between a substrate strand and a template strand as shown in FIG. **15**. By the term "substrate strand" as used herein, is meant that strand of nucleic acid in which the cleavage mediated by the 5' nuclease activity occurs. The substrate strand is always depicted as the top strand in the bifurcated complex which serves as a substrate for 5' nuclease cleavage (FIG. **15**). By the term "template strand" as used herein, is meant the strand of nucleic acid which is at least partially complementary to the substrate strand and which anneals to the substrate strand to form the cleavage structure. The template strand is always depicted as the bottom strand of the bifurcated cleavage structure (FIG. **15**). If a primer (a short oligonucleotide of 19 to 30 nucleotides in length) is added to the complex, as when primer-dependent cleavage is to be tested, it is designed to anneal to the 3' arm of the template strand (FIG. **15**B). Such a primer would be extended along the template strand if the polymerase used in the reaction has synthetic activity.

[0708] The cleavage structure may be made as a single hairpin molecule, with the 3' end of the target and the 5' end of the pilot joined as a loop as shown in FIG. **15**E. A primer oligonucleotide complementary to the 3' arm is also required for these tests so that the enzyme's sensitivity to the presence of a primer may be tested.

[0709] Nucleic acids to be used to form test cleavage structures can be chemically synthesized, or can be generated by standard recombinant DNA techniques. By the latter method, the hairpin portion of the molecule can be created by inserting into a cloning vector duplicate copies of a short DNA segment, adjacent to each other but in opposing orientation. The double-stranded fragment encompassing this inverted repeat, and including enough flanking sequence to give short (about 20 nucleotides) unpaired 5' and 3' arms, can then be released from the vector by restriction enzyme digestion, or by PCR performed with an enzyme lacking a 5' exonuclease (e.g., the Stoffel fragment of AMPLITAQ DNA polymerase, Vent™ DNA polymerase).

[0710] The test DNA can be labeled on either end, or internally, with either a radioisotope, or with a non-isotopic tag. Whether the hairpin DNA is a synthetic single strand or a cloned double strand, the DNA is heated prior to use to melt all duplexes. When cooled on ice, the structure depicted in FIG. **16**E is formed, and is stable for sufficient time to perform these assays.

[0711] To test for primer-directed cleavage (Reaction 1), a detectable quantity of the test molecule (typically 1-100 fmol of ^{32}P-labeled hairpin molecule) and a 10 to 100-fold molar excess of primer are placed in a buffer known to be compatible with the test enzyme. For Reaction 2, where primer-directed cleavage is performed under condition which allow primer-independent cleavage, the same quantities of molecules are placed in a solution that is the same as the buffer used in Reaction 1 regarding pH, enzyme stabilizers (e.g., bovine serum albumin, nonionic detergents, gelatin) and reducing agents (e.g., dithiothreitol, 2-mercaptoethanol) but that replaces any monovalent cation salt with 20 mM KCl; 20 mM KCl is the demonstrated optimum for primer-independent cleavage. Buffers for enzymes, such as DNAPEc1, that usually operate in the absence of salt are not

supplemented to achieve this concentration. To test for primer-independent cleavage (Reaction 3) the same quantity of the test molecule, but no primer, are combined under the same buffer conditions used for Reaction 2.

[0712] All three test reactions are then exposed to enough of the enzyme that the molar ratio of enzyme to test complex is approximately 1:1. The reactions are incubated at a range of temperatures up to, but not exceeding, the temperature allowed by either the enzyme stability or the complex stability, whichever is lower, up to 80° C. for enzymes from thermophiles, for a time sufficient to allow cleavage (10 to 60 minutes). The products of Reactions 1, 2 and 3 are resolved by denaturing polyacrylamide gel electrophoresis, and visualized by autoradiography or by a comparable method appropriate to the labeling system used. Additional labeling systems include chemiluminescence detection, silver or other stains, blotting and probing and the like. The presence of cleavage products is indicated by the presence of molecules which migrate at a lower molecular weight than does the uncleaved test structure. These cleavage products indicate that the candidate polymerase has structure-specific 5' nuclease activity.

[0713] To determine whether a modified DNA polymerase has substantially the same 5' nuclease activity as that of the native DNA polymerase, the results of the above-described tests are compared with the results obtained from these tests performed with the native DNA polymerase. By "substantially the same 5' nuclease activity" it is meant that the modified polymerase and the native polymerase will both cleave test molecules in the same manner. It is not necessary that the modified polymerase cleave at the same rate as the native DNA polymerase.

[0714] Some enzymes or enzyme preparations may have other associated or contaminating activities that may be functional under the cleavage conditions described above and that may interfere with 5' nuclease detection. Reaction conditions can be modified in consideration of these other activities, to avoid destruction of the substrate, or other masking of the 5' nuclease cleavage and its products. For example, the DNA polymerase I of *E. coli* (Pol I), in addition to its polymerase and 5' nuclease activities, has a 3' exonuclease that can degrade DNA in a 3' to 5' direction. Consequently, when the molecule in FIG. **15**E is exposed to this polymerase under the conditions described above, the 3' exonuclease quickly removes the unpaired 3' arm, destroying the bifurcated structure required of a substrate for the 5' exonuclease cleavage and no cleavage is detected. The true ability of Pol I to cleave the structure can be revealed if the 3' exonuclease is inhibited by a change of conditions (e.g., pH), mutation, or by addition of a competitor for the activity. Addition of 500 pmoles of a single-stranded competitor oligonucleotide, unrelated to the FIG. **15**E structure, to the cleavage reaction with Pol I effectively inhibits the digestion of the 3' arm of the FIG. **15**E structure without interfering with the 5' exonuclease release of the 5' arm. The concentration of the competitor is not critical, but should be high enough to occupy the 3' exonuclease for the duration of the reaction.

[0715] Similar destruction of the test molecule may be caused by contaminants in the candidate polymerase preparation. Several sets of the structure specific nuclease reactions may be performed to determine the purity of the candidate nuclease and to find the window between under and over exposure of the test molecule to the polymerase preparation being investigated.

[0716] The above described modified polymerases were tested for 5' nuclease activity as follows: Reaction 1 was performed in a buffer of 10 mM Tris-Cl, pH 8.5 at 20° C., 1.5 mM $MgCl_2$ and 50 mM KCl and in Reaction 2 the KCl concentration was reduced to 20 mM. In Reactions 1 and 2, 10 fmoles of the test substrate molecule shown in FIG. **15**E were combined with 1 pmole of the indicated primer and 0.5 to 1.0 μl of extract containing the modified polymerase (prepared as described above). This mixture was then incubated for 10 minutes at 55° C. For all of the mutant polymerases tested these conditions were sufficient to give complete cleavage. When the molecule shown in FIG. **15**E was labeled at the 5' end, the released 5' fragment, 25 nucleotides long, was conveniently resolved on a 20% polyacrylamide gel (19:1 cross-linked) with 7 M urea in a buffer containing 45 mM Tris-borate pH 8.3, 1.4 mM EDTA. Clones 3C-F and 4B exhibited structure-specific cleavage comparable to that of the unmodified DNA polymerase. Additionally, clones 3E, 3F and 3G have the added ability to cleave DNA in the absence of a 3' arm as discussed above. Representative cleavage reactions are shown in FIG. **16**.

[0717] For the reactions shown in FIG. **16**, the mutant polymerase clones 3E (Taq mutant) and 4B (Tfl mutant) were examined for their ability to cleave the hairpin substrate molecule shown in FIG. **15**E. The substrate molecule was labeled at the 5' terminus with ^{32}P. Ten fmoles of heat-denatured, end-labeled substrate DNA and 0.5 units of DNAPTaq (lane 1) or 0.5 μl of 3E or 4B extract (FIG. **16**, lanes 2-7, extract was prepared as described above) were mixed together in a buffer containing 10 mM Tris-Cl, pH 8.5, 50 mM KCl and 1.5 mM $MgCl_2$. The final reaction volume was 10 μl. Reactions shown in lanes 4 and 7 contain in addition 50 μM of each dNTP. Reactions shown in lanes 3, 4, 6 and 7 contain 0.2 μM of the primer oligonucleotide (complementary to the 3' arm of the substrate and shown in FIG. **15**E). Reactions were incubated at 55° C. for 4 minutes. Reactions were stopped by the addition of 8 μl of 95% formamide containing 20 mM EDTA and 0.05% marker dyes per 10 μl reaction volume. Samples were then applied to 12% denaturing acrylamide gels. Following electrophoresis, the gels were autoradiographed. FIG. **16** shows that clones 3E and 4B exhibit cleavage activity similar to that of the native DNAPTaq. Note that some cleavage occurs in these reactions in the absence of the primer. When long hairpin structure, such as the one used here (FIG. **15**E), are used in cleavage reactions performed in buffers containing 50 mM KCl a low level of primer-independent cleavage is seen. Higher concentrations of KCl suppress, but do not eliminate, this primer-independent cleavage under these conditions.

[0718] 2. Assay for Synthetic Activity

[0719] The ability of the modified enzyme or proteolytic fragments is assayed by adding the modified enzyme to an assay system in which a primer is annealed to a template and DNA synthesis is catalyzed by the added enzyme. Many standard laboratory techniques employ such an assay. For example, nick translation and enzymatic sequencing involve extension of a primer along a DNA template by a polymerase molecule.

[0720] In a preferred assay for determining the synthetic activity of a modified enzyme an oligonucleotide primer is annealed to a single-stranded DNA template (e.g., bacteriophage M13 DNA), and the primer/template duplex is incubated in the presence of the modified polymerase in question, deoxynucleoside triphosphates (dNTPs) and the buffer and salts known to be appropriate for the unmodified or native enzyme. Detection of either primer extension (by denaturing gel electrophoresis) or dNTP incorporation (by acid precipitation or chromatography) is indicative of an active polymerase. A label, either isotopic or non-isotopic, is preferably included on either the primer or as a dNTP to facilitate detection of polymerization products. Synthetic activity is quantified as the amount of free nucleotide incorporated into the growing DNA chain and is expressed as amount incorporated per unit of time under specific reaction conditions.

[0721] Representative results of an assay for synthetic activity is shown in FIG. **17**. The synthetic activity of the mutant DNAPTaq clones 3B-F was tested as follows: A master mixture of the following buffer was made: 1.2×PCR buffer (1×PCR buffer contains 50 mM KCl, 1.5 mM $MgCl_2$, 10 mM Tris-Cl, pH 8.5 and 0.05% each Tween 20 and Nonidet P40), 50 μM each of dGTP, dATP and dTTP, 5 μM dCTP and 0.125 μM α-^{32}P-dCTP at 600 Ci/mmol. Before adjusting this mixture to its final volume, it was divided into two equal aliquots. One received distilled water up to a volume of 50 μl to give the concentrations above. The other received 5 μg of single-stranded M13mp18 DNA (approximately 2.5 pmol or 0.05 μM final concentration) and 250 pmol of M13 sequencing primer (5 μM final concentration) and distilled water to a final volume of 50 μl. Each cocktail was warmed to 75° C. for 5 minutes and then cooled to room temperature. This allowed the primers to anneal to the DNA in the DNA-containing mixtures.

[0722] For each assay, 4 μl of the cocktail with the DNA was combined with 1 μl of the mutant polymerase, prepared as described, or 1 unit of DNAPTaq (Perkin Elmer) in 1 μl of dH_2O. A "no DNA" control was done in the presence of the DNAPTaq (FIG. **17**, lane 1), and a "no enzyme" control was done using water in place of the enzyme (lane 2). Each reaction was mixed, then incubated at room temperature (approx. 22° C.) for 5 minutes, then at 55° C. for 2 minutes, then at 72° C. for 2 minutes. This step incubation was done to detect polymerization in any mutants that might have optimal temperatures lower than 72° C. After the final incubation, the tubes were spun briefly to collect any condensation and were placed on ice. One μl of each reaction was spotted at an origin 1.5 cm from the bottom edge of a polyethyleneimine (PEI) cellulose thin layer chromatography plate and allowed to dry. The chromatography plate was run in 0.75 M NaH_2PO_4, pH 3.5, until the buffer front had run approximately 9 cm from the origin. The plate was dried, wrapped in plastic wrap, marked with luminescent ink, and exposed to X-ray film. Incorporation was detected as counts that stuck where originally spotted, while the unincorporated nucleotides were carried by the salt solution from the origin.

[0723] Comparison of the locations of the counts with the two control lanes confirmed the lack of polymerization activity in the mutant preparations. Among the modified DNAPTaq clones, only clone 3B retains any residual synthetic activity as shown in FIG. **17**.

Example 3

5' Nucleases Derived from Thermostable DNA Polymerases can Cleave Short Hairpin Structures with Specificity

[0724] The ability of the 5' nucleases to cleave hairpin structures to generate a cleaved hairpin structure suitable as a detection molecule was examined. The structure and sequence of the hairpin test molecule is shown in FIG. **18**A (SEQ ID NO:15). The oligonucleotide (labeled "primer" in FIG. **18**A, SEQ ID NO:22) is shown annealed to its complementary sequence on the 3' arm of the hairpin test molecule. The hairpin test molecule was single-end labeled with ^{32}P using a labeled T7 promoter primer in a polymerase chain reaction. The label is present on the 5' arm of the hairpin test molecule and is represented by the star in FIG. **18**A.

[0725] The cleavage reaction was performed by adding 10 fmoles of heat-denatured, end-labeled hairpin test molecule, 0.2 μM of the primer oligonucleotide (complementary to the 3' arm of the hairpin), 50 μM of each dNTP and 0.5 units of DNAPTaq (Perkin Elmer) or 0.5 μl of extract containing a 5' nuclease (prepared as described above) in a total volume of 10 μl in a buffer containing 10 mM Tris-Cl, pH 8.5, 50 mM KCl and 1.5 mM $MgCl_2$. Reactions shown in lanes 3, 5 and 7 were run in the absence of dNTPs.

[0726] Reactions were incubated at 55° C. for 4 minutes. Reactions were stopped at 55° C. by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes per 10 μl reaction volume. Samples were not heated before loading onto denaturing polyacrylamide gels (10% polyacrylamide, 19:1 crosslinking, 7 M urea, 89 mM Tris-borate, pH 8.3, 2.8 mM EDTA). The samples were not heated to allow for the resolution of single-stranded and re-duplexed uncleaved hairpin molecules.

[0727] FIG. **18**B shows that altered polymerases lacking any detectable synthetic activity cleave a hairpin structure when an oligonucleotide is annealed to the single-stranded 3' arm of the hairpin to yield a single species of cleaved product (FIG. **18**B, lanes 3 and 4). 5' nucleases, such as clone 3D, shown in lanes 3 and 4, produce a single cleaved product even in the presence of dNTPs. 5' nucleases that retain a residual amount of synthetic activity (less than 1% of wild type activity) produce multiple cleavage products as the polymerase can extend the oligonucleotide annealed to the 3' arm of the hairpin thereby moving the site of cleavage (clone 3B, lanes 5 and 6). Native DNATaq produces even more species of cleavage products than do mutant polymerases retaining residual synthetic activity and additionally converts the hairpin structure to a double-stranded form in the presence of dNTPs due to the high level of synthetic activity in the native polymerase (FIG. **18**B, lane 8).

Example 4

Cleavage of Linear Nucleic Acid Substrates

[0728] From the above, it should be clear that native (i.e., "wild type") thermostable DNA polymerases are capable of cleaving hairpin structures in a specific manner and that this discovery can be applied with success to a detection assay. In this example, the mutant DNAPs of the present invention are tested against three different cleavage structures shown in FIG. **20**A. Structure 1 in FIG. **20**A is simply single

stranded 206-mer (the preparation and sequence information for which was discussed in Example 1C). Structures 2 and 3 are duplexes; structure 2 is the same hairpin structure as shown in FIG. **11**A (bottom), while structure 3 has the hairpin portion of structure 2 removed.

[**0729**] The cleavage reactions comprised 0.01 pmoles of the resulting substrate DNA, and 1 pmole of pilot oligonucleotide in a total volume of 10 μl of 10 mM Tris-Cl, pH 8.3, 100 mM KCl, 1 mM $MgCl_2$. Reactions were incubated for 30 minutes at 55° C., and stopped by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 10% polyacrylamide gel (19:1 cross link), with 7M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

[**0730**] The results were visualized by autoradiography and are shown in FIG. **20**B with the enzymes indicated as follows: I is native Taq DNAP; II is native Tfl DNAP; III is CLEAVASE BX shown in FIG. **3**E; IV is CLEAVASE BB shown in FIG. **3**F; V is the mutant shown in FIG. **4**B; and VI is CLEAVASE BN shown in FIG. **3**G.

[**0731**] Structure 2 was used to "normalize" the comparison. For example, it was found that it took 50 ng of Taq DNAP and 300 ng of CLEAVASE BN to give similar amounts of cleavage of Structure 2 in thirty (30) minutes. Under these conditions native Taq DNAP is unable to cleave Structure 3 to any significant degree. Native Tfl DNAP cleaves Structure 3 in a manner that creates multiple products.

[**0732**] By contrast, all of the mutants tested cleave the linear duplex of Structure 3. This finding indicates that this characteristic of the mutant DNA polymerases is consistent of thermostable polymerases across thermophilic species.

Example 5

5' Exonucleolytic Cleavage ("Nibbling") by Thermostable DNAPs

[**0733**] It has been found that thermostable DNAPs, including those of the present invention, have a true 5' exonuclease capable of nibbling the 5' end of a linear duplex nucleic acid structures. In this Example, the 206 base pair DNA duplex substrate is again employed (See, Example 1C). In this case, it was produced by the use of one ^{32}P-labeled primer and one unlabeled primer in a polymerase chain reaction. The cleavage reactions comprised 0.01 pmoles of heat-denatured, end-labeled substrate DNA (with the unlabeled strand also present), 5 pmoles of pilot oligonucleotide (see pilot oligos in FIG. **11**A) and 0.5 units of DNAPTaq or 0.5μ of CLEAVASE BB in the *E. coli* extract (see above), in a total volume of 10 μl of 10 mM Tris.Cl, pH 8.5, 50 mM KCl, 1.5 mM $MgCl_2$.

[**0734**] Reactions were initiated at 65° C. by the addition of pre-warmed enzyme, then shifted to the final incubation temperature for 30 minutes. The results are shown in FIG. **21**A. Samples in lanes 1-4 are the results with native Taq DNAP, while lanes 5-8 shown the results with CLEAVASE BB. The reactions for lanes 1, 2, 5, and 6 were performed at 65° C. and reactions for lanes 3, 4, 7, and 8 were performed at 50° C. and all were stopped at temperature by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 10% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris.Borate, pH 8.3, 1.4 mM EDTA. The expected product in reactions 1, 2, 5, and 6 is 85 nucleotides long; in reactions 3 and 7, the expected product is 27 nucleotides long. Reactions 4 and 8 were performed without pilot, and should remain at 206 nucleotides. The faint band seen at 24 nucleotides is residual end-labeled primer from the PCR.

[**0735**] The surprising result is that CLEAVASE BB under these conditions causes all of the label to appear in a very small species, suggesting the possibility that the enzyme completely hydrolyzed the substrate. To determine the composition of the fastest-migrating band seen in lanes 5-8 (reactions performed with the deletion mutant), samples of the 206 base pair duplex were treated with either T7 gene 6 exonuclease (USB) or with calf intestine alkaline phosphatase (Promega), according to manufacturers' instructions, to produce either labeled mononucleotide (lane a of FIG. **21**B) or free ^{32}P-labeled inorganic phosphate (lane b of FIG. **21**B), respectively. These products, along with the products seen in lane 7 of panel A were resolved by brief electrophoresis through a 20% acrylamide gel (19:1 cross-link), with 7 M urea, in a buffer of 45 mM Tris.Borate, pH 8.3, 1.4 mM EDTA. CLEAVASE BB is thus capable of converting the substrate to mononucleotides.

Example 6

Nibbling is Duplex Dependent

[**0736**] The nibbling by CLEAVASE BB is duplex dependent. In this Example, internally labeled, single strands of the 206-mer were produced by 15 cycles of primer extension incorporating α-^{32}P labeled dCTP combined with all four unlabeled dNTPs, using an unlabeled 206-bp fragment as a template. Single and double stranded products were resolved by electrophoresis through a non-denaturing 6% polyacrylamide gel (29:1 cross-link) in a buffer of 45 mM Tris.Borate, pH 8.3, 1.4 mM EDTA, visualized by autoradiography, excised from the gel, eluted by passive diffusion, and concentrated by ethanol precipitation.

[**0737**] The cleavage reactions comprised 0.04 pmoles of substrate DNA, and 2 μl of CLEAVASE BB (in an *E. Coli* extract as described above) in a total volume of 40 μl of 10 mM Tris.Cl, pH 8.5, 50 mM KCl, 1.5 mM $MgCl_2$. Reactions were initiated by the addition of pre-warmed enzyme; 10 μl aliquots were removed at 5, 10, 20, and 30 minutes, and transferred to prepared tubes containing 8 μl of 95% formamide with 30 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 10% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris.Borate, pH 8.3, 1.4 mM EDTA. Results were visualized by autoradiography as shown in FIG. **22**. Clearly, the cleavage by CLEAVASE BB depends on a duplex structure; no cleavage of the single strand structure is detected whereas cleavage of the 206-mer duplex is complete.

Example 7

[**0738**] Nibbling can be Target Directed

[**0739**] The nibbling activity of the DNAPs of the present invention can be employed with success in a detection assay.

One embodiment of such an assay is shown in FIG. **23**. In this assay, a labeled oligo is employed that is specific for a target sequence. The oligo is in excess of the target so that hybridization is rapid. In this embodiment, the oligo contains two fluorescein labels whose proximity on the oligo causes their emission to be quenched. When the DNAP is permitted to nibble the oligo the labels separate and are detectable. The shortened duplex is destabilized and disassociates. Importantly, the target is now free to react with an intact labeled oligo. The reaction can continue until the desired level of detection is achieved. An analogous, although different, type of cycling assay has been described employing lambda exonuclease. See C. G. Copley and C. Boot, *BioTechniques* 13:888 (1992).

[**0740**] The success of such an assay depends on specificity. In other words, the oligo must hybridize to the specific target. It is also preferred that the assay be sensitive; the oligo ideally should be able to detect small amounts of target. FIG. **24**A shows a 5'-end ^{32}P-labeled primer bound to a plasmid target sequence. In this case, the plasmid was pUC19 (commercially available) which was heat denatured by boiling two (2) minutes and then quick chilling. The primer is a 21-mer (SEQ ID NO:28). The enzyme employed was CLEAVASE BX (a dilution equivalent to 5×10^{-3} μl extract) in 100 mM KCl, 10 mM Tris.Cl, pH 8.3, 2 mM $MnCl_2$. The reaction was performed at 55° C. for sixteen (16) hours with or without genomic background DNA (from chicken blood). The reaction was stopped by the addition of 8 μl of 95% formamide with 20 mM EDTA and marker dyes.

[**0741**] The products of the reaction were resolved by PAGE (10% polyacrylamide, 19:1 cross link, 1×TBE) as seen in FIG. **24**B. Lane "M" contains the labeled 21-mer. Lanes 1-3 contain no specific target, although Lanes 2 and 3 contain 100 ng and 200 ng of genomic DNA, respectively. Lanes 4, 5 and 6 all contain specific target with either 0 ng, 100 ng, or 200 ng of genomic DNA, respectively. It is clear that conversion to mononucleotides occurs in Lanes 4, 5 and 6 regardless of the presence or amount of background DNA. Thus, the nibbling can be target directed and specific.

Example 8

Cleavase Purification

[**0742**] As noted above, expressed thermostable proteins (i.e., the 5' nucleases), were isolated by crude bacterial cell extracts. The precipitated *E. coli* proteins were then, along with other cell debris, removed by centrifugation. In this Example, cells expressing the BN clone were cultured and collected (500 grams). For each gram (wet weight) of *E. coli,* 3 ml of lysis buffer (50 mM Tris-HCl, pH 8.0, 1 mM EDTA, 100 μM NaCl) was added. The cells were lysed with 200 μg/ml lysozyme at room temperature for 20 minutes. Thereafter deoxycholic acid was added to make a 0.2% final concentration and the mixture was incubated 15 minutes at room temperature.

[**0743**] The lysate was sonicated for approximately 6-8 minutes at 0° C. The precipitate was removed by centrifugation (39,000 g for 20 minutes). Polyethyleneimine was added (0.5%) to the supernatant and the mixture was incubated on ice for 15 minutes. The mixture was centrifuged (5,000 g for 15 minutes) and the supernatant was retained. This was heated for 30 minutes at 60° C. and then centrifuged again (5,000 g for 15 minutes) and the supernatant was again retained.

[**0744**] The supernatant was precipitated with 35% ammonium sulfate at 4° C. for 15 minutes. The mixture was then centrifuged (5,000 g for 15 minutes) and the supernatant was removed. The precipitate was then dissolved in 0.25M KCl, 20 Tris pH 7.6, 0.2% Tween and 0.1 EDTA) and then dialyzed against Binding Buffer (8× Binding Buffer comprises: 40 mM imidazole, 4M NaCl, 160 mM Tris-HCl, pH 7.9).

[**0745**] The solubilized protein is then purified on the Ni^{++}column (Novagen). The Binding Buffer is allows to drain to the top of the column bed and load the column with the prepared extract. A flow rate of about 10 column volumes per hour is optimal for efficient purification. If the flow rate is too fast, more impurities will contaminate the eluted fraction.

[**0746**] The column is washed with 25 ml (10 volumes) of 1× Binding Buffer and then washed with 15 ml (6 volumes) of 1× Wash Buffer (8× Wash Buffer comprises: 480 mM imidazole, 4 M NaCl, 160 mM Tris-HCl, pH 7.9). The bound protein was eluted with 15 ml (6 volumes) of IX Elute Buffer (4× Elute Buffer comprises: 4 mM imidazole, 2 M NaCl, 80 mM Tris-HCl, pH 7.9). Protein is then reprecipitated with 35% ammonium sulfate as above. The precipitate was then dissolved and dialyzed against: 20 mM Tris, 100 mM KCl, 1 mM EDTA). The solution was brought up to 0.1% each of Tween 20 and NP-40 and stored at 4° C.

Example 9

The Use of Various Divalent Cations in the Cleavage Reaction Influences the Nature of the Resulting Cleavage Products

[**0747**] In comparing the 5' nucleases generated by the modification and/or deletion of the C-terminal polymerization domain of *Thermus aquaticus* DNA polymerase (DNAPTaq), as diagrammed in FIG. **3**B-G, significant differences in the strength of the interactions of these proteins with the 3' end of primers located upstream of the cleavage site (as depicted in FIG. **5**) were noted. In describing the cleavage of these structures by Pol I-type DNA polymerases (See, Example 1, and Lyamichev et al., Science 260:778 [1993]), it was observed that in the absence of a primer, the location of the junction between the double-stranded region and the single-stranded 5' and 3' arms determined the site of cleavage, but in the presence of a primer, the location of the 3' end of the primer became the determining factor for the site of cleavage. It was postulated that this affinity for the 3' end was in accord with the synthesizing function of the DNA polymerase.

[**0748**] Structure 2, shown in FIG. **20**A, was used to test the effects of a 3' end proximal to the cleavage site in cleavage reactions comprising several different solutions (e.g., solutions containing different salts [KCl or NaCl], different divalent cations [Mn^{2+} or Mg^{2+}], etc.) as well as the use of different temperatures for the cleavage reaction. When the reaction conditions were such that the binding of the enzyme (e.g., a DNAP comprising a 5' nuclease, a modified DNAP or a 5' nuclease) to the 3' end (of the pilot oligonucleotide) near the cleavage site was strong, the structure shown is cleaved at the site indicated in FIG. **20**A. This cleavage releases the unpaired 5' arm and leaves a nick between the remaining portion of the target nucleic acid and

the folded 3' end of the pilot oligonucleotide. In contrast, when the reaction conditions are such that the binding of the DNAP (comprising a 5' nuclease) to the 3' end was weak, the initial cleavage was as described above, but after the release of the 5' arm, the remaining duplex is digested by the exonuclease function of the DNAP.

[0749] One way of weakening the binding of the DNAP to the 3' end is to remove all or part of the domain to which at least some of this function has been attributed. Some of 5' nucleases created by deletion of the polymerization domain of DNAPTaq have enhanced true exonuclease function, as demonstrated in Example 5.

[0750] The affinity of these types of enzymes (i.e., 5' nucleases associated with or derived from DNAPs) for recessed 3' ends may also be affected by the identity of the divalent cation present in the cleavage reaction. It was demonstrated by Longley et al. (Nucl. Acids Res., 18:7317 [1990]) that the use of $MnCl_2$ in a reaction with DNAPTaq enabled the polymerase to remove nucleotides from the 5' end of a primer annealed to a template, albeit inefficiently. Similarly, by examination of the cleavage products generated using Structure 2 from FIG. **20**A, as described above, in a reaction containing either DNAPTaq or the CLEAVASE BB nuclease, it was observed that the substitution of $MnCl_2$ for $MgCl_2$ in the cleavage reaction resulted in the exonucleolytic "nibbling" of the duplex downstream of the initial cleavage site. While not limiting the invention to any particular mechanism, it is thought that the substitution of $MnCl_2$ for $MgCl_2$ in the cleavage reaction lessens the affinity of these enzymes for recessed 3' ends.

[0751] In all cases, the use of $MnCl_2$ enhances the 5' nuclease function, and in the case of the CLEAVASE BB nuclease, a 50- to 100-fold stimulation of the 5' nuclease function is seen. Thus, while the exonuclease activity of these enzymes was demonstrated above in the presence of $MgCl_2$, the assays described below show a comparable amount of exonuclease activity using 50 to 100-fold less enzyme when $MnCl_2$ is used in place of $MgCl_2$. When these reduced amounts of enzyme are used in a reaction mixture containing $MgCl_2$, the nibbling or exonuclease activity is much less apparent than that seen in Examples 5-7.

[0752] Similar effects are observed in the performance of the nucleic acid detection assay described in Examples 10-39 below when reactions performed in the presence of either $MgCl_2$ or $MnCl_2$ are compared. In the presence of either divalent cation, the presence of the INVADER oligonucleotide (described below) forces the site of cleavage into the probe duplex, but in the presence of $MnCl_2$ the probe duplex can be further nibbled producing a ladder of products that are visible when a 3' end label is present on the probe oligonucleotide. When the INVADER oligonucleotide is omitted from a reaction containing Mn^{2+}, the probe is nibbled from the 5' end. Mg^{2+}-based reactions display minimal nibbling of the probe oligonucleotide. In any of these cases, the digestion of the probe is dependent upon the presence of the target nucleic acid. In the examples below, the ladder produced by the enhanced nibbling activity observed in the presence of $Mn^{2+}$is used as a positive indicator that the probe oligonucleotide has hybridized to the target sequence.

Example 10

Invasive 5' Endonucleolytic Cleavage by Thermostable 5' Nucleases in the Absence of Polymerization

[0753] As described in the Examples above, 5' nucleases cleave near the junction between single-stranded and base-paired regions in a bifurcated duplex, usually about one base pair into the base-paired region. In this Example, it is shown that thermostable 5' nucleases, including those of the present invention (e.g., CLEAVASE BN nuclease, CLEAVASE A/G nuclease), have the ability to cleave a greater distance into the base paired region when provided with an upstream oligonucleotide bearing a 3' region that is homologous to a 5' region of the subject duplex, as shown in FIG. **26**.

[0754] FIG. **26** shows a synthetic oligonucleotide that was designed to fold upon itself and that consists of the following sequence: 5'-GTTCTCTGCTCTCTGGTCGCT-GTCTCGCTTGTGAAACAAGCGAGA-CAGCGTGGTCTCTCG-3' (SEQ ID NO:29). This oligonucleotide is referred to as the "S-60 Hairpin." The 15 basepair hairpin formed by this oligonucleotide is further stabilized by a "tri-loop" sequence in the loop end (i.e., three nucleotides form the loop portion of the hairpin) (Hiraro et al., Nucleic Acids Res., 22(4):576 [1994]). FIG. **26** also show the sequence of the P-15 oligonucleotide and the location of the region of complementarity shared by the P-15 and S-60 hairpin oligonucleotides. The sequence of the P-15 oligonucleotide is 5'-CGAGAGACCACGCTG-3' (SEQ ID NO:30). As discussed in detail below, the solid black arrowheads shown in FIG. **26** indicate the sites of cleavage of the S-60 hairpin in the absence of the P-15 oligonucleotide and the hollow arrow heads indicate the sites of cleavage in the presence of the P-15 oligonucleotide. The size of the arrow head indicates the relative utilization of a particular site.

[0755] The S-60 hairpin molecule was labeled on its 5' end with biotin for subsequent detection. The S-60 hairpin was incubated in the presence of a thermostable 5' nuclease in the presence or the absence of the P-15 oligonucleotide. The presence of the full duplex that can be formed by the S-60 hairpin is demonstrated by cleavage with the CLEAVASE BN 5' nuclease, in a primer-independent fashion (i.e., in the absence of the P-15 oligonucleotide). The release of 18 and 19-nucleotide fragments from the 5' end of the S-60 hairpin molecule showed that the cleavage occurred near the junction between the single and double stranded regions when nothing is hybridized to the 3' arm of the S-60 hairpin (FIG. **27**, lane 2).

[0756] The reactions shown in FIG. **27** were conducted as follows. Twenty fmole of the 5' biotin-labeled hairpin DNA (SEQ ID NO:29) was combined with 0.1 ng of CLEAVASE BN enzyme and 1 μl of 100 mM MOPS (pH 7.5) containing 0.5% each of Tween-20 and NP-40 in a total volume of 9 μl. In the reaction shown in lane 1, the enzyme was omitted and the volume was made up by addition of distilled water (this served as the uncut or no enzyme control). The reaction shown in lane 3 of FIG. **27** also included 0.5 pmole of the P15 oligonucleotide (SEQ ID NO:30), which can hybridize to the unpaired 3' arm of the S-60 hairpin (SEQ ID NO:29), as diagrammed in FIG. **26**.

[0757] The reactions were overlaid with a drop of mineral oil, heated to 95° C. for 15 seconds, then cooled to 37° C.,

and the reaction was started by the addition of 1 μl of 10 mM $MnCl_2$ to each tube. After 5 minutes, the reactions were stopped by the addition of 6 μl of 95% formamide containing 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 15% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

[0758] After electrophoresis, the gel plates were separated allowing the gel to remain flat on one plate. A 0.2 mm-pore positively-charged nylon membrane (NYTRAN, Schleicher and Schueli, Keene, N.H.), pre-wetted in H_2O, was laid on top of the exposed gel. All air bubbles were removed. Two pieces of 3 MM filter paper (Whatman) were then placed on top of the membrane, the other glass plate was replaced, and the sandwich was clamped with binder clips. Transfer was allowed to proceed overnight. After transfer, the membrane was carefully peeled from the gel and allowed to air dry. After complete drying, the membrane was washed in 1.2× Sequenase Images Blocking Buffer (United States Biochemical) using 0.3 ml of buffer/cm^2 of membrane. The wash was performed for 30 minutes at room temperature. A streptavidin-alkaline phosphatase conjugate (SAAP, United States Biochemical) was added to a 1:4000 dilution directly to the blocking solution, and agitated for 15 minutes. The membrane was rinsed briefly with H_2O and then washed three times for 5 minutes per wash using 0.5 ml/cm^2 of 1×SAAP buffer (100 mM Tris-HCl, pH 10, 50 mM NaCl) with 0.1% sodium dodecyl sulfate (SDS). The membrane was rinsed briefly with H_2O between each wash. The membrane was then washed once in 1×SAAP buffer containing 1 mM $MgCl_2$ without SDS, drained thoroughly and placed in a plastic heat-sealable bag. Using a sterile pipet, 5 mls of CDP-Star™ (Tropix, Bedford, Mass.) chemiluminescent substrate for alkaline phosphatase were added to the bag and distributed over the entire membrane for 2-3 minutes. The CDP-Star™-treated membrane was exposed to XRP X-ray film (Kodak) for an initial exposure of 10 minutes.

[0759] The resulting autoradiograph is shown in FIG. **27**. In FIG. **27**, the lane labeled "M" contains the biotinylated P-15 oligonucleotide, which served as a marker. The sizes (in nucleotides) of the uncleaved S-60 hairpin (60 nuc; lane 1), the marker (15 nuc; lane "M") and the cleavage products generated by cleavage of the S-60 hairpin in the presence (lane 3) or absence (lane 2) of the P-15 oligonucleotide are indicated.

[0760] Because the complementary regions of the S-60 hairpin are located on the same molecule, essentially no lag time should be needed to allow hybridization (i.e., to form the duplex region of the hairpin). This hairpin structure would be expected to form long before the enzyme could locate and cleave the molecule. As expected, cleavage in the absence of the primer oligonucleotide was at or near the junction between the duplex and single-stranded regions, releasing the unpaired 5' arm (FIG. **27**, lane 2). The resulting cleavage products were 18 and 19 nucleotides in length.

[0761] It was expected that stability of the S-60 hairpin with the tri-loop would prevent the P-15 oligonucleotide from promoting cleavage in the "primer-directed" manner described in Example 1 above, because the 3' end of the "primer" would remain unpaired. Surprisingly, it was found that the enzyme seemed to mediate an "invasion" by the P-15 primer into the duplex region of the S-60 hairpin, as evidenced by the shifting of the cleavage site 3 to 4 basepairs further into the duplex region, releasing the larger products (22 and 21 nuc.) observed in lane 3 of FIG. **27**.

[0762] The precise sites of cleavage of the S-60 hairpin are diagrammed on the structure in FIG. **26**, with the solid black arrowheads indicating the sites of cleavage in the absence of the P-15 oligonucleotide and the hollow arrow heads indicating the sites of cleavage in the presence of P-15.

[0763] These data show that the presence on the 3' arm of an oligonucleotide having some sequence homology with the first several bases of the similarly oriented strand of the downstream duplex can be a dominant factor in determining the site of cleavage by 5' nucleases. Because the oligonucleotide that shares some sequence homology with the first several bases of the similarly oriented strand of the downstream duplex appears to invade the duplex region of the hairpin, it is referred to as an "INVADER" oligonucleotide. As shown in the Examples below, an INVADER oligonucleotide appears to invade (or displace) a region of duplexed nucleic acid regardless of whether the duplex region is present on the same molecule (i.e., a hairpin) or whether the duplex is formed between two separate nucleic acid strands.

Example 11

The INVADER Oligonucleotide Shifts the Site of Cleavage in a Pre-Formed Probe/Target Duplex

[0764] In Example 10, it was demonstrated that an INVADER oligonucleotide could shift the site at which a 5' nuclease cleaves a duplex region present on a hairpin molecule. In this Example, the ability of an INVADER oligonucleotide to shift the site of cleavage within a duplex region formed between two separate strands of nucleic acid molecules was examined.

[0765] A single-stranded target DNA comprising the single-stranded circular M13mp19 molecule and a labeled (fluorescein) probe oligonucleotide were mixed in the presence of the reaction buffer containing salt (KCl) and divalent cations (Mg^{2+} or Mn^{2+}) to promote duplex formation. The probe oligonucleotide refers to a labeled oligonucleotide that is complementary to a region along the target molecule (e.g., M13mp19). A second oligonucleotide (unlabeled) was added to the reaction after the probe and target had been allowed to anneal. The second oligonucleotide binds to a region of the target that is located downstream of the region to which the probe oligonucleotide binds. This second oligonucleotide contains sequences that are complementary to a second region of the target molecule. If the second oligonucleotide contains a region that is complementary to a portion of the sequences along the target to which the probe oligonucleotide also binds, this second oligonucleotide is referred to as an INVADER oligonucleotide (see FIG. **28***c*).

[0766] FIG. **32** depicts the annealing of two oligonucleotides to regions along the M13mp19 target molecule (bottom strand in all three structures shown). In FIG. **28** only a 52 nucleotide portion of the M13mp19 molecule is shown; this 52 nucleotide sequence is listed in SEQ ID NO:31. The probe oligonucleotide contains a fluorescein label at the 3' end; the sequence of the probe is 5'-AGAAAGGAAGG-

GAAGAAAGCGAAAGG-3' (SEQ ID NO:32). In FIG. **28**, sequences comprising the second oligonucleotide, including the INVADER oligonucleotide are underlined. In FIG. **28***a*, the second oligonucleotide, which has the sequence 5'-GACGGGGAAAGCCGGCGAACG-3' (SEQ ID NO:33), is complementary to a different and downstream region of the target molecule than is the probe oligonucleotide (labeled with fluorescein or "Fluor"); there is a gap between the second, upstream oligonucleotide and the probe for the structure shown in FIG. **28***a*. In FIG. **28***b*, the second, upstream oligonucleotide, which has the sequence 5'-GAAAGCCGGCGAACGTGGCG-3' (SEQ ID NO:34), is complementary to a different region of the target molecule than is the probe oligonucleotide, but in this case, the second oligonucleotide and the probe oligonucleotide abut one another (that is the 3' end of the second, upstream oligonucleotide is immediately adjacent to the 5' end of the probe such that no gap exists between these two oligonucleotides). In FIG. **28***c*, the second, upstream oligonucleotide (5'-GGCGAACGTGGCGAGAAAGGA-3'[SEQ ID NO:35]) and the probe oligonucleotide share a region of complementarity with the target molecule. Thus, the upstream oligonucleotide has a 3' arm that has a sequence identical to the first several bases of the downstream probe. In this situation, the upstream oligonucleotide is referred to as an "INVADER" oligonucleotide.

[0767] The effect of the presence of an INVADER oligonucleotide upon the pattern of cleavage in a probe/target duplex formed prior to the addition of the INVADER was examined. The INVADER oligonucleotide and the enzyme were added after the probe was allowed to anneal to the target and the position and extent of cleavage of the probe were examined to determine a) if the INVADER was able to shift the cleavage site to a specific internal region of the probe, and b), if the reaction could accumulate specific cleavage products over time, even in the absence of thermal cycling, polymerization, or exonuclease removal of the probe sequence.

[0768] The reactions were carried out as follows. Twenty μl each of two enzyme mixtures were prepared, containing 2 μl of CLEAVASE A/G nuclease extract (prepared as described in Example 2), with or without 50 pmole of the INVADER oligonucleotide (SEQ ID NO:35), as indicated, per 4 μl of the mixture. For each of the eight reactions shown in FIG. **29**, 150 fmole of M13mp19 single-stranded DNA (available from Life Technologies, Inc.) was combined with 5 pmoles of fluorescein labeled probe (SEQ ID NO:32), to create the structure shown in FIG. **28***c*, but without the INVADER oligonucleotide present (the probe/target mixture). One half (4 tubes) of the probe/target mixtures were combined with 1 μl of 100 mM MOPS, pH 7.5 with 0.5% each of Tween-20 and NP-40, 0.5 μl of 1 M KCl and 0.25 μl of 80 mM $MnCl_2$, and distilled water to a volume of 6 μl. The second set of probe/target mixtures were combined with 1 μl of 100 mM MOPS, pH 7.5 with 0.5% each of Tween-20 and NP-40, 0.5 μl of 1 M KCl and 0.25 μl of 80 mM $MgCl_2$. The second set of mixtures therefore contained $MgCl_2$ in place of the $MnCl_2$ present in the first set of mixtures.

[0769] The mixtures (containing the probe/target with buffer, KCl and divalent cation) were covered with a drop of CHILLOUT evaporation barrier and were brought to 60° C. for 5 minutes to allow annealing. Four μl of the above enzyme mixtures without the INVADER oligonucleotide was added to reactions whose products are shown in lanes 1, 3, 5 and 7 of FIG. **29**. Reactions whose products are shown lanes 2, 4, 6, and 8 of FIG. **29** received the same amount of enzyme mixed with the INVADER oligonucleotide (SEQ ID NO:35). Reactions 1, 2, 5 and 6 were incubated for 5 minutes at 60° C. and reactions 3, 4, 7 and 8 were incubated for 15 minutes at 60° C.

[0770] All reactions were stopped by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 90° C. for 1 minute immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Following electrophoresis, the reaction products and were visualized by the use of an Hitachi FMBIO fluorescence imager, the output of which is seen in FIG. **29**. The very low molecular weight fluorescent material seen in all lanes at or near the salt front in FIG. **29** and other fluoro-imager Figures is observed when fluorescently-labeled oligonucleotides are electrophoresed and imaged on a fluoro-imager. This material is not a product of the cleavage reaction.

[0771] The use of $MnCl_2$ in these reactions (lanes 1-4) stimulates the true exonuclease or "nibbling" activity of the CLEAVASE enzyme, as described in Example 6, as is clearly seen in lanes 1 and 3 of FIG. **29**. This nibbling of the probe oligonucleotide (SEQ ID NO:32) in the absence of INVADER oligonucleotide (SEQ ID NO:35) confirms that the probe oligonucleotide is forming a duplex with the target sequence. The ladder-like products produced by this nibbling reaction may be difficult to differentiate from degradation of the probe by nucleases that might be present in a clinical specimen. In contrast, introduction of the INVADER oligonucleotide (SEQ ID NO:35) caused a distinctive shift in the cleavage of the probe, pushing the site of cleavage 6 to 7 bases into the probe, confirming the annealing of both oligonucleotides. In presence of $MnCl_2$, the exonuclease "nibbling" may occur after the INVADER-directed cleavage event, until the residual duplex is destabilized and falls apart.

[0772] In a magnesium based cleavage reaction (lanes 5-8), the nibbling or true exonuclease function of the CLEAVASE A/G is enzyme suppressed (but the endonucleolytic function of the enzyme is essentially unaltered), so the probe oligonucleotide is not degraded in the absence of the INVADER (FIG. **29**, lanes 5 and 7). When the INVADER is added, it is clear that the INVADER oligonucleotide can promote a shift in the site of the endonucleolytic cleavage of the annealed probe. Comparison of the products of the 5 and 15 minute reactions with INVADER (lanes 6 and 8 in FIG. **29**) shows that additional probe hybridizes to the target and is cleaved. The calculated melting temperature (T_m) of the portion of probe that is not invaded (i.e., nucleotides 9-26 of SEQ ID NO:32) is 56° C., so the observed turnover (as evidenced by the accumulation of cleavage products with increasing reaction time) suggests that the full length of the probe molecule, with a calculated T_m of 76° C., is must be involved in the subsequent probe annealing events in this 60° C. reaction.

Example 12

The Overlap of the 3' INVADER Oligonucleotide Sequence with the 5' Region of the Probe Causes a Shift in the Site of Cleavage

[0773] In Example 11, the ability of an INVADER oligonucleotide to cause a shift in the site of cleavage of a probe annealed to a target molecule was demonstrated. In this Example, experiments were conducted to examine whether the presence of an oligonucleotide upstream from the probe was sufficient to cause a shift in the cleavage site(s) along the probe or whether the presence of nucleotides on the 3' end of the INVADER oligonucleotide that have the same sequence as the first several nucleotides at the 5' end of the probe oligonucleotide were required to promote the shift in cleavage.

[0774] To examine this point, the products of cleavage obtained from three different arrangements of target-specific oligonucleotides are compared. A diagram of these oligonucleotides and the way in which they hybridize to a test nucleic acid, M13mp19, is shown in FIG. **28**. In FIG. **28***a*, the 3' end of the upstream oligonucleotide (SEQ ID NO:33) is located upstream of the 5' end of the downstream "probe" oligonucleotide (SEQ ID NO:32) such that a region of the M13 target that is not paired to either oligonucleotide is present. In FIG. **28***b*, the sequence of the upstream oligonucleotide (SEQ ID NO:34) is immediately upstream of the probe (SEQ ID NO:32), having neither a gap nor an overlap between the sequences. FIG. **28***c* diagrams the arrangement of the substrates used in the assay of the present invention, showing that the upstream "INVADER" oligonucleotide (SEQ ID NO:35) has the same sequence on a portion of its 3' region as that present in the 5' region of the downstream probe (SEQ ID NO:32). That is to say, these regions will compete to hybridize to the same segment of the M13 target nucleic acid.

[0775] In these experiments, four enzyme mixtures were prepared as follows (planning 5 μl per digest): Mixture 1 contained 2.25 μl of CLEAVASE A/G nuclease extract (prepared as described in Example 2) per 5 μl of mixture, in 20 mM MOPS, pH 7.5 with 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$ and 100 mM KCl. Mixture 2 contained 11.25 units of Taq DNA polymerase (Promega) per 5 μl of mixture in 20 mM MOPS, pH 7.5 with 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$ and 100 mM KCl. Mixture 3 contained 2.25 μl of CLEAVASE A/G nuclease extract per 5 μl of mixture in 20 mM Tris-HCl, pH 8.5, 4 mM $MgCl_2$ and 100 mM KCl. Mixture 4 contained 11.25 units of Taq DNA polymerase per 5 μl of mixture in 20 mM Tris-HCl, pH 8.5, 4 mM $MgCl_2$ and 100 mM KCl.

[0776] For each reaction, 50 fmole of M13mp19 single-stranded DNA (the target nucleic acid) was combined with 5 pmole of the probe oligonucleotide (SEQ ID NO:32 which contained a fluorescein label at the 3' end) and 50 pmole of one of the three upstream oligonucleotides diagrammed in FIG. **28** (i.e., one of SEQ ID NOS:33-35), in a total volume of 5 μl of distilled water. The reactions were overlaid with a drop of ChillOut™ evaporation barrier and warmed to 62° C. The cleavage reactions were started by the addition of 5 μl of an enzyme mixture to each tube, and the reactions were incubated at 62° C. for 30 min. The reactions shown in lanes 1-3 of FIG. **30** received Mixture 1; reactions 4-6 received Mixture 2; reactions 7-9 received Mixture 3 and reactions 10-12 received Mixture 4.

[0777] After 30 minutes at 62° C., the reactions were stopped by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

[0778] Following electrophoresis, the products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager, the output of which is seen in FIG. **30**. The reaction products shown in lanes 1, 4, 7 and 10 of FIG. **30** were from reactions that contained SEQ ID NO:33 as the upstream oligonucleotide (see FIG. **28***a*). The reaction products shown in lanes 2, 5, 8 and 11 of FIG. **30** were from reactions that contained SEQ ID NO:34 as the upstream oligonucleotide (see FIG. **28***b*). The reaction products shown in lanes 3, 6, 9 and 12 of FIG. **30** were from reactions that contained SEQ ID NO:35, the INVADER oligonucleotide, as the upstream oligonucleotide (see FIG. **28***c*).

[0779] Examination of the Mn^{2+}based reactions using either CLEAVASE A/G nuclease or DNAPTaq as the cleavage agent (lanes 1 through 3 and 4 through 6, respectively) shows that both enzymes have active exonuclease function in these buffer conditions. The use of a 3' label on the probe oligonucleotide allows the products of the nibbling activity to remain labeled, and therefore visible in this assay. The ladders seen in lanes 1, 2, 4 and 5 confirm that the probe hybridize to the target DNA as intended. These lanes also show that the location of the non-invasive oligonucleotides have little effect on the products generated. The uniform ladder created by these digests would be difficult to distinguish from a ladder causes by a contaminating nuclease, as one might find in a clinical specimen. In contrast, the products displayed in lanes 3 and 6, where an INVADER oligonucleotide was provided to direct the cleavage, show a very distinctive shift, so that the primary cleavage product is smaller than those seen in the non-invasive cleavage. This product is then subject to further nibbling in these conditions, as indicated by the shorter products in these lanes. These INVADER-directed cleavage products would be easily distinguished from a background of non-specific degradation of the probe oligonucleotide.

[0780] When Mg^{2+} is used as the divalent cation the results are even more distinctive. In lanes 7, 8, 10 and 11 of FIG. **30**, where the upstream oligonucleotides were not invasive, minimal nibbling is observed. The products in the DNAPTaq reactions show some accumulation of probe that has been shortened on the 5' end by one or two nucleotides consistent with previous examination of the action of this enzyme on nicked substrates (Longley et al., supra). When the upstream oligonucleotide is invasive, however, the appearance of the distinctively shifted probe band is seen. These data clearly indicated that it is the invasive 3' portion of the upstream oligonucleotide that is responsible for fixing the site of cleavage of the downstream probe.

[0781] Thus, the above results demonstrate that it is the presence of the free or initially non-annealed nucleotides at the 3' end of the INVADER oligonucleotide that mediate the shift in the cleavage site, not just the presence of an oligonucleotide annealed upstream of the probe. Nucleic acid detection assays that employ the use of an INVADER oligonucleotide are termed "INVADER-directed cleavage" assays.

Example 13

INVADER-Directed Cleavage Recognizes Single and Double Stranded Target Molecules in a Background of Non-Target DNA Molecules

[0782] For a nucleic acid detection method to be broadly useful, it must be able to detect a specific target in a sample that may contain large amounts of other DNA, (e.g., bacterial or human chromosomal DNA). The ability of the INVADER directed cleavage assay to recognize and cleave either single- or double-stranded target molecules in the presence of large amounts of non-target DNA was examined. In these experiments a model target nucleic acid, M13, in either single or double stranded form (single-stranded M13mp18 is available from Life Technologies, Inc and double-stranded M13mp19 is available from NEB), was combined with human genomic DNA (Novagen) and then utilized in INVADER-directed cleavage reactions. Before the start of the cleavage reaction, the DNAs were heated to 95° C. for 15 minutes to completely denature the samples, as is standard practice in assays, such as polymerase chain reaction or enzymatic DNA sequencing, which involve solution hybridization of oligonucleotides to double-stranded target molecules.

[0783] For each of the reactions shown in lanes 2-5 of FIG. **31**, the target DNA (25 fmole of the ss DNA or 1 pmole of the ds DNA) was combined with 50 pmole of the INVADER oligonucleotide (SEQ ID NO:35); for the reaction shown in lane 1 the target DNA was omitted. Reactions 1, 3 and 5 also contained 470 ng of human genomic DNA. These mixtures were brought to a volume of 10 μl with distilled water, overlaid with a drop of ChillOut™ evaporation barrier, and brought to 95° C. for 15 minutes. After this incubation period, and still at 95° C., each tube received 10 μl of a mixture comprising 2.25 μl of CLEAVASE A/G nuclease extract (prepared as described in Example 2) and 5 pmole of the probe oligonucleotide (SEQ ID NO:32), in 20 mM MOPS, pH 7.5 with 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$ and 100 mM KCl. The reactions were brought to 62° C. for 15 minutes and stopped by the addition of 12 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager. The results are displayed in FIG. **31**.

[0784] In FIG. **31**, lane 1 contains the products of the reaction containing the probe (SEQ ID NO:32), the INVADER oligonucleotide (SEQ ID NO:35) and human genomic DNA. Examination of lane 1 shows that the probe and INVADER oligonucleotides are specific for the target sequence, and that the presence of genomic DNA does not cause any significant background cleavage.

[0785] In FIG. **31**, lanes 2 and 3 contain reaction products from reactions containing the single-stranded target DNA (M13mp18), the probe (SEQ ID NO:32) and the INVADER oligonucleotide (SEQ ID NO:35) in the absence or presence of human genomic DNA, respectively. Examination of lanes 2 and 3 demonstrate that the INVADER detection assay may be used to detect the presence of a specific sequence on a single-stranded target molecule in the presence or absence of a large excess of competitor DNA (human genomic DNA).

[0786] In FIG. **31**, lanes 4 and 5 contain reaction products from reactions containing the double-stranded target DNA (M13mp19), the probe (SEQ ID NO:32) and the INVADER oligonucleotide (SEQ ID NO:35) in the absence or presence of human genomic DNA, respectively. Examination of lanes 4 and 5 show that double stranded target molecules are eminently suitable for INVADER-directed detection reactions. The success of this reaction using a short duplexed molecule, M13mp19, as the target in a background of a large excess of genomic DNA is especially noteworthy as it would be anticipated that the shorter and less complex M13 DNA strands would be expected to find their complementary strand more easily than would the strands of the more complex human genomic DNA. If the M13 DNA reannealed before the probe and/or INVADER oligonucleotides could bind to the target sequences along the M13 DNA, the cleavage reaction would be prevented. In addition, because the denatured genomic DNA would potentially contain regions complementary to the probe and/or INVADER oligonucleotides it was possible that the presence of the genomic DNA would inhibit the reaction by binding these oligonucleotides thereby preventing their hybridization to the M13 target. The above results demonstrate that these theoretical concerns are not a problem under the reaction conditions employed above.

[0787] In addition to demonstrating that the INVADER detection assay may be used to detect sequences present in a double-stranded target, these data also show that the presence of a large amount of non-target DNA (470 ng/20 μl reaction) does not lessen the specificity of the cleavage. While this amount of DNA does show some impact on the rate of product accumulation, probably by binding a portion of the enzyme, the nature of the target sequence, whether single- or double-stranded nucleic acid, does not limit the application of this assay.

Example 14

Signal Accumulation in the INVADER-Directed Cleavage Assay as a Function of Target Concentration

[0788] To investigate whether the INVADER-directed cleavage assay could be used to indicate the amount of target nucleic acid in a sample, the following experiment was performed. Cleavage reactions were assembled that contained an INVADER oligonucleotide (SEQ ID NO:35), a labeled probe (SEQ ID NO:32) and a target nucleic acid, M13mp19. A series of reactions, which contained smaller and smaller amounts of the M13 target DNA, was employed in order to examine whether the cleavage products would accumulate in a manner that reflected the amount of target DNA present in the reaction.

[0789] The reactions were conducted as follows. A master mix containing enzyme and buffer was assembled. Each 5 μl of the master mixture contained 25 ng of CLEAVASE BN nuclease in 20 mM MOPS (pH 7.5) with 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$ and 100 mM KCl. For each of the cleavage reactions shown in lanes 4-13 of FIG. **32**, a DNA mixture was generated that contained 5 pmoles of the fluorescein-labeled probe oligonucleotide (SEQ ID NO:32), 50 pmoles of the INVADER oligonucleotide (SEQ ID NO:35) and 100, 50, 10, 5, 1, 0.5, 0.1, 0.05, 0.01 or 0.005 fmoles of single-stranded M13mp19, respectively, for every

5 μl of the DNA mixture. The DNA solutions were covered with a drop of CHILLOUT evaporation barrier and brought to 61° C. The cleavage reactions were started by the addition of 5 μl of the enzyme mixture to each of tubes (final reaction volume was 10 μl). After 30 minutes at 61° C., the reactions were terminated by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 90° C. for 1 minute immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. To provide reference (i.e., standards), 1.0, 0.1 and 0.01 pmole aliquots of fluorescein-labeled probe oligonucleotide (SEQ ID NO:32) were diluted with the above formamide solution to a final volume of 18 μl. These reference markers were loaded into lanes 1-3, respectively of the gel. The products of the cleavage reactions (as well as the reference standards) were visualized following electrophoresis by the use of a Hitachi FMBIO fluorescence imager. The results are displayed in FIG. **32**.

[**0790**] In FIG. **32**, boxes appear around fluorescein-containing nucleic acid (i.e., the cleaved and uncleaved probe molecules) and the amount of fluorescein contained within each box is indicated under the box. The background fluorescence of the gel (see box labeled "background") was subtracted by the fluoro-imager to generate each value displayed under a box containing cleaved or uncleaved probe products (the boxes are numbered 1-14 at top left with a V followed by a number below the box). The lane marked "M" contains fluoresceinated oligonucleotides, which served as markers.

[**0791**] The results shown in FIG. **32**, demonstrate that the accumulation of cleaved probe molecules in a fixed-length incubation period reflects the amount of target DNA present in the reaction. The results also demonstrate that the cleaved probe products accumulate in excess of the copy number of the target. This is clearly demonstrated by comparing the results shown in lane 3, in which 10 fmole (0.01 pmole) of uncut probe are displayed with the results shown in 5, where the products that accumulated in response to the presence of 10 fmole of target DNA are displayed. These results show that the reaction can cleave hundreds of probe oligonucleotide molecules for each target molecule present, dramatically amplifying the target-specific signal generated in the INVADER-directed cleavage reaction.

Example 15

Effect of Saliva Extract on the INVADER-Directed Cleavage Assay

[**0792**] For a nucleic acid detection method to be useful in a medical (i.e., a diagnostic) setting, it must not be inhibited by materials and contaminants likely to be found in a typical clinical specimen. To test the susceptibility of the INVADER-directed cleavage assay to various materials, including but not limited to nucleic acids, glycoproteins and carbohydrates, likely to be found in a clinical sample, a sample of human saliva was prepared in a manner consistent with practices in the clinical laboratory and the resulting saliva extract was added to the INVADER-directed cleavage assay. The effect of the saliva extract upon the inhibition of cleavage and upon the specificity of the cleavage reaction was examined.

[**0793**] One and one-half milliliters of human saliva were collected and extracted once with an equal volume of a mixture containing phenol:chloroform:isoamyl alcohol (25:24:1). The resulting mixture was centrifuged in a microcentrifuge to separate the aqueous and organic phases. The upper, aqueous phase was transferred to a fresh tube. One-tenth volumes of 3 M NaOAc were added and the contents of the tube were mixed. Two volumes of 100% ethyl alcohol were added to the mixture and the sample was mixed and incubated at room temperature for 15 minutes to allow a precipitate to form. The sample was centrifuged in a microcentrifuge at 13,000 rpm for 5 minutes and the supernatant was removed and discarded. A milky pellet was easily visible. The pellet was rinsed once with 70% ethanol, dried under vacuum and dissolved in 200 μl of 10 mM Tris-HCl, pH 8.0, 0.1 mM EDTA (this constitutes the saliva extract). Each μl of the saliva extract was equivalent to 7.5 μl of saliva. Analysis of the saliva extract by scanning ultraviolet spectrophotometry showed a peak absorbance at about 260 nm and indicated the presence of approximately 45 ng of total nucleic acid per μl of extract.

[**0794**] The effect of the presence of saliva extract upon the following enzymes was examined: CLEAVASE BN nuclease, CLEAVASE A/G nuclease and three different lots of DNAPTaq: AmpliTaq® (Perkin Elmer; a recombinant form of DNAPTaq), AmpliTaq® LD (Perkin-Elmer; a recombinant DNAPTaq preparation containing very low levels of DNA) and Taq DNA polymerase (Fischer). For each enzyme tested, an enzyme/probe mixture was made comprising the chosen amount of enzyme with 5 pmole of the probe oligonucleotide (SEQ ID NO:32) in 10 μl of 20 mM MOPS (pH 7.5) containing 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$, 100 mM KCl and 100 μg/ml BSA. The following amounts of enzyme were used: 25 ng of CLEAVASE BN prepared as described in Example 8; 2 μl of CLEAVASE A/G nuclease extract prepared as described in Example 2; 2.25 μl (11.25 polymerase units) the following DNA polymerases: AmpliTaq® DNA polymerase (Perkin Elmer); AmpliTaq® DNA polymerase LD (low DNA; from Perkin Elmer); Taq DNA polymerase (Fisher Scientific).

[**0795**] For each of the reactions shown in FIG. **33**, except for that shown in lane 1, the target DNA (50 fmoles of single-stranded M13mp19 DNA) was combined with 50 pmole of the INVADER oligonucleotide (SEQ ID NO:35) and 5 pmole of the probe oligonucleotide (SEQ ID NO:32); target DNA was omitted in reaction 1 (lane 1). Reactions 1, 3, 5, 7, 9 and 11 included 1.5 μl of saliva extract. These mixtures were brought to a volume of 5 μl with distilled water, overlaid with a drop of CHILLOUT evaporation barrier and brought to 95° C. for 10 minutes. The cleavage reactions were then started by the addition of 5 μl of the desired enzyme/probe mixture; reactions 1, 4 and 5 received CLEAVASE A/G nuclease. Reactions 2 and 3 received CLEAVASE BN; reactions 6 and 7 received AmpliTaq®; reactions 8 and 9 received AmpliTaq® LD; and reactions 10 and 11 received Taq DNA Polymerase from Fisher Scientific.

[**0796**] The reactions were incubated at 63° C. for 30 minutes and were stopped by the addition of 6 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-

Borate, pH 8.3, 1.4 mM EDTA. The products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager, and the results are displayed in FIG. **33**.

[**0797**] A pairwise comparison of the lanes shown in FIG. **33** without and with the saliva extract, treated with each of the enzymes, shows that the saliva extract has different effects on each of the enzymes. While the CLEAVASE BN nuclease and the AmpliTaq® are significantly inhibited from cleaving in these conditions, the CLEAVASE A/G nuclease and AmpliTaq® LD display little difference in the yield of cleaved probe. The preparation of Taq DNA polymerase from Fisher Scientific shows an intermediate response, with a partial reduction in the yield of cleaved product. From the standpoint of polymerization, the three DNAPTaq variants should be equivalent; these should be the same protein with the same amount of synthetic activity. It is possible that the differences observed could be due to variations in the amount of nuclease activity present in each preparation caused by different handling during purification, or by different purification protocols. In any case, quality control assays designed to assess polymerization activity in commercial DNAP preparations would be unlikely to reveal variation in the amount of nuclease activity present. If preparations of DNAPTaq were screened for full 5' nuclease activity (i.e., if the 5' nuclease activity was specifically quantitated), it is likely that the preparations would display sensitivities (to saliva extract) more in line with that observed using CLEAVASE A/G nuclease, from which DNAPTaq differs by a very few amino acids.

[**0798**] It is worthy of note that even in the slowed reactions of CLEAVASE BN and the DNAPTaq variants there is no noticeable increase in non-specific cleavage of the probe oligonucleotide due to inappropriate hybridization or saliva-borne nucleases.

Example 16

Comparison of Additional 5' Nucleases in the INVADER-Directed Cleavage Assay

[**0799**] A number of eubacterial Type A DNA polymerases (i.e., Pol I type DNA polymerases) have been shown to function as structure specific endonucleases (See, Example 1, and Lyamichev et al., supra). In this Example, it was demonstrated that the enzymes of this class can also be made to catalyze the INVADER-directed cleavage of the present invention, albeit not as efficiently as the CLEAVASE enzymes.

[**0800**] CLEAVASE BN nuclease and CLEAVASE A/G nuclease were tested along side three different thermostable DNA polymerases: *Thermus aquaticus* DNA polymerase (Promega), *Thermus thermophilus* and *Thermus flavus* DNA polymerases (Epicentre). The enzyme mixtures used in the reactions shown in lanes 1-11 of FIG. **34** contained the following, each in a volume of 5 μl: Lane 1: 20 mM MOPS (pH 7.5) with 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$, 100 mM KCl; Lane 2: 25 ng of CLEAVASE BN nuclease in the same solution described for lane 1; Lane 3: 2.25 μl of CLEAVASE A/G nuclease extract (prepared as described in Example 2), in the same solution described for lane 1; Lane 4: 2.25 μl of CLEAVASE A/G nuclease extract in 20 mM Tris-Ci, (pH 8.5), 4 mM $MgCl_2$ and 100 mM KCl; Lane 5: 11.25 polymerase units of Taq DNA polymerase in the same buffer described for lane 4; Lane 6: 11.25 polymerase units of Tth DNA polymerase in the same buffer described for lane 1; Lane 7: 11.25 polymerase units of Tth DNA polymerase in a 2× concentration of the buffer supplied by the manufacturer, supplemented with 4 mM $MnCl_2$; Lane 8: 11.25 polymerase units of Tth DNA polymerase in a 2× concentration of the buffer supplied by the manufacturer, supplemented with 4 mM $MgCl_2$; Lane 9: 2.25 polymerase units of Tfl DNA polymerase in the same buffer described for lane 1; Lane 10: 2.25 polymerase units of Tfl polymerase in a 2× concentration of the buffer supplied by the manufacturer, supplemented with 4 mM $MnCl_2$; Lane 11: 2.25 polymerase units of Tfl DNA polymerase in a 2× concentration of the buffer supplied by the manufacturer, supplemented with 4 mM $MgCl_2$.

[**0801**] Sufficient target DNA, probe and INVADER for all 11 reactions was combined into a master mix. This mix contained 550 fmoles of single-stranded M13mp19 target DNA, 550 pmoles of the INVADER oligonucleotide (SEQ ID NO:35) and 55 pmoles of the probe oligonucleotide (SEQ ID NO:32), each as depicted in FIG. **28***c*, in 55 μl of distilled water. Five μl of the DNA mixture was dispensed into each of 11 labeled tubes and overlaid with a drop of CHILLOUT evaporation barrier. The reactions were brought to 63° C. and cleavage was started by the addition of 5 μl of the appropriate enzyme mixture. The reaction mixtures were then incubated at 63° C. temperature for 15 minutes. The reactions were stopped by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 90° C. for 1 minute immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. Following electrophoresis, the products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager, and the results are displayed in FIG. **34**. Examination of the results shown in FIG. **34** demonstrates that all of the 5' nucleases tested have the ability to catalyze INVADER-directed cleavage in at least one of the buffer systems tested. Although not optimized here, these cleavage agents are suitable for use in the methods of the present invention.

Example 17

The INVADER-Directed Cleavage Assay can Detect Single Base Differences in Target Nucleic Acid Sequences

[**0802**] The ability of the INVADER-directed cleavage assay to detect single base mismatch mutations was examined. Two target nucleic acid sequences containing CLEAVASE enzyme-resistant phosphorothioate backbones were chemically synthesized and purified by polyacrylamide gel electrophoresis. Targets comprising phosphorothioate backbones were used to prevent exonucleolytic nibbling of the target when duplexed with an oligonucleotide. A target oligonucleotide, which provides a target sequence that is completely complementary to the INVADER oligonucleotide (SEQ ID NO:35) and the probe oligonucleotide (SEQ ID NO:32), contained the following sequence: 5'-CCTTTCGCTTTCTTCCCTTC-CTTTCTCGCCACGTTCGCCGGC-3' (SEQ ID NO:36). A second target sequence containing a single base change

relative to SEQ ID NO:36 was synthesized: 5'-CCTTTCGCTCTCTTCCCTTC-CTTTCTCGCCACGTTCGCCGGC-3 (SEQ ID NO:37; the single base change relative to SEQ ID NO:36 is shown using bold and underlined type). The consequent mismatch occurs within the "Z" region of the target as represented in FIG. **25**.

[**0803**] To discriminate between two target sequences that differ by the presence of a single mismatch), INVADER-directed cleavage reactions were conducted using two different reaction temperatures (55° C. and 60° C.). Mixtures containing 200 fmoles of either SEQ ID NO:36 or SEQ ID NO:37, 3 pmoles of fluorescein-labeled probe oligonucleotide (SEQ ID NO:32), 7.7 pmoles of INVADER oligonucleotide (SEQ ID NO:35) and 2 μl of CLEAVASE A/G nuclease extract (prepared as described in Example 2) in 9 μl of 10 mM MOPS (pH 7.4) with 50 mM KCl were assembled, covered with a drop of CHILLOUT evaporation barrier and brought to the appropriate reaction temperature. The cleavage reactions were initiated by the addition of 1 μl of 20 mM $MgCl_2$. After 30 minutes at either 55° C. or 60° C., 10 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes was added to stop the reactions. The reaction mixtures where then heated to 90° C. for one minute prior to loading 4 μl onto 20% denaturing polyacrylamide gels. The resolved reaction products were visualized using a Hitachi FMBIO fluorescence imager. The resulting image is shown in FIG. **35**.

[**0804**] In FIG. **35**, lanes 1 and 2 show the products from reactions conducted at 55° C.; lanes 3 and 4 show the products from reactions conducted at 60° C. Lanes 1 and 3 contained products from reactions containing SEQ ID NO:36 (perfect match to probe) as the target. Lanes 2 and 4 contained products from reactions containing SEQ ID NO:37 (single base mis-match with probe) as the target. The target that does not have a perfect hybridization match (i.e., complete complementarity) with the probe will not bind as strongly (i.e., the T_m of that duplex will be lower than the T_m of the same region if perfectly matched). The results presented here show that reaction conditions can be varied to either accommodate the mis-match (e.g., by lowering the temperature of the reaction) or to exclude the binding of the mis-matched sequence (e.g., by raising the reaction temperature).

[**0805**] The results shown in FIG. **35** demonstrate that the specific cleavage event that occurs in INVADER-directed cleavage reactions can be eliminated by the presence of a single base mis-match between the probe oligonucleotide and the target sequence. Thus, reaction conditions can be chosen so as to exclude the hybridization of mismatched INVADER-directed cleavage probes thereby diminishing or even eliminating the cleavage of the probe. In an extension of this assay system, multiple cleavage probes, each possessing a separate reporter molecule (i.e., a unique label), could also be used in a single cleavage reaction, to simultaneously probe for two or more variants in the same target region. The products of such a reaction would allow not only the detection of mutations that exist within a target molecule, but would also allow a determination of the relative concentrations of each sequence (i.e., mutant and wild type or multiple different mutants) present within samples containing a mixture of target sequences. When provided in equal amounts, but in a vast excess (e.g., at least a 100-fold molar excess; typically at least 1 pmole of each probe oligonucleotide would be used when the target sequence was present at about 10 fmoles or less) over the target and used in optimized conditions. As discussed above, any differences in the relative amounts of the target variants will not affect the kinetics of hybridization, so the amounts of cleavage of each probe will reflect the relative amounts of each variant present in the reaction.

[**0806**] The results shown in the Example clearly demonstrate that the INVADER-directed cleavage reaction can be used to detect single base difference between target nucleic acids.

Example 18

The INVADER-Directed Cleavage Reaction is Insensitive to Large Changes in Reaction Conditions

[**0807**] The results shown above demonstrated that the INVADER-directed cleavage reaction can be used for the detection of target nucleic acid sequences and that this assay can be used to detect single base difference between target nucleic acids. These results demonstrated that 5' nucleases (e.g., CLEAVASEBN, CLEAVASE A/G, DNAPTaq, DNAPTth, DNAPTfl) could be used in conjunction with a pair of overlapping oligonucleotides as an efficient way to recognize nucleic acid targets. In the experiments below it is demonstrated that invasive cleavage reaction is relatively insensitive to large changes in conditions thereby making the method suitable for practice in clinical laboratories.

[**0808**] The effects of varying the conditions of the cleavage reaction were examined for their effect(s) on the specificity of the invasive cleavage and the on the amount of signal accumulated in the course of the reaction. To compare variations in the cleavage reaction a "standard" INVADER cleavage reaction was first defined. In each instance, unless specifically stated to be otherwise, the indicated parameter of the reaction was varied, while the invariant aspects of a particular test were those of this standard reaction. The results of these tests are either shown in FIGS. **38-40**, or the results described below.

[**0809**] a) The Standard INVADER-Directed Cleavage Reaction

[**0810**] The standard reaction was defined as comprising 1 fmole of M13mp18 single-stranded target DNA (NEB), 5 pmoles of the labeled probe oligonucleotide (SEQ ID NO:38), 10 pmole of the upstream INVADER oligonucleotide (SEQ ID NO:39) and 2 units of CLEAVASE A/G in 10 μl of 10 mM MOPS, pH 7.5 with 100 mM KCl, 4 mM $MnCl_2$, and 0.05% each Tween-20 and Nonidet-P40. For each reaction, the buffers, salts and enzyme were combined in a volume of 5 μl; the DNAs (target and two oligonucleotides) were combined in 5 μl of dH_2O and overlaid with a drop of CHILLOUT evaporation barrier. When multiple reactions were performed with the same reaction constituents, these formulations were expanded proportionally.

[**0811**] Unless otherwise stated, the sample tubes with the DNA mixtures were warmed to 61° C., and the reactions were started by the addition of 5 μl of the enzyme mixture. After 20 minutes at this temperature, the reactions were stopped by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75° C. for 2 minutes immediately before electrophoresis

through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager. In each case, the uncut probe material was visible as an intense black band or blob, usually in the top half of the panel, while the desired products of INVADER specific cleavage were visible as one or two narrower black bands, usually in the bottom half of the panel. Under some reaction conditions, particularly those with elevated salt concentrations, a secondary cleavage product is also visible (thus generating a doublet). Ladders of lighter grey bands generally indicate either exonuclease nibbling of the probe oligonucleotide or heat-induced, non-specific breakage of the probe.

[0812] FIG. **37** depicts the annealing of the probe and INVADER oligonucleotides to regions along the M13mp18 target molecule (the bottom strand). In FIG. **37** only a 52 nucleotide portion of the M13mp18 molecule is shown; this 52 nucleotide sequence is listed in SEQ ID NO:31 (this sequence is identical in both M13mp18 and M13mp19). The probe oligonucleotide (top strand) contains a Cy3 amidite label at the 5' end; the sequence of the probe is 5'-AGAAAGGAAGGGAAGAAAGCGAAAGGT-3' (SEQ ID NO:38. The bold type indicates the presence of a modified base (2'-O—CH_3). Cy3 amidite (Pharmacia) is a indodicarbocyanine dye amidite that can be incorporated at any position during the synthesis of oligonucleotides; Cy3 fluoresces in the yellow region (excitation and emission maximum of 554 and 568 nm, respectively). The INVADER oligonucleotide (middle strand) has the following sequence: 5'-GCCGGCGAACGTGGCGAGAAAGGA-3' (SEQ ID NO:39).

[0813] b) KCl Titration

[0814] FIG. **38** shows the results of varying the KCl concentration in combination with the use of 2 mM $MnCl_2$, in an otherwise standard reaction. The reactions were performed in duplicate for confirmation of observations; the reactions shown in lanes 1 and 2 contained no added KCl, lanes 3 and 4 contained KCl at 5 mM, lanes 5 and 6 contained 25 mM KCl, lanes 7 and 8 contained 50 mM KCl, lanes 9 and 10 contained 100 mM KCl and lanes 11 and 12 contained 200 mM KCl. These results show that the inclusion of KCl allows the generation of a specific cleavage product. While the strongest signal is observed at the 100 mM KCl concentration, the specificity of signal in the other reactions with KCl at or above 25 mM indicates that concentrations in the full range (i.e., 25-200 mM) may be chosen if it is so desirable for any particular reaction conditions.

[0815] As shown in FIG. **38**, the INVADER-directed cleavage reaction requires the presence of salt (e.g., KCl) for effective cleavage to occur. In other reactions, it has been found that KCl can inhibit the activity of certain CLEAVASE enzymes when present at concentrations above about 25 mM. For example, in cleavage reactions using the S-60 oligonucleotide shown in FIG. **26**, in the absence of primer, the CLEAVASE BN enzyme loses approximately 50% of its activity in 50 mM KCl. Therefore, the use of alternative salts in the INVADER-directed cleavage reaction was examined. In these experiments, the potassium ion was replaced with either Na^+ or Li^+or the chloride ion was replaced with glutamic acid. The replacement of KCl with alternative salts is described below in Sections c-e.

[0816] c) NaCl Titration

[0817] NaCl was used in place of KCl at 75, 100, 150 or 200 mM, in combination with the use 2 mM $MnCl_2$, in an otherwise standard reaction. These results showed that NaCl can be used as a replacement for KCl in the INVADER-directed cleavage reaction, with like concentration giving like results, (i.e., the presence of NaCl, like KCl, enhances product accumulation).

[0818] d) LiCl Titration

[0819] LiCl was used in place of KCl in otherwise standard reactions. Concentrations tested were 25, 50, 75, 100, 150 and 200 mM LiCl. The results demonstrated that LiCl can be used as a suitable replacement for KCl in the INVADER-directed cleavage reaction (i.e., the presence of LiCl, like KCl, enhances product accumulation), in concentrations of about 100 mM or higher.

[0820] e) KGlu Titration

[0821] The results of using a glutamate salt of potassium (KGlu) in place of the more commonly used chloride salt (KCl) in reactions performed over a range of temperatures were examined. KGlu has been shown to be a highly effective salt source for some enzymatic reactions, showing a broader range of concentrations that permit maximum enzymatic activity (Leirmo et al., Biochem., 26:2095 [1987]). The ability of KGlu to facilitate the annealing of the probe and INVADER oligonucleotides to the target nucleic acid was compared to that of LiCl. In these experiments, the reactions were run for 15 minutes, rather than the standard 20 minutes, in standard reactions that replaced KCl 200 mM, 300 mM or 400 mM KGlu. The reactions were run at 65° C., 67° C., 69° C. or 71° C. The results showed demonstrated that KGlu was very effective as a salt in the invasive cleavage reactions, with full activity apparent even at 400 mM KGlu, though at the lowest temperature cleavage was reduced by about 30% at 300 mM KGlu, and by about 90% to 400 mM KGlu.

[0822] f) $MnCl_2$ and $MgCl_2$ Titration and Ability to Replace $MnCl_2$ with $MgCl_2$

[0823] In some instances it may be desirable to perform the invasive cleavage reaction in the presence of Mg^{2+}, either in addition to, or in place of Mn^{2+} as the necessary divalent cation required for activity of the enzyme employed. For example, some common methods of preparing DNA from bacterial cultures or tissues use $MgCl_2$ in solutions that are used to facilitate the collection of DNA by precipitation. In addition, elevated concentrations (i.e., greater than 5 mM) of divalent cation can be used to facilitate hybridization of nucleic acids, in the same way that the monovalent salts were used above, thereby enhancing the invasive cleavage reaction. In this experiment, the tolerance of the invasive cleavage reaction was examined for 1) the substitution of $MgCl_2$ for $MnCl_2$ and for the ability to produce specific product in the presence of increasing concentrations of $MgCl_2$ and $MnCl_2$.

[0824] FIG. **39** shows the results of either varying the concentration of $MnCl_2$ from 2 mM to 8 mM, replacing the $MnCl_2$ with $MgCl_2$ at 2 to 4 mM, or of using these components in combination in an otherwise standard reaction. The reactions analyzed in lanes 1 and 2 contained 2 mM each $MnCl_2$ and $MgCl_2$, lanes 3 and 4 contained 2 mM $MnCl_2$

only, lanes 5 and 6 contained 3 mM $MnCl_2$, lanes 7 and 8 contained 4 mM $MnCl_2$, lanes 9 and 10 contained 8 mM $MnCl_2$. The reactions analyzed in lanes 11 and 12 contained 2 mM $MgCl_2$ and lanes 13 and 14 contained 4 mM $MgCl_2$. These results show that both $MnCl_2$ and $MgCl_2$ can be used as the necessary divalent cation to enable the cleavage activity of the CLEAVASE A/G enzyme in these reactions and that the invasive cleavage reaction can tolerate a broad range of concentrations of these components.

[0825] In addition to examining the effects of the salt environment on the rate of product accumulation in the invasive cleavage reaction, the use of reaction constituents shown to be effective in enhancing nucleic acid hybridization in either standard hybridization assays (e.g., blot hybridization) or in ligation reactions was examined. These components may act as volume excluders, increasing the effective concentration of the nucleic acids of interest and thereby enhancing hybridization, or they may act as charge-shielding agents to minimize repulsion between the highly charged backbones of the nucleic acids strands. The results of these experiments are described in Sections g and h below.

[0826] g) Effect of CTAB Addition

[0827] The polycationic detergent cetyltrietheylammonium bromide (CTAB) has been shown to dramatically enhance hybridization of nucleic acids (Pontius and Berg, Proc. Natl. Acad. Sci. USA 88:8237 [1991]). The effect of adding the detergent CTAB in concentrations from 100 mM to 1 mM to invasive cleavage reactions in which 150 mM LiCl was used in place of the KCl in otherwise standard reactions was also investigated. These results showed that 200 mM CTAB may have a very moderate enhancing effect under these reaction conditions, and the presence of CTAB in excess of about 500 μM was inhibitory to the accumulation of specific cleavage product.

[0828] h) Effect of PEG Addition

[0829] The effect of adding polyethylene glycol (PEG) at 4.8 or 12% (w/v) concentrations to otherwise standard reactions was also examined. The effects of increasing the reaction temperature of the PEG-containing reactions was examined by performing duplicate sets of PEG titration reactions at 61° C. and 65° C. The results showed that at all percentages tested, and at both temperatures tested, the inclusion of PEG substantially eliminated the production of specific cleavage product.

[0830] In addition to, the presence of 1×Denhardts in the reaction mixture was found to have no adverse effect upon the cleavage reaction (50×Denhardts contains per 500 ml: 5 g Ficoll, 5 g polyvinylpyrrolidone, 5 g BSA). Further, the presence of each component of Denhardt's was examined individually (i.e., Ficoll alone, polyvinylpyrrolidone alone, BSA alone) for the effect upon the INVADER-directed cleavage reaction; no adverse effect was observed.

[0831] i) Effect of the Addition of Stabilizing Agents

[0832] Another approach to enhancing the output of the invasive cleavage reaction is to enhance the activity of the enzyme employed, either by increasing its stability in the reaction environment or by increasing its turnover rate. Without regard to the precise mechanism by which various agents operate in the invasive cleavage reaction, a number of agents commonly used to stabilize enzymes during prolonged storage were tested for the ability to enhance the accumulation of specific cleavage product in the invasive cleavage reaction.

[0833] The effects of adding glycerol at 15% and of adding the detergents Tween-20 and Nonidet-P40 at 1.5%, alone or in combination, in otherwise standard reactions were also examined. The results demonstrated that under these conditions these adducts had little or no effect on the accumulation of specific cleavage product.

[0834] The effects of adding gelatin to reactions in which the salt identity and concentration were varied from the standard reaction were also investigated. The results demonstrated that in the absence of salt the gelatin had a moderately enhancing effect on the accumulation of specific cleavage product, but when either salt (KCl or LiCl) was added to reactions performed under these conditions, increasing amounts of gelatin reduced the product accumulation.

[0835] j) Effect of Adding Large Amounts of Non-Target Nucleic Acid

[0836] In detecting specific nucleic acid sequences within samples, it is important to determine if the presence of additional genetic material (i.e., non-target nucleic acids) will have a negative effect on the specificity of the assay. In this experiment, the effect of including large amounts of non-target nucleic acid, either DNA or RNA, on the specificity of the invasive cleavage reaction was examined. The data was examined for either an alteration in the expected site of cleavage, or for an increase in the nonspecific degradation of the probe oligonucleotide.

[0837] FIG. **40** shows the effects of adding non-target nucleic acid (e.g., genomic DNA or tRNA) to an invasive cleavage reaction performed at 65° C., with 150 mM LiCl in place of the KCl in the standard reaction. The reactions assayed in lanes 1 and 2 contained 235 and 470 ng of genomic DNA, respectively. The reactions analyzed in lanes 3, 4, 5 and 6 contained 100 ng, 200 ng, 500 ng and 1 μg of tRNA, respectively. Lane 7 represents a control reaction that contained no added nucleic acid beyond the amounts used in the standard reaction. The results shown in FIG. **40** demonstrate that the inclusion of non-target nucleic acid in large amounts could visibly slow the accumulation of specific cleavage product (while not limiting the invention to any particular mechanism, it is thought that the additional nucleic acid competes for binding of the enzyme with the specific reaction components). In additional experiments it was found that the effect of adding large amounts of non-target nucleic acid can be compensated for by increasing the enzyme in the reaction. The data shown in FIG. **40** also demonstrate that a key feature of the invasive cleavage reaction, the specificity of the detection, was not compromised by the presence of large amounts of non-target nucleic acid.

[0838] In addition to the data presented above, invasive cleavage reactions were run with succinate buffer at pH 5.9 in place of the MOPS buffer used in the "standard" reaction; no adverse effects were observed.

[0839] The data shown in FIGS. **38-40** and described above demonstrate that the invasive cleavage reaction can be

performed using a wide variety of reaction conditions and is therefore suitable for practice in clinical laboratories.

Example 19

Detection of RNA Targets by INVADER-Directed Cleavage

[0840] In addition to the clinical need to detect specific DNA sequences for infectious and genetic diseases, there is a need for technologies that can quantitatively detect target nucleic acids that are composed of RNA. For example, a number of viral agents, such as hepatitis C virus (HCV) and human immunodeficiency virus (HIV) have RNA genomic material, the quantitative detection of which can be used as a measure of viral load in a patient sample. Such information can be of critical diagnostic or prognostic value.

[0841] Hepatitis C virus (HCV) infection is the predominant cause of post-transfusion non-A, non-B (NANB) hepatitis around the world. In addition, HCV is the major etiologic agent of hepatocellular carcinoma (HCC) and chronic liver disease world wide. The genome of HCV is a small (9.4 kb) RNA molecule. In studies of transmission of HCV by blood transfusion it has been found the presence of HCV antibody, as measured in standard immunological tests, does not always correlate with the infectivity of the sample, while the presence of HCV RNA in a blood sample strongly correlates with infectivity. Conversely, serological tests may remain negative in immunosuppressed infected individuals, while HCV RNA may be easily detected (Cuthbert, Clin. Microbiol. Rev., 7:505 [1994]).

[0842] The need for and the value of developing a probe-based assay for the detection the HCV RNA is clear. The polymerase chain reaction has been used to detect HCV in clinical samples, but the problems associated with carry-over contamination of samples has been a concern. Direct detection of the viral RNA without the need to perform either reverse transcription or amplification would allow the elimination of several of the points at which existing assays may fail.

[0843] The genome of the positive-stranded RNA hepatitis C virus comprises several regions including 5' and 3' noncoding regions (i.e., 5' and 3' untranslated regions) and a polyprotein coding region that encodes the core protein (C), two envelope glycoproteins (E1 and E2/NS1) and six nonstructural glycoproteins (NS2-NS5b). Molecular biological analysis of the HCV genome has showed that some regions of the genome are very highly conserved between isolates, while other regions are fairly rapidly changeable. The 5' noncoding region (NCR) is the most highly conserved region in the HCV. These analyses have allowed these viruses to be divided into six basic genotype groups, and then further classified into over a dozen sub-types (the nomenclature and division of HCV genotypes is evolving; see Altamirano et al., J. Infect. Dis., 171:1034 (1995) for a recent classification scheme).

[0844] In order to develop a rapid and accurate method of detecting HCV present in infected individuals, the ability of the INVADER-directed cleavage reaction to detect HCV RNA was examined. Plasmids containing DNA derived from the conserved 5'-untranslated region of six different HCV RNA isolates were used to generate templates for in vitro transcription. The HCV sequences contained within these six plasmids represent genotypes 1 (four sub-types represented; 1a, 1b, 1c, and Δ1c), 2, and 3. The nomenclature of the HCV genotypes used herein is that of Simmonds et al. (as described in Altamirano et al., supra). The Δ1c subtype was used in the model detection reaction described below.

[0845] a) Generation of Plasmids Containing HCV Sequences

[0846] Six DNA fragments derived from HCV were generated by RT-PCR using RNA extracted from serum samples of blood donors; these PCR fragments were a gift of Dr. M. Altamirano (University of British Columbia, Vancouver). These PCR fragments represent HCV sequences derived from HCV genotypes 1a, 1b, 1c, Δ1c, 2c and 3a.

[0847] The RNA extraction, reverse transcription and PCR were performed using standard techniques (Altamirano et al., supra). Briefly, RNA was extracted from 100 μl of serum using guanidine isothiocyanate, sodium lauryl sarkosate and phenol-chloroform (Inchauspe et al., Hepatol., 14:595 [1991]). Reverse transcription was performed according to the manufacturer's instructions using a GeneAmp rTh reverse transcriptase RNA PCR kit (Perkin-Elmer) in the presence of an external antisense primer, HCV342. The sequence of the HCV342 primer is 5'-GGTTTTTCTTTGAGGTTTAG-3' (SEQ ID NO:40). Following termination of the RT reaction, the sense primer HCV7 (5'-GCGACACTCCACCATAGAT-3'[SEQ ID NO:41]) and magnesium were added and a first PCR was performed. Aliquots of the first PCR products were used in a second (nested) PCR in the presence of primers HCV46 (5'-CTGTCTTCACGCAGAAAGC-3'[SEQ ID NO:42]) and HCV308 [5'-GCACGGT CTACGAGACCTC-3'[SEQ ID NO:43]). The PCRs produced a 281 bp product that corresponds to a conserved 5' noncoding region (NCR) region of HCV between positions −284 and −4 of the HCV genome (Altramirano et al., supra).

[0848] The six 281 bp PCR fragments were used directly for cloning or they were subjected to an additional amplification step using a 50 μl PCR comprising approximately 100 fmoles of DNA, the HCV46 and HCV308 primers at 0.1 μM, 100 μM of all four dNTPs and 2.5 units of Taq DNA polymerase in a buffer containing 10 mM Tris-HCl, pH 8.3, 50 mM KCl, 1.5 mM $MgCl_2$ and 0.1% Tween 20. The PCRs were cycled 25 times at 96° C. for 45 sec., 55° C. for 45 sec. and 72° C. for 1 min. Two microliters of either the original DNA samples or the reamplified PCR products were used for cloning in the linear pT7Blue T-vector (Novagen) according to manufacturer's protocol. After the PCR products were ligated to the pT7Blue T-vector, the ligation reaction mixture was used to transform competent JM109 cells (Promega). Clones containing the pT7Blue T-vector with an insert were selected by the presence of colonies having a white color on LB plates containing 40 μg/ml X-Gal, 40 μg/ml IPTG and 50 μg/ml ampicillin. Four colonies for each PCR sample were picked and grown overnight in 2 ml LB media containing 50 μg/ml carbenicillin. Plasmid DNA was isolated using the following alkaline miniprep protocol. Cells from 1.5 ml of the overnight culture were collected by centrifugation for 2 min. in a microcentrifuge (14K rpm), the supernatant was discarded and the cell pellet was resuspended in 50 μl TE buffer with 10 μg/ml RNAse A (Pharmacia). One hundred microliters of

a solution containing 0.2 N NaOH, 1% SDS was added and the cells were lysed for 2 min. The lysate was gently mixed with 100 μl of 1.32 M potassium acetate, pH 4.8, and the mixture was centrifuged for 4 min. in a microcentrifuge (14K rpm); the pellet comprising cell debris was discarded. Plasmid DNA was precipitated from the supernatant with 200 μl ethanol and pelleted by centrifugation a microcentrifuge (14K rpm). The DNA pellet was air dried for 15 min. and was then redissolved in 50 μl TE buffer (10 mM Tris-HCl, pH 7.8, 1 mM EDTA).

[0849] b) Reamplification of HCV Clones to Add the Phage T7 Promoter for Subsequent In Vitro Transcription

[0850] To ensure that the RNA product of transcription had a discrete 3' end it was necessary to create linear transcription templates that stopped at the end of the HCV sequence. These fragments were conveniently produced using the PCR to reamplify the segment of the plasmid containing the phage promoter sequence and the HCV insert. For these studies, the clone of HCV type Δ1c was reamplified using a primer that hybridizes to the T7 promoter sequence: 5'-TAATACGACTCACTATAGGG-3' (SEQ ID NO:44; "the T7 promoter primer") (Novagen) in combination with the 3' terminal HCV-specific primer HCV308 (SEQ ID NO:43). For these reactions, 1 μl of plasmid DNA (approximately 10 to 100 ng) was reamplified in a 200 μl PCR using the T7 and HCV308 primers as described above with the exception that 30 cycles of amplification were employed. The resulting amplicon was 354 bp in length. After amplification the PCR mixture was transferred to a fresh 1.5 ml microcentrifuge tube, the mixture was brought to a final concentration of 2 M NH_4OAc, and the products were precipitated by the addition of one volume of 100% isopropanol. Following a 10 min. incubation at room temperature, the precipitates were collected by centrifugation, washed once with 80% ethanol and dried under vacuum. The collected material was dissolved in 100 μl nuclease-free distilled water (Promega).

[0851] Segments of RNA were produced from this amplicon by in vitro transcription using the RiboMAX™ Large Scale RNA Production System (Promega) in accordance with the manufacturer's instructions, using 5.3 μg of the amplicon described above in a 100 μl reaction. The transcription reaction was incubated for 3.75 hours, after which the DNA template was destroyed by the addition of 5-6 μl of RQ1 RNAse-free DNAse (1 unit/μl) according to the RiboMAX™ kit instructions. The reaction was extracted twice with phenol/chloroform/isoamyl alcohol (50:48:2) and the aqueous phase was transferred to a fresh microcentrifuge tube. The RNA was then collected by the addition of 10 μl of 3M NH_4OAc, pH 5.2 and 110 μl of 100% isopropanol. Following a 5 min. incubation at 4° C., the precipitate was collected by centrifugation, washed once with 80% ethanol and dried under vacuum. The sequence of the resulting RNA transcript (HCV1.1 transcript) is listed in SEQ ID NO:45.

[0852] c) Detection of the HCV1.1 Transcript in the INVADER-Directed Cleavage Assay

[0853] Detection of the HCV1.1 transcript was tested in the INVADER-directed cleavage assay using an HCV-specific probe oligonucleotide (5'-CCGGTCGTCCTGGCAAT XCC-3'[SEQ ID NO:46]); X indicates the presence of a fluorescein dye on an abasic linker) and an HCV-specific INVADER oligonucleotide (5'-GTTTATCCAAGAAAG-GAC CCGGTC-3'[SEQ ID NO:47]) that causes a 6-nucleotide invasive cleavage of the probe.

[0854] Each 10 μl of reaction mixture comprised 5 pmole of the probe oligonucleotide (SEQ ID NO:46) and 10 pmole of the INVADER oligonucleotide (SEQ ID NO:47) in a buffer of 10 mM MOPS, pH 7.5 with 50 mM KCl, 4 mM $MnCl_2$, 0.05% each Tween-20 and Nonidet-P40 and 7.8 units RNasin® ribonuclease inhibitor (Promega). The cleavage agents employed were CLEAVASE A/G (used at 5.3 ng/10 μl reaction) or DNAPTth (used at 5 polymerase units/10 μl reaction). The amount of RNA target was varied as indicated below. When RNAse treatment is indicated, the target RNAs were pre-treated with 10 μg of RNase A (Sigma) at 37° C. for 30 min. to demonstrate that the detection was specific for the RNA in the reaction and not due to the presence of any residual DNA template from the transcription reaction. RNase-treated aliquots of the HCV RNA were used directly without intervening purification.

[0855] For each reaction, the target RNAs were suspended in the reaction solutions as described above, but lacking the cleavage agent and the $MnCl_2$ for a final volume of 10 μl, with the INVADER and probe at the concentrations listed above. The reactions were warmed to 46° C. and the reactions were started by the addition of a mixture of the appropriate enzyme with $MnCl_2$. After incubation for 30 min. at 46° C., the reactions were stopped by the addition of 8 μl of 95% formamide, 10 mM EDTA and 0.02% methyl violet (methyl violet loading buffer). Samples were then resolved by electrophoresis through a 15% denaturing polyacrylamide gel (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Following electrophoresis, the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi), with the resulting imager scan shown in FIG. **41**.

[0856] In FIG. **41**, the samples analyzed in lanes 1-4 contained 1 pmole of the RNA target, the reactions shown in lanes 5-8 contained 100 fmoles of the RNA target and the reactions shown in lanes 9-12 contained 10 fmoles of the RNA target. All odd-numbered lanes depict reactions performed using CLEAVASE A/G enzyme and all even-numbered lanes depict reactions performed using DNAPTth. The reactions analyzed in lanes 1, 2, 5, 6, 9 and 10 contained RNA that had been pre-digested with RNase A. These data demonstrate that the invasive cleavage reaction efficiently detects RNA targets and further, the absence of any specific cleavage signal in the RNase-treated samples confirms that the specific cleavage product seen in the other lanes is dependent upon the presence of input RNA.

Example 20

The Fate of the Target RNA in the INVADER-Directed Cleavage Reaction

[0857] In this Example, the fate of the RNA target in the INVADER-directed cleavage reaction was examined. As shown above in Example 1D, when RNAs are hybridized to DNA oligonucleotides, the 5' nucleases associated with DNA polymerases can be used to cleave the RNAs; such cleavage can be suppressed when the 5' arm is long or when it is highly structured (Lyamichev et al., Science 260:778 [1993], and U.S. Pat. No. 5,422,253, the disclosure of which is herein incorporated by reference). In this experiment, the

extent to which the RNA target would be cleaved by the cleavage agents when hybridized to the detection oligonucleotides (i.e., the probe and INVADER oligonucleotides) was examined using reactions similar to those described in Example 20, performed using fluorescein-labeled RNA as a target.

[0858] Transcription reactions were performed as described in Example 19 with the exception that 2% of the UTP in the reaction was replaced with fluorescein-12-UTP (Boehringer Mannheim) and 5.3 μg of the amplicon was used in a 100 μl reaction. The transcription reaction was incubated for 2.5 hours, after which the DNA template was destroyed by the addition of 5-6 μl of RQ1 RNAse-free DNAse (1 unit/μl) according to the RiboMAX™ kit instructions. The organic extraction was omitted and the RNA was collected by the addition of 10 μl of 3M NaOAc, pH 5.2 and 110 μl of 100% isopropanol. Following a 5 min. incubation at 4° C., the precipitate was collected by centrifugation, washed once with 80% ethanol and dried under vacuum. The resulting RNA was dissolved in 100 μl of nuclease-free water. Half (i.e., 50%) of the sample was purified by electrophoresis through a 8% denaturing polyacrylamide gel (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The gel slice containing the full-length material was excised and the RNA was eluted by soaking the slice overnight at 4° C. in 200 μl of 10 mM Tris-Cl, pH 8.0, 0.1 mM EDTA and 0.3 M NaOAc. The RNA was then precipitated by the addition of 2.5 volumes of 100% ethanol. After incubation at −20° C. for 30 min., the precipitates were recovered by centrifugation, washed once with 80% ethanol and dried under vacuum. The RNA was dissolved in 25 μl of nuclease-free water and then quantitated by UV absorbance at 260 nm.

[0859] Samples of the purified RNA target were incubated for 5 or 30 min. in reactions that duplicated the CLEAVASE A/G and DNAPTth INVADER reactions described in Example 20 with the exception that the reactions lacked probe and INVADER oligonucleotides. Subsequent analysis of the products showed that the RNA was very stable, with a very slight background of non-specific degradation, appearing as a gray background in the gel lane. The background was not dependent on the presence of enzyme in the reaction.

[0860] INVADER detection reactions using the purified RNA target were performed using the probe/INVADER pair described in Example 19 (SEQ ID NOS:46 and 47). Each reaction included 500 fmole of the target RNA, 5 pmoles of the fluorescein-labeled probe and 10 pmoles of the INVADER oligonucleotide in a buffer of 10 mM MOPS, pH 7.5 with 150 mM LiCl, 4 mM $MnCl_2$, 0.05% each Tween-20 and Nonidet-P40 and 39 units RNAsin® (Promega). These components were combined and warmed to 50° C. and the reactions were started by the addition of either 53 ng of CLEAVASE A/G or 5 polymerase units of DNAPTth. The final reaction volume was 10 μl. After 5 min at 50° C., 5 μl aliquots of each reaction were removed to tubes containing 4 μl of 95% formamide, 10 mM EDTA and 0.02% methyl violet. The remaining aliquot received a drop of CHILLOUT evaporation barrier and was incubated for an additional 25 min. These reactions were then stopped by the addition of 4 μl of the above formamide solution. The products of these reactions were resolved by electrophoresis through separate 20% denaturing polyacrylamide gels (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Following electrophoresis, the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi), with the resulting imager scans shown in FIGS. **42**A (5 min reactions) and **42**B (30 min. reactions).

[0861] In FIG. **53** the target RNA is seen very near the top of each lane, while the labeled probe and its cleavage products are seen just below the middle of each panel. The FMBIO-100 Image Analyzer was used to quantitate the fluorescence signal in the probe bands. In each panel, lane 1 contains products from reactions performed in the absence of a cleavage agent, lane 2 contains products from reactions performed using CLEAVASE A/G and lane 3 contains products from reactions performed using DNAPTth.

[0862] Quantitation of the fluorescence signal in the probe bands revealed that after a 5 min. incubation, 12% or 300 fmole of the probe was cleaved by the CLEAVASE A/G and 29% or 700 fmole was cleaved by the DNAPTth. After a 30 min. incubation, CLEAVASE A/G had cleaved 32% of the probe molecules and DNAPTth had cleaved 70% of the probe molecules. (The images shown in FIGS. **42**A and **42**B were printed with the intensity adjusted to show the small amount of background from the RNA degradation, so the bands containing strong signals are saturated and therefore these images do not accurately reflect the differences in measured fluorescence)

[0863] The data shown in FIG. **42** clearly shows that, under invasive cleavage conditions, RNA molecules are sufficiently stable to be detected as a target and that each RNA molecule can support many rounds of probe cleavage.

Example 21

Titration of Target RNA in the INVADER-Directed Cleavage Assay

[0864] One of the primary benefits of the INVADER-directed cleavage assay as a means for detection of the presence of specific target nucleic acids is the correlation between the amount of cleavage product generated in a set amount of time and the quantity of the nucleic acid of interest present in the reaction. The benefits of quantitative detection of RNA sequences was discussed in Example 19. In this Example, the quantitative nature of the detection assay was demonstrated through the use of various amounts of target starting material. In addition to demonstrating the correlation between the amounts of input target and output cleavage product, these data graphically show the degree to which the RNA target can be recycled in this assay

[0865] The RNA target used in these reactions was the fluorescein-labeled material described in Example 20 (i.e., SEQ ID NO:45). Because the efficiency of incorporation of the fluorescein-12-UTP by the T7 RNA polymerase was not known, the concentration of the RNA was determined by measurement of absorbance at 260 nm, not by fluorescence intensity. Each reaction comprised 5 pmoles of the fluorescein-labeled probe (SEQ ID NO:46) and 10 pmoles of the INVADER oligonucleotide (SEQ ID NO:47) in a buffer of 10 mM MOPS, pH 7.5 with 150 mM LiCl, 4 mM $MnCl_2$, 0.05% each Tween-20 and Nonidet-P40 and 39 units of RNAsin® (Promega). The amount of target RNA was varied from 1 to 100 fmoles, as indicated below. These components

were combined, overlaid with CHILLOUT evaporation barrier and warmed to 50° C.; the reactions were started by the addition of either 53 ng of CLEAVASE A/G or 5 polymerase units of DNAPTth, to a final reaction volume of 10 μl. After 30 minutes at 50° C., reactions were stopped by the addition of 8 μl of 95% formamide, 10 mM EDTA and 0.02% methyl violet. The unreacted markers in lanes 1 and 2 were diluted in the same total volume (18 μl). The samples were heated to 90° C. for 1 minute and 2.5 μl of each of these reactions were resolved by electrophoresis through a 20% denaturing polyacrylamide gel (19:1 cross link) with 7M urea in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA, and the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi), with the resulting imager scans shown in FIG. **43**.

[**0866**] In FIG. **43**, lanes 1 and 2 show 5 pmoles of uncut probe and 500 fmoles of untreated RNA, respectively. The probe is the very dark signal near the middle of the panel, while the RNA is the thin line near the top of the panel. These RNAs were transcribed with a 2% substitution of fluorescein-12-UTP for natural UTP in the transcription reaction. The resulting transcript contains 74 U residues, which would give an average of 1.5 fluorescein labels per molecule. With one tenth the molar amount of RNA loaded in lane 2, the signal in lane 2 should be approximately one seventh (0.15×) the fluorescence intensity of the probe in lane 1. Measurements indicated that the intensity was closer to one fortieth, indicating an efficiency of label incorporation of approximately 17%. Because the RNA concentration was verified by A260 measurement this does not alter the experimental observations below, but it should be noted that the signal from the RNA and the probes does not accurately reflect the relative amounts in the reactions.

[**0867**] The reactions analyzed in lanes 3 through 7 contained 1, 5, 10, 50 and 100 fmoles of target, respectively, with cleavage of the probe accomplished by CLEAVASE A/G. The reactions analyzed in lanes 8 through 12 repeated the same array of target amounts, with cleavage of the probe accomplished by DNAPTth. The boxes seen surrounding the product bands show the area of the scan in which the fluorescence was measured for each reaction. The number of fluorescence units detected within each box is indicated below each box; background florescence was also measured.

[**0868**] It can be seen by comparing the detected fluorescence in each lane that the amount of product formed in these 30 minute reactions can be correlated to the amount of target material. The accumulation of product under these conditions is slightly enhanced when DNAPTth is used as the cleavage agent, but the correlation with the amount of target present remains. This demonstrates that the INVADER assay can be used as a means of measuring the amount of target RNA within a sample.

[**0869**] Comparison of the fluorescence intensity of the input RNA with that of the cleaved product shows that the INVADER-directed cleavage assay creates signal in excess of the amount of target, so that the signal visible as cleaved probe is far more intense than that representing the target RNA. This further confirms the results described in Example 20, in which it was demonstrated that each RNA molecule could be used many times.

Example 22

Detection of DNA by Charge Reversal

[**0870**] The detection of specific targets is achieved in the INVADER-directed cleavage assay by the cleavage of the probe oligonucleotide. In addition to the methods described in the preceding Examples, the cleaved probe may be separated from the uncleaved probe using the charge reversal technique described below. This novel separation technique is related to the observation that positively charged adducts can affect the electrophoretic behavior of small oligonucleotides because the charge of the adduct is significant relative to charge of the whole complex. Observations of aberrant mobility due to charged adducts have been reported in the literature, but in all cases found, the applications pursued by other scientists have involved making oligonucleotides larger by enzymatic extension. As the negatively charged nucleotides are added on, the positive influence of the adduct is reduced to insignificance. As a result, the effects of positively charged adducts have been dismissed and have received infinitesimal notice in the existing literature.

[**0871**] This observed effect is of particular utility in assays based on the cleavage of DNA molecules. When an oligonucleotide is shortened through the action of a CLEAVASE enzyme or other cleavage agent, the positive charge can be made to not only significantly reduce the net negative charge, but to actually override it, effectively "flipping" the net charge of the labeled entity. This reversal of charge allows the products of target-specific cleavage to be partitioned from uncleaved probe by extremely simple means. For example, the products of cleavage can be made to migrate towards a negative electrode placed at any point in a reaction vessel, for focused detection without gel-based electrophoresis. When a slab gel is used, sample wells can be positioned in the center of the gel, so that the cleaved and uncleaved probes can be observed to migrate in opposite directions. Alternatively, a traditional vertical gel can be used, but with the electrodes reversed relative to usual DNA gels (i.e., the positive electrode at the top and the negative electrode at the bottom) so that the cleaved molecules enter the gel, while the uncleaved disperse into the upper reservoir of electrophoresis buffer.

[**0872**] An additional benefit of this type of readout is that the absolute nature of the partition of products from substrates means that an abundance of uncleaved probe can be supplied to drive the hybridization step of the probe-based assay, yet the unconsumed probe can be subtracted from the result to reduce background.

[**0873**] Through the use of multiple positively charged adducts, synthetic molecules can be constructed with sufficient modification that the normally negatively charged strand is made nearly neutral. When so constructed, the presence or absence of a single phosphate group can mean the difference between a net negative or a net positive charge. This observation has particular utility when one objective is to discriminate between enzymatically generated fragments of DNA, which lack a 3' phosphate, and the products of thermal degradation, which retain a 3' phosphate (and thus two additional negative charges).

[0874] a) Characterization of the Products of Thermal Breakage of DNA Oligonucleotides

[0875] Thermal degradation of DNA probes results in high background that can obscure signals generated by specific enzymatic cleavage, decreasing the signal-to-noise ratio. To better understand the nature of DNA thermal degradation products, the 5' tetrachloro-fluorescein (TET)-labeled oligonucleotides 78 (SEQ ID NO:48) and 79 (SEQ ID NO:49) (100 pmole each) were incubated in 50 μl 10 mM $NaCO_3$ (pH 10.6), 50 mM NaCl at 90° C. for 4 hours. To prevent evaporation of the samples, the reaction mixture was overlaid with 50 μl of CHILLOUT liquid wax. The reactions were then divided in two equal aliquots (A and B). Aliquot A was mixed with 25 μl of methyl violet loading buffer and Aliquot B was dephosphorylated by addition of 2.5 μl of 100 mM $MgCl_2$ and 1 μl of 1 unit/μl Calf Intestinal Alkaline Phosphatase (CIAP) (Promega), with incubation at 37° C. for 30 min. after which 25 μl of methyl violet loading buffer was added. One microliter of each sample was resolved by electrophoresis through a 12% polyacrylamide denaturing gel and imaged as described in Example 21; a 585 nm filter was used with the FMBIO Image Analyzer. The resulting imager scan is shown in FIG. **44**.

[0876] In FIG. **44**, lanes 1-3 contain the TET-labeled oligonucleotide 78 and lanes 4-6 contain the TET-labeled oligonucleotides 79. Lanes 1 and 4 contain products of reactions that were not heat treated. Lanes 2 and 5 contain products from reactions that were heat treated and lanes 3 and 6 contain products from reactions that were heat treated and subjected to phosphatase treatment.

[0877] As shown in FIG. **44**, heat treatment causes significant breakdown of the 5'-TET-labeled DNA, generating a ladder of degradation products (FIG. **44**, lanes 2, 3, 5 and 6). Band intensities correlate with purine and pyrimidine base positioning in the oligonucleotide sequences, indicating that backbone hydrolysis may occur through formation of abasic intermediate products that have faster rates for purines than for pyrimidines (Lindahl and Karlström, Biochem., 12:5151 [1973]).

[0878] Dephosphorylation decreases the mobility of all products generated by the thermal degradation process, with the most pronounced effect observed for the shorter products (FIG. **44**, lanes 3 and 6). This demonstrates that thermally degraded products possess a 3' end terminal phosphoryl group that can be removed by dephosphorylation with CIAP. Removal of the phosphoryl group decreases the overall negative charge by 2. Therefore, shorter products that have a small number of negative charges are influenced to a greater degree upon the removal of two charges. This leads to a larger mobility shift in the shorter products than that observed for the larger species.

[0879] The fact that the majority of thermally degraded DNA products contain 3' end phosphate groups and CLEAVASE enzyme-generated products do not allowed the development of simple isolation methods for products generated in the INVADER-directed cleavage assay. The extra two charges found in thermal breakdown products do not exist in the specific cleavage products. Therefore, if one designs assays that produce specific products that contain a net positive charge of one or two, then similar thermal breakdown products will either be negative or neutral. The difference can be used to isolate specific products by reverse charge methods as shown below.

[0880] b) Dephosphorylation of Short Amino-Modified Oligonucleotides can Reverse the Net Charge of the Labeled Product

[0881] To demonstrate how oligonucleotides can be transformed from net negative to net positively charged compounds, the four short amino-modified oligonucleotides labeled 70, 74, 75 and 76 and shown in FIGS. **45-47** were synthesized (FIG. **45** shows both oligonucleotides 70 and 74). All four modified oligonucleotides possess Cy-3 dyes positioned at the 5'-end, which individually are positively charged under reaction and isolation conditions described in this Example. Compounds 70 and 74 contain two amino modified thymidines that, under reaction conditions, display positively charged R—NH_3^+groups attached at the C5 position through a C_{10} or C_6 linker, respectively. Because compounds 70 and 74 are 3'-end phosphorylated, they consist of four negative charges and three positive charges. Compound 75 differs from 74 in that the internal C_6 amino modified thymidine phosphate in 74 is replaced by a thymidine methyl phosphonate. The phosphonate backbone is uncharged and so there are a total of three negative charges on compound 75. This gives compound 75 a net negative one charge. Compound 76 differs from 70 in that the internal amino modified thymidine is replaced by an internal cytosine phosphonate. The pK_a of the N3 nitrogen of cytosine can be from 4 to 7. Thus, the net charges of this compound, can be from −1 to 0 depending on the pH of the solution. For the simplicity of analysis, each group is assigned a whole number of charges, although it is realized that, depending on the pK_a of each chemical group and ambient pH, a real charge may differ from the whole number assigned. It is assumed that this difference is not significant over the range of pHs used in the enzymatic reactions studied here.

[0882] Dephosphorylation of these compounds, or the removal of the 3' end terminal phosphoryl group, results in elimination of two negative charges and generates products that have a net positive charge of one. In this experiment, the method of isoelectric focusing (IEF) was used to demonstrate a change from one negative to one positive net charge for the described substrates during dephosphorylation.

[0883] Substrates 70, 74, 75 and 76 were synthesized by standard phosphoramidite chemistries and deprotected for 24 hours at 22° C. in 14 M aqueous ammonium hydroxide solution, after which the solvent was removed in vacuo. The dried powders were resuspended in 200 μl of H_2O and filtered through 0.2 μm filters. The concentration of the stock solutions was estimated by UV-absorbance at 261 nm of samples diluted 200-fold in H_2O using a spectrophotometer (Spectronic Genesys 2, Milton Roy, Rochester, N.Y.).

[0884] Dephosphorylation of compounds 70 and 74, 75 and 76 was accomplished by treating 10 μl of the crude stock solutions (ranging in concentration from approximately 0.5 to 2 mM) with 2 units of CIAP in 100 μl of CIAP buffer (Promega) at 37° C. for 1 hour. The reactions were then heated to 75° C. for 15 min. in order to inactivate the CIAP. For clarity, dephosphorylated compounds are designated 'dp'. For example, after dephosphorylation, substrate 70 becomes 70dp.

[0885] To prepare samples for IEF experiments, the concentration of the stock solutions of substrate and dephosphorylated product were adjusted to a uniform absorbance of

8.5×10^{-3} at 532 nm by dilution with water. Two microliters of each sample were analyzed by IEF using a PhastSystem electrophoresis unit (Pharmacia) and PhastGel IEF 3-9 media (Pharmacia) according to the manufacturer's protocol. Separation was performed at 15° C. with the following program: pre-run; 2,000 V, 2.5 mA, 3.5 W, 75 Vh; load; 200 V, 2.5 mA, 3.5 W, 15 Vh; run; 2,000 V; 2.5 mA; 3.5 W, 130 Vh. After separation, samples were visualized by using the FMBIO Image Analyzer (Hitachi) fitted with a 585 nm filter. The resulting imager scan is shown in FIG. **48**.

[**0886**] FIG. **48** shows results of IEF separation of substrates 70, 74, 75 and 76 and their dephosphorylated products. The arrow labeled "Sample Loading Position" indicates a loading line, the '+' sign shows the position of the positive electrode and the '−' sign indicates the position of the negative electrode.

[**0887**] The results shown in FIG. **48** demonstrate that substrates 70, 74, 75 and 76 migrated toward the positive electrode, while the dephosphorylated products 70dp, 74dp, 75dp and 76dp migrated toward negative electrode. The observed differences in mobility direction was in accord with predicted net charge of the substrates (minus one) and the products (plus one). Small perturbations in the mobilities of the phosphorylated compounds indicate that the overall pIs vary. This was also true for the dephosphorylated compounds. The presence of the cytosine in 76dp, for instance, moved this compound further toward the negative electrode, which was indicative of a higher overall pI relative to the other dephosphorylated compounds. It is important to note that additional positive charges can be obtained by using a combination of natural amino modified bases (70dp and 74dp) along with uncharged methylphosphonate bridges (products 75dp and 76dp).

[**0888**] The results shown above demonstrate that the removal of a single phosphate group can flip the net charge of an oligonucleotide to cause reversal in an electric field, allowing easy separation of products, and that the precise base composition of the oligonucleotides affect absolute mobility but not the charge-flipping effect.

Example 23

Detection of Specific Cleavage Products in the INVADER-Directed Cleavage Reaction by Charge Reversal

[**0889**] In this Example the ability to isolate products generated in the INVADER-directed cleavage assay from all other nucleic acids present in the reaction cocktail was demonstrated using charge reversal. This experiment utilized the following Cy3-labeled oligonucleotide: 5'-Cy3-AminoT-AminoT-CTTTTCACCAGCGAGACGGG-3' (SEQ ID NO:50; termed "oligo 61"). Oligo 61 was designed to release upon cleavage a net positively charged labeled product. To test whether or not a net positively charged 5'-end labeled product would be recognized by the CLEAVASE enzymes in the INVADER-directed cleavage assay format, probe oligo 61 (SEQ ID NO:50) and invading oligonucleotide 67 (SEQ ID NO:51) were chemically synthesized on a DNA synthesizer (ABI 391) using standard phosphoramidite chemistries and reagents obtained from Glen Research (Sterling, Va.).

[**0890**] Each assay reaction comprised 100 fmoles of M13mp18 single stranded DNA, 10 pmoles each of the probe (SEQ ID NO:50) and INVADER (SEQ ID NO:51) oligonucleotides, and 20 units of CLEAVASE A/G in a 10 μl solution of 10 mM MOPS, pH 7.4 with 100 mM KCl. Samples were overlaid with mineral oil to prevent evaporation. The samples were brought to either 50° C., 55° C., 60° C., or 65° C. and cleavage was initiated by the addition of 1 μl of 40 mM $MnCl_2$. Reactions were allowed to proceed for 25 minutes and then were terminated by the addition of 10 μl of 95% formamide containing 20 mM EDTA and 0.02% methyl violet. The negative control experiment lacked the target M13mp18 and was run at 60° C. Five microliters of each reaction were loaded into separate wells of a 20% denaturing polyacrylamide gel (cross-linked 29:1) with 8 M urea in a buffer containing 45 mM Tris-Borate (pH 8.3) and 1.4 mM EDTA. An electric field of 20 watts was applied for 30 minutes, with the electrodes oriented as indicated in FIG. **49**B (i.e., in reverse orientation). The products of these reactions were visualized using the FMBIO fluorescence imager and the resulting imager scan is shown in FIG. **49**B.

[**0891**] FIG. **49**A provides a schematic illustration showing an alignment of the INVADER (SEQ ID NO:50) and probe (SEQ ID NO:51) along the target M13mp18 DNA; only 53 bases of the M13mp18 sequence is shown (SEQ ID NO:52). The sequence of the INVADER oligonucleotide is displayed under the M13mp18 target and an arrow is used above the M13mp18 sequence to indicate the position of the INVADER relative to the probe and target. As shown in FIG. **49**A, the INVADER and probe oligonucleotides share a 2 base region of overlap.

[**0892**] In FIG. **49**B, lanes 1-6 contain reactions performed at 50° C., 55° C., 60° C., and 65° C., respectively; lane 5 contained the control reaction (lacking target). In FIG. **49**B, the products of cleavage are seen as dark bands in the upper half of the panel; the faint lower band seen appears in proportion to the amount of primary product produced and, while not limiting the invention to a particular mechanism, may represent cleavage one nucleotide into the duplex. The uncleaved probe does not enter the gel and is thus not visible. The control lane showed no detectable signal over background (lane 5). As expected in an invasive cleavage reaction, the rate of accumulation of specific cleavage product was temperature-dependent. Using these particular oligonucleotides and target, the fastest rate of accumulation of product was observed at 55° C. (lane 2) and very little product observed at 65° C. (lane 4).

[**0893**] When incubated for extended periods at high temperature, DNA probes can break non-specifically (i.e., suffer thermal degradation) and the resulting fragments contribute an interfering background to the analysis. The products of such thermal breakdown are distributed from single-nucleotides up to the full length probe. In this experiment, the ability of charge based separation of cleavage products (i.e., charge reversal) would allow the sensitive separation of the specific products of target-dependent cleavage from probe fragments generated by thermal degradation was examined.

[**0894**] To test the sensitivity limit of this detection method, the target M13mp18 DNA was serially diluted ten fold over than range of 1 fmole to 1 amole. The INVADER and probe oligonucleotides were those described above (i.e., SEQ ID NOS:50 and 51). The invasive cleavage reactions were run as described above with the following modifica-

tions: the reactions were performed at 55° C., 250 mM or 100 mM KGlu was used in place of the 100 mM KCl and only 1 pmole of the INVADER oligonucleotide was added. The reactions were initiated as described above and allowed to progress for 12.5 hours. A negative control reaction that lacked added M13 m18 target DNA was also run. The reactions were terminated by the addition of 10 μl of 95% formamide containing 20 mM EDTA and 0.02% methyl violet, and 5 μl of these mixtures were electrophoresed and visualized as described above. The resulting imager scan is shown in FIG. **50**.

[**0895**] In FIG. **50**, lane 1 contains the negative control; lanes 2-5 contain reactions performed using 100 mM KGlu; lanes 6-9 contain reactions performed using 250 mM KGlu. The reactions resolved in lanes 2 and 6 contained 1 fmole of target DNA; those in lanes 3 and 7 contained 100 amole of target; those in lanes 4 and 8 contained 10 amole of target and those in lanes 5 and 9 contained 1 amole of target. The results shown in FIG. **50** demonstrate that the detection limit using charge reversal to detect the production of specific cleavage products in an invasive cleavage reaction is at or below 1 attomole or approximately 6.02×10^5 target molecules. No detectable signal was observed in the control lane, which indicates that non-specific hydrolysis or other breakdown products do not migrate in the same direction as enzyme-specific cleavage products. The excitation and emission maxima for Cy3 are 554 and 568, respectively, while the FMBIO Imager Analyzer excites at 532 and detects at 585. Therefore, the limit of detection of specific cleavage products can be improved by the use of more closely matched excitation source and detection filters.

Example 24

Devices and Methods for the Separation and Detection of Charged Reaction Products

[**0896**] This Example is directed at methods and devices for isolating and concentrating specific reaction products produced by enzymatic reactions conducted in solution whereby the reactions generate charged products from either a charge neutral substrate or a substrate bearing the opposite charge borne by the specific reaction product. The methods and devices of this Example allow isolation of, for example, the products generated by the INVADER-directed cleavage assay of the present invention.

[**0897**] The methods and devices of this Example are based on the principle that when an electric field is applied to a solution of charged molecules, the migration of the molecules toward the electrode of the opposite charge occurs very rapidly. If a matrix or other inhibitory material is introduced between the charged molecules and the electrode of opposite charge such that this rapid migration is dramatically slowed, the first molecules to reach the matrix will be nearly stopped, thus allowing the lagging molecules to catch up. In this way a dispersed population of charged molecules in solution can be effectively concentrated into a smaller volume. By tagging the molecules with a detectable moiety (e.g., a fluorescent dye), detection is facilitated by both the concentration and the localization of the analytes. This Example illustrates two embodiments of devices contemplated by the present invention; of course, variations of these devices will be apparent to those skilled in the art and are within the spirit and scope of the present invention.

[**0898**] FIG. **51** depicts one embodiment of a device for concentrating the positively-charged products generated using the methods of the present invention. As shown in FIG. **51**, the device comprises a reaction tube (**10**) that contains the reaction solution (**11**). One end of each of two thin capillaries (or other tubes with a hollow core) (**13**A and **13**B) are submerged in the reaction solution (**11**). The capillaries (**13**A and **13**B) may be suspended in the reaction solution (**11**) such that they are not in contact with the reaction tube itself; one appropriate method of suspending the capillaries is to hold them in place with clamps (not shown). Alternatively, the capillaries may be suspended in the reaction solution (**11**) such that they are in contact with the reaction tube itself. Suitable capillaries include glass capillary tubes commonly available from scientific supply companies (e.g., Fisher Scientific or VWR Scientific) or from medical supply houses that carry materials for blood drawing and analysis. Though the present invention is not limited to capillaries of any particular inner diameter, tubes with inner diameters of up to about ⅛ inch (approximately 3 mm) are particularly preferred for use with the present invention; for example, Kimble No. 73811-99 tubes (VWR Scientific) have an inner diameter of 1.1 mm and are a suitable type of capillary tube. Although the capillaries of the device are commonly composed of glass, any nonconductive tubular material, either rigid or flexible, that can contain either a conductive material or a trapping material is suitable for use in the present invention. One example of a suitable flexible tube is Tygon® clear plastic tubing (Part No. R3603; inner diameter=1/16 inch; outer diameter=⅛ inch).

[**0899**] As illustrated in FIG. **51**, capillary **13**A is connected to the positive electrode of a power supply (**20**) (e.g., a controllable power supply available through the laboratory suppliers listed above or through electronics supply houses like Radio Shack) and capillary **13**B is connected to the negative electrode of the power supply (**20**). Capillary **13**B is filled with a trapping material (**14**) capable of trapping the positively-charged reaction products by allowing minimal migration of products that have entered the trapping material (**14**). Suitable trapping materials include, but are not limited to, high percentage (e.g., about 20%) acrylamide polymerized in a high salt buffer (0.5 M or higher sodium acetate or similar salt); such a high percentage polyacrylamide matrix dramatically slows the migration of the positively-charged reaction products. Alternatively, the trapping material may comprise a solid, negatively-charged matrix, such as negatively-charged latex beads, that can bind the incoming positively-charged products. It should be noted that any amount of trapping material (**14**) capable of inhibiting any concentrating the positively-charged reaction products may be used. Thus, while the capillary **13**B in FIG. **51** only contains trapping material in the lower, submerged portion of the tube, the trapping material (**14**) can be present in the entire capillary (**13**B); similarly, less trapping material (**14**) could be present than that shown in FIG. **51** because the positively-charged reaction products generally accumulate within a very small portion of the bottom of the capillary (**13**B). The amount of trapping material need only be sufficient to make contact with the reaction solution (**11**) and have the capacity to collect the reaction products. When capillary **13**B is not completely filled with the trapping

material, the remaining space is filled with any conductive material (**15**); suitable conductive materials are discussed below.

[**0900**] By comparison, the capillary (**13**A) connected to the positive electrode of the power supply **20** may be filled with any conductive material (**15**; indicated by the hatched lines in FIG. **51**). This may be the sample reaction buffer (e.g., 10 mM MOPS, pH 7.5 with 150 mM LiCl, 4 mM $MnCl_2$), a standard electrophoresis buffer (e.g., 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA), or the reaction solution (**11**) itself. The conductive material (**15**) is frequently a liquid, but a semi-solid material (e.g., a gel) or other suitable material might be easier to use and is within the scope of the present invention. Moreover, that trapping material used in the other capillary (i.e., capillary **13**B) may also be used as the conductive material. Conversely, it should be noted that the same conductive material used in the capillary (**13**A) attached to the positive electrode may also be used in capillary **13**B to fill the space above the region containing the trapping material (**14**) (see FIG. **51**).

[**0901**] The top end of each of the capillaries (**13**A and **13**B) is connected to the appropriate electrode of the power supply (**20**) by electrode wire (18) or other suitable material. Fine platinum wire (e.g., 0.1 to 0.4 mm, Aesar Johnson Matthey, Ward Hill, Mass.) is commonly used as conductive wire because it does not corrode under electrophoresis conditions. The electrode wire (**18**) can be attached to the capillaries (**13**A and **13**B) by a nonconductive adhesive (not shown), such as the silicone adhesives that are commonly sold in hardware stores for sealing plumbing fixtures. If the capillaries are constructed of a flexible material, the electrode wire (**18**) can be secured with a small hose clamp or constricting wire (not shown) to compress the opening of the capillaries around the electrode wire. If the conducting material (**15**) is a gel, an electrode wire (**18**) can be embedded directly in the gel within the capillary.

[**0902**] The cleavage reaction is assembled in the reaction tube (**10**) and allowed to proceed therein as described in proceeding Examples (e.g., Examples 22-23). Though not limited to any particular volume of reaction solution (**11**), a preferred volume is less than 10 ml and more preferably less than 0.1 ml. The volume need only be sufficient to permit contact with both capillaries. After the cleavage reaction is completed, an electric field is applied to the capillaries by turning on the power source (**20**). As a result, the positively-charged products generated in the course of the INVADER-directed cleavage reaction that employs an oligonucleotide, which when cleaved, generates a positively charged fragment (described in Ex. 23) but when uncleaved bears a net negative charge, migrate to the negative capillary, where their migration is slowed or stopped by the trapping material (**14**), and the negatively-charged uncut and thermally degraded probe molecules migrate toward the positive electrode. Through the use of this or a similar device, the positively-charged products of the invasive cleavage reaction are separated from the other material (i.e., uncut and thermally degraded probe) and concentrated from a large volume. Concentration of the product in a small amount of trapping material (**14**) allows for simplicity of detection, with a much higher signal-to-noise ratio than possible with detection in the original reaction volume. Because the concentrated product is labeled with a detectable moiety like a fluorescent dye, a commercially-available fluorescent plate reader (not shown) can be used to ascertain the amount of product. Suitable plate readers include both top and bottom laser readers. Capillary **13**B can be positioned with the reaction tube (**10**) at any desired position so as to accommodate use with either a top or a bottom plate reading device.

[**0903**] In the alternative embodiment of the present invention depicted in FIG. **52**, the procedure described above is accomplished by utilizing only a single capillary (**13**B). The capillary (**13**B) contains the trapping material (**14**) described above and is connected to an electrode wire (**18**), which in turn is attached to the negative electrode of a power supply (**20**). The reaction tube (**10**) has an electrode (**25**) embedded into its surface such that one surface of the electrode is exposed to the interior of the reaction tube (**10**) and another surface is exposed to the exterior of the reaction tube. The surface of the electrode (**25**) on the exterior of the reaction tube is in contact with a conductive surface (**26**) connected to the positive electrode of the power supply (**20**) through an electrode wire (**18**). Variations of the arrangement depicted in FIG. **52** are also contemplated by the present invention. For example, the electrode (**25**) may be in contact with the reaction solution (**11**) through the use of a small hole in the reaction tube (**10**); furthermore, the electrode wire (**18**) can be directly attached to the electrode wire (**18**), thereby eliminating the conductive surface (**26**).

[**0904**] As indicated in FIG. **52**, the electrode (**25**) is embedded in the bottom of a reaction tube (**10**) such that one or more reaction tubes may be set on the conductive surface (**26**). This conductive surface could serve as a negative electrode for multiple reaction tubes; such a surface with appropriate contacts could be applied through the use of metal foils (e.g., copper or platinum, Aesar Johnson Matthey, Ward Hill, Mass.) in much the same way contacts are applied to circuit boards. Because such a surface contact would not be exposed to the reaction sample directly, less expensive metals, such as the copper could be used to make the electrical connections.

[**0905**] The above devices and methods are not limited to separation and concentration of positively charged oligonucleotides. As will be apparent to those skilled in the art, negatively charged reaction products may be separated from neutral or positively charged reactants using the above device and methods with the exception that capillary **13**B is attached to the positive electrode of the power supply (**20**) and capillary **13**A or alternatively, electrode **25**, is attached to the negative electrode of the power supply (**20**).

Example 25

Primer-Directed and Primer Independent Cleavage Occur at the Same Site when the Primer Extends to the 3' Side of a Mismatched "Bubble" in the Downstream Duplex

[**0906**] As discussed above in Example 1, the presence of a primer upstream of a bifurcated duplex can influence the site of cleavage, and the existence of a gap between the 3' end of the primer and the base of the duplex can cause a shift of the cleavage site up the unpaired 5' arm of the structure (see also Lyamichev et al., supra and U.S. Pat. No. 5,422,253). The resulting non-invasive shift of the cleavage site in response to a primer is demonstrated in FIGS. **8**, **9** and **10**,

in which the primer used left a 4-nucleotide gap (relative to the base of the duplex). In FIGS. **8-10**, all of the "primer-directed" cleavage reactions yielded a 21 nucleotide product, while the primer-independent cleavage reactions yielded a 25 nucleotide product. The site of cleavage obtained when the primer was extended to the base of the duplex, leaving no gap was examined. The results are shown in FIG. **53** (FIG. **53** is a reproduction of FIG. **2**C in Lyamichev et al. These data were derived from the cleavage of the structure shown in FIG. **5**, as described in Example 1. Unless otherwise specified, the cleavage reactions comprised 0.01 pmoles of heat-denatured, end-labeled hairpin DNA (with the unlabeled complementary strand also present), 1 pmole primer (complementary to the 3' arm shown in FIG. **5** and having the sequence: 5'-GAATTC-GATTTAGGTGACAC TATAGAATACA [SEQ ID NO:53]) and 0.5 units of DNAPTaq (estimated to be 0.026 pmoles) in a total volume of 10 μl of 10 mM Tris-Cl, pH 8.5, and 1.5 mM $MgCl_2$ and 50 mM KCl. The primer was omitted from the reaction shown in the first lane of FIG. **53** and included in lane 2. These reactions were incubated at 55° C. for 10 minutes. Reactions were initiated at the final reaction temperature by the addition of either the $MgCl_2$ or enzyme. Reactions were stopped at their incubation temperatures by the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes.

[**0907**] FIG. **53** is an autoradiogram that indicates the effects on the site of cleavage of a bifurcated duplex structure in the presence of a primer that extends to the base of the hairpin duplex. The size of the released cleavage product is shown to the left (i.e., 25 nucleotides). A dideoxynucleotide sequencing ladder of the cleavage substrate is shown on the right as a marker (lanes 3-6).

[**0908**] These data show that the presence of a primer that is adjacent to a downstream duplex (lane 2) produces cleavage at the same site as seen in reactions performed in the absence of the primer (lane 1). (See FIGS. **8**A and B, **9**B and **10**A for additional comparisons). When the 3' terminal nucleotides of the upstream oligonucleotide can base pair to the template strand but are not homologous to the displaced strand in the region immediately upstream of the cleavage site (i.e., when the upstream oligonucleotide is opening up a "bubble" in the duplex), the site to which cleavage is apparently shifted is not wholly dependent on the presence of an upstream oligonucleotide.

[**0909**] As discussed above in the Background, and in Table 1, the requirement that two independent sequences be recognized in an assay provides a highly desirable level of specificity. In the invasive cleavage reactions of the present invention, the INVADER and probe oligonucleotides must hybridize to the target nucleic acid with the correct orientation and spacing to enable the production of the correct cleavage product. When the distinctive pattern of cleavage is not dependent on the successful alignment of both oligonucleotides in the detection system these advantages of independent recognition are lost.

Example 26

Invasive Cleavage and Primer-Directed Cleavage when there is Only Partial Homology in the "X" Overlap Region

[**0910**] While not limiting the present invention to any particular mechanism, invasive cleavage occurs when the site of cleavage is shifted to a site within the duplex formed between the probe and the target nucleic acid in a manner that is dependent on the presence of an upstream oligonucleotide that shares a region of overlap with the downstream probe oligonucleotide. In some instances, the 5' region of the downstream oligonucleotide may not be completely complementary to the target nucleic acid. In these instances, cleavage of the probe may occur at an internal site within the probe even in the absence of an upstream oligonucleotide (in contrast to the base-by-base nibbling seen when a fully paired probe is used without an INVADER). Invasive cleavage is characterized by an apparent shifting of cleavage to a site within a downstream duplex that is dependent on the presence of the INVADER oligonucleotide.

[**0911**] A comparison between invasive cleavage and primer-directed cleavage may be illustrated by comparing the expected cleavage sites of a set of probe oligonucleotides having decreasing degrees of complementarity to the target strand in the 5' region of the probe (i.e., the region that overlaps with the INVADER). A simple test, similar to that performed on the hairpin substrate above (Ex. 25), can be performed to compare invasive cleavage with the non-invasive primer-directed cleavage described above. Such a set of test oligonucleotides is diagrammed in FIG. **54**. The structures shown in FIG. **54** are grouped in pairs, labeled "a", "b", "c", and "d". Each pair has the same probe sequence annealed to the target strand (SEQ ID NO:54), but the top structure of each pair is drawn without an upstream oligonucleotide, while the bottom structure includes this oligonucleotide (SEQ ID NO:55). The sequences of the probes shown in FIGS. **54***a*-**54***d* are listed in SEQ ID NOS:32, 56, 57 and 58, respectively. Probable sites of cleavage are indicated by the black arrowheads. (It is noted that the precise site of cleavage on each of these structures may vary depending on the choice of cleavage agent and other experimental variables. These particular sites are provided for illustrative purposes only.)

[**0912**] To conduct this test, the site of cleavage of each probe is determined both in the presence and the absence of the upstream oligonucleotide, in reaction conditions such as those described in Example 18. The products of each pair of reactions are then be compared to determine whether the fragment released from the 5' end of the probe increases in size when the upstream oligonucleotide is included in the reaction.

[**0913**] The arrangement shown in FIG. **54***a*, in which the probe molecule is completely complementary to the target strand, is similar to that shown in FIG. **28**. Treatment of the top structure with the 5' nuclease of a DNA polymerase would cause exonucleolytic nibbling of the probe (i.e., in the absence of the upstream oligonucleotide). In contrast, inclusion of an INVADER oligonucleotide would cause a distinctive cleavage shift similar, to those observed in FIG. **29**.

[**0914**] The arrangements shown in FIGS. **54***b* and **54***c* have some amount of unpaired sequence at the 5' terminus of the probe (3 and 5 bases, respectively). These small 5' arms are suitable cleavage substrate for the 5' nucleases and would be cleaved within 2 nucleotide's of the junction between the single stranded region and the duplex. In these arrangements, the 3' end of the upstream oligonucleotide shares identity with a portion of the 5' region of the probe that is complementary to the target sequence (that is the 3'

end of the INVADER has to compete for binding to the target with a portion of the 5' end of the probe). Therefore, when the upstream oligonucleotide is included it is thought to mediate a shift in the site of cleavage into the downstream duplex (although the present invention is not limited to any particular mechanism of action), and this would, therefore, constitute invasive cleavage. If the extreme 5' nucleotides of the unpaired region of the probe were able to hybridize to the target strand, the cleavage site in the absence of the INVADER might change but the addition of the INVADER oligonucleotide would still shift the cleavage site to the proper position.

[0915] Finally, in the arrangement shown in FIG. **54***d*, the probe and upstream oligonucleotides share no significant regions of homology, and the presence of the upstream oligonucleotide would not compete for binding to the target with the probe. Cleavage of the structures shown in FIG. **54***d* would occur at the same site with or without the upstream oligonucleotide, and is thus would not constitute invasive cleavage.

[0916] By examining any upstream oligonucleotide/probe pair in this way, it can easily be determined whether the resulting cleavage is invasive or merely primer-directed. Such analysis is particularly useful when the probe is not fully complementary to the target nucleic acid, so that the expected result may not be obvious by simple inspection of the sequences.

Example 27

Modified CLEAVASE Enzymes

[0917] In order to develop nucleases having useful activities for the cleavage of nucleic acids the following modified nucleases were produced.

[0918] a) CLEAVASE BN/thrombin Nuclease

[0919] i) Cloning and Expression of CLEAVASE BN/Thrombin Nuclease

[0920] Site directed mutagenesis was used to introduce a protein sequence recognized by the protease thrombin into the region of the CLEAVASE BN nuclease that is thought to form the helical arch of the protein through which the single-stranded DNA that is cleaved must presumably pass. Mutagenesis was carried out using the Transformer™ mutagenesis kit (Clonetech, Palo Alto, Calif.) according to manufacturer's protocol using the mutagenic oligonucleotide 5'-GGGAAAGTCCTCGCAGCCGCGCGGGACGAGCGTGGGGGCCCG (SEQ ID NO:59). After mutagenesis, the DNA was sequenced to verify the insertion of the thrombin cleavage site. The DNA sequence encoding the CLEAVASE BN/thrombin nuclease is provided in SEQ ID NO:60; the amino acid sequence of CLEAVASE BN/thrombin nuclease is provided in SEQ ID NO:61.

[0921] A large scale preparation of the thrombin mutant (i.e., CLEAVASE BN/thrombin) was done using *E. coli* cells overexpressing the CLEAVASE BN/thrombin nuclease as described in Example 28.

[0922] ii) Thrombin Cleavage of CLEAVASE BN/Thrombin

[0923] Six point four (6.4) mg of the purified CLEAVASE BN/thrombin nuclease was digested with 0.4 U of thrombin (Novagen) for 4 hours at 23° C. or 37° C. Complete digestion was verified by electrophoresis on a 15% SDS polyacrylamide gel followed by staining with Coomassie Brilliant Blue R. Wild-type CLEAVASE BN nuclease was also digested with thrombin as a control. The resulting gel is shown in FIG. **61**.

[0924] In FIG. **61**, lane 1 contains molecular weight markers (Low-Range Protein Molecular Weight Markers; Promega), lane 2 contains undigested CLEAVASE BN/thrombin nuclease, lanes 3 and 4 contain CLEAVASE BN/thrombin nuclease digested with thrombin at 23° C. for 2 and 4 hours, respectively, and lanes 5 and 6 contain CLEAVASE BN/thrombin nuclease digested with thrombin at 37° C. for 2 and 4 hours, respectively. These results show that the CLEAVASE BN/thrombin nuclease has an apparent molecular weight of 36.5 kilodaltons and demonstrate that CLEAVASE BN/thrombin nuclease is efficiently cleaved by thrombin. In addition, the thrombin cleavage products have approximate molecular weights of 27 kilodaltons and 9 kilodaltons, the size expected based upon the position of the inserted thrombin site in the CLEAVASE BN/thrombin nuclease.

[0925] To determine the level of hairpin cleavage activity in digested and undigested CLEAVASE BN/thrombin nuclease, dilutions were made and used to cleave a test hairpin containing a 5' fluoroscein label. Varying amounts of digested and undigested CLEAVASE BN/thrombin nuclease were incubated with 5 μM oligonucleotide S-60 hairpin (SEQ ID NO:29; see FIG. **26**) in 10 mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40, and 1 mM $MnCl_2$ for 5 minutes at 60° C. The digested mixture was electrophoresed on a 20% acrylamide gel and visualized on a Hitachi FMBIO 100 fluoroimager. The resulting image is shown in FIG. **62**.

[0926] In FIG. **62**, lane 1 contains the no enzyme control, lane 2 contains reaction products produced using 0.01 ng of CLEAVASE BN nuclease, lanes 3, 4, and 5 contain reaction products produced using 0.01 ng, 0.04 ng, and 4 ng of undigested CLEAVASE BN/thrombin nuclease, respectively, and lanes 6, 7, and 8 contain reaction products produced using 0.01 ng, 0.04 ng, and 4 ng of thrombin-digested CLEAVASE BN/thrombin nuclease, respectively. The results shown in FIG. **62** demonstrated that the insertion of the thrombin cleavage site reduced cleavage activity about 200-fold (relative to the activity of CLEAVASE BN nuclease), but that digestion with thrombin did not reduce the activity significantly.

[0927] M13 single-stranded DNA was used as a substrate for cleavage by CLEAVASE BN nuclease and digested and undigested CLEAVASE BN/thrombin nuclease. Seventy nanograms of single-stranded M13 DNA (NEB) was incubated in 10 mM MOPS, pH 7.5, 0.05% Tween-20, 0.05% NP-40, 1 mM $MgCl_2$ or 1 mM $MnCl_2$, with 8 ng of CLEAVASE BN nuclease, undigested CLEAVASE BN/thrombin nuclease, or digested CLEAVASE BN/thrombin nuclease for 10 minutes at 50° C. Reaction mixtures were electrophoresed on a 0.8% agarose gel and then stained with a solution containing 0.5 μg/ml ethidium bromide (EtBr) to visualize DNA bands. A negative image of the EtBr-stained gel is shown in FIG. **63**.

[0928] In FIG. **63**, lane 1 contains the no enzyme control, lane 2 contains reaction products produced using CLEAVASE BN nuclease and 1 mM $MgCl_2$, lane 3 contains

reaction products produced using CLEAVASE BN nuclease and 1 mM $MnCl_2$, lane 4 contains reaction products produced using undigested CLEAVASE BN/thrombin nuclease and 1 mM $MgCl_2$, lane 5 contains reaction products produced using undigested CLEAVASE BN/thrombin nuclease and 1 mM $MnCl_2$, lane 6 contains reaction products produced using thrombin-digested CLEAVASE BN/thrombin nuclease and 1 mM $MgCl_2$, and lane 7 contains reaction products produced using thrombin-digested CLEAVASE BN/thrombin nuclease and 1 mM $MnCl_2$. The results shown in FIG. **63** demonstrated that the CLEAVASE BN/thrombin nuclease had an enhanced ability to cleave circular DNA (and thus a reduced requirement for the presence of a free 5' end) as compared to the CLEAVASE BN nuclease.

[**0929**] It can be seen from these data that the helical arch of these proteins can be opened without destroying the enzyme or its ability to specifically recognize cleavage structures. The CLEAVASE BN/thrombin mutant has an increased ability to cleave without reference to a 5' end, as discussed above. The ability to cleave such structures will allow the cleavage of long molecules, such as genomic DNA that, while often not circular, may present many desirable cleavage sites that are at a far removed from any available 5' end. Cleavage structures may be made at such sites either by folding of the strands (i.e., CFLP® cleavage) or by the introduction of structure-forming oligonucleotides (U.S. Pat. No. 5,422,253). 5' ends of nucleic acids can also be made unavailable because of binding of a substance too large to thread through the helical arch. Such binding moieties may include proteins such as streptavidin or antibodies, or solid supports such as beads or the walls of a reaction vessel. A cleavage enzyme with an opening in the loop of the helical arch will be able to cleave DNAs that are configured in this way, extending the number of ways in which reactions using such enzymes can be formatted.

[**0930**] b) CLEAVASE DN Nuclease

[**0931**] i) Construction and Expression of CLEAVASE DN Nuclease

[**0932**] A polymerization deficient mutant of Taq DNA polymerase, termed CLEAVASE DN nuclease, was constructed. CLEAVASE DN nuclease contains an asparagine residue in place of the wild-type aspartic acid residue at position 785 (D785N).

[**0933**] DNA encoding the CLEAVASE DN nuclease was constructed from the gene encoding for CLEAVASE A/G (mutTaq, Ex. 2) in two rounds of site-directed mutagenesis. First, the G at position 1397 and the G at position 2264 of the CLEAVASE A/G gene (SEQ ID NO:21) were changed to A at each position to recreate a wild-type DNAPTaq gene. As a second round of mutagenesis, the wild type DNAPTaq gene was converted to the CLEAVASE DN gene by changing the G at position 2356 to A. These manipulations were performed as follows.

[**0934**] DNA encoding the CLEAVASE A/G nuclease was recloned from pTTQ18 plasmid (Ex. 2) into the pTrc99A plasmid (Pharmacia) in a two step procedure. First, the pTrc99A vector was modified by removing the G at position 270 of the pTrc99A map, creating the pTrc99G cloning vector. To this end, pTrc99A plasmid DNA was cut with NcoI and the recessive 3' ends were filled-in using the Klenow fragment of *E. coli* polymerase I in the presence of all four dNTPs at 37° C. for 15 min. After inactivation of the Klenow fragment by incubation at 65° C. for 10 min, the plasmid DNA was cut with EcoRI, the ends were again filled-in using the Klenow fragment in the presence of all four dNTPs at 37° C. for 15 min. The Klenow fragment was then inactivated by incubation at 65° C. for 10 min. The plasmid DNA was ethanol precipitated, recircularized by ligation, and used to transform *E. coli* JM109 cells (Promega). Plasmid DNA was isolated from single colonies and deletion of the G at position 270 of the pTrc99A map was confirmed by DNA sequencing.

[**0935**] As a second step, DNA encoding the CLEAVASE A/G nuclease was removed from the pTTQ18 plasmid using EcoRI and SalI and the DNA fragment carrying the CLEAVASE A/G nuclease gene was separated on a 1% agarose gel and isolated with Geneclean II Kit (Bio 101, Vista, Calif.). The purified fragment was ligated into the pTrc99G vector, which had been cut with EcoRI and SalI. The ligation mixture was used to transform competent *E. coli* JM109 cells (Promega). Plasmid DNA was isolated from single colonies and insertion of the CLEAVASE A/G nuclease gene was confirmed by restriction analysis using EcoRI and SalI.

[**0936**] Plasmid DNA pTrcAG carrying the CLEAVASE A/G nuclease gene cloned into the pTrc99A vector was purified from 200 ml of JM109 overnight culture using QIAGEN Plasmid Maxi kit (QIAGEN, Chatsworth, Calif.) according to manufacturer's protocol. pTrcAG plasmid DNA was mutagenized using two mutagenic primers, E465 (SEQ ID NO:62) (Integrated DNA Technologies, Iowa) and R754Q (SEQ ID NO:63) (Integrated DNA Technologies), and the selection primer Trans Oligo AlwNI/SpeI (Clontech, Palo Alto, Calif., catalog #6488-1) according to Transformer™ Site-Directed Mutagenesis Kit protocol (Clontech) to produce a restored wild-type DNAPTaq gene (pTrcWT).

[**0937**] pTrcWT plasmid DNA carrying the wild-type DNAPTaq gene cloned into the pTrc99A vector was purified from 200 ml of JM109 overnight culture using QIAGEN Plasmid Maxi kit (QIAGEN, Chatsworth, Calif.) according to manufacturer's protocol. pTrcWT was then mutagenized using the mutagenic primer D785N (SEQ ID NO:64) (Integrated DNA Technologies) and the selection primer Switch Oligo SpeI/AlwNI (Clontech, catalog #6373-1) according to Transformer™ Site-Directed Mutagenesis Kit protocol (Clontech) to create a plasmid containing DNA encoding the CLEAVASE DN nuclease. The DNA sequence encoding the CLEAVASE DN nuclease is provided in SEQ ID NO:65; the amino acid sequence of CLEAVASE DN nuclease is provided in SEQ ID NO:66.

[**0938**] A large scale preparation of the CLEAVASE DN nuclease was done using *E. coli* cells overexpressing the CLEAVASE DN nuclease as described in Example 28.

[**0939**] c) CLEAVASE DA Nuclease and CLEAVASE DV Nuclease

[**0940**] Two polymerization deficient mutants of Taq DNA polymerase, termed CLEAVASE DA nuclease and CLEAVASE DV nuclease, were constructed. The CLEAVASE DA nuclease contains a alanine residue in place of the wild-type aspartic acid residue at position 610 (D785A). The CLEAVASE DV nuclease contains a valine residue in place of the wild-type aspartic acid residue at position 610 (D610V).

[0941] i) Construction and Expression of the CLEAVASE DA and CLEAVASE DV Nucleases

[0942] To construct vectors encoding the CLEAVASE DA and DV nucleases, the CLEAVASE A/G nuclease gene contained within pTrcAG was mutagenized with two mutagenic primers, R754Q (SEQ ID NO:63) and D610AV (SEQ ID NO:67) and the selection primer Trans Oligo AlwNI/SpeI (Clontech, catalog #6488-1) according to the Transformer™ Site-Directed Mutagenesis Kit protocol (Clontech) to create a plasmid containing DNA encoding the CLEAVASE DA nuclease or CLEAVASE DV nuclease. The D610AV oligonucleotide was synthesized to have a purine, A or G, at position 10 from the 5' end of the oligonucleotide. Following mutagenesis, plasmid DNA was isolated from single colonies and the type of mutation present, DA or DV, was determined by DNA sequencing. The DNA sequence encoding the CLEAVASE DA nuclease is provided in SEQ ID NO:68; the amino acid sequence of CLEAVASE DA nuclease is provided in SEQ ID NO:69. The DNA sequence encoding the CLEAVASE DV nuclease is provided in SEQ ID NO:70; the amino acid sequence of CLEAVASE DV nuclease is provided in SEQ ID NO:71.

[0943] d) CLEAVASE Tth DN Nuclease

[0944] i) Construction and Expression of CLEAVASE TthDN Nuclease

[0945] The DNA polymerase enzyme from the bacterial species *Thermus thermophilus* (Tth) was produced by cloning the gene for this protein into an expression vector and overproducing it in *E. coli* cells. Genomic DNA was prepared from 1 vial of dried *Thermus thermophilus* strain HB-8 from ATCC (ATCC #27634) as described in Ex. 28a. The DNA polymerase gene was amplified by PCR as described in Ex. 27b using the following primers: 5'-CACGAATTCCGAGGCGATGCTTCCGCTC-3' (SEQ ID NO:254) and 5'-TCGACGTCGACTAACCCTTGGCGGAAAGCC-3' (SEQ ID NO:255), as described in Ex. 28a.

[0946] The resulting PCR product was digested with EcoR I and SalI restriction endonucleases and inserted into EcoRI/Sal I digested plasmid vector pTrc99 g (described in Example 27b) by ligation, as described in Example 27b, to create the plasmid pTrcTth-1. This Tth polymerase construct is missing a single nucleotide which was inadvertently omitted from the 5' oligonucleotide, resulting in the polymerase gene being out of frame. This mistake was corrected by mutagenesis of pTrcTth-1 as described in Example 27b using the following oligonucleotide: 5'-GCATCGCCTCGGAATTCATGGTC-3' (SEQ ID NO:256), to create the plasmid pTrcTth-2. The Tth DN construct was created by mutating the sequence encoding an aspartic acid at position 787 to a sequence encoding asparagine. Mutagenesis of pTrcTth-2 with the following oligonucleotide: 5'-CAGGAGGAGCTCGTTGTGGACCTGGA-3' (SEQ ID NO:257) as described in Example 27b, to create the plasmid pTrcTth-DN. The resulting polymerase-deficient nuclease, Cleavase® TthDN was expressed and purified as described in Ex. 28.

[0947] Large scale preparations of the CLEAVASE DA and CLEAVASE DV nucleases was done using *E. coli* cells overexpressing the CLEAVASE DA nuclease or the CLEAVASE DV nuclease as described in Example 28.

Example 28

Cloning and Expression of Thermostable FEN-1 Endonucleases

[0948] Sequences encoding thermostable FEN-1 proteins derived from several Archaebacterial species were cloned and overexpressed in *E. coli*. This Example involved a) cloning and expression of a FEN-1 endonuclease from *Methanococcus jannaschi*; b) cloning and expression of a FEN-1 endonuclease from *Pyrococcus furiosus*; c) cloning and expression of a FEN-1 endonuclease from *Pyrococcus woesei*; d) cloning and expression of a FEN-1 endonuclease from *Archaeoglobus fulgidus*; e) large scale preparation of recombinant thermostable FEN-1 proteins; and f) activity assays using FEN-1 endonucleases.

[0949] a) Cloning and Expression of a FEN-1 Endonuclease from *Methanococcus jannaschi*

[0950] DNA encoding the FEN-1 endonuclease from *Methanococcus jannaschi* (*M. jannaschi*) was isolated from *M. jannaschi* cells and inserted into a plasmid under the transcriptional control of an inducible promoter as follows. Genomic DNA was prepared from 1 vial of live *M. jannaschi* bacteria (DSMZ, Deutsche Sammlung von Mikroorganismen und Zellkulturen, Braunschweig, Germany # 2661) with the DNA XTRAX kit (Gull Laboratories, Salt Lake City, Utah) according to the manufacturer's protocol. The final DNA pellet was resuspended in 100 µl of TE (10 mM Tris HCl, pH 8.0, 1 mM EDTA). One microliter of the DNA solution was employed in a PCR using the Advantage™ cDNA PCR kit (Clonetech); the PCR was conducted according to manufacturer's recommendations. The 5'-end primer (SEQ ID NO:72) is complementary to the 5' end of the Mja FEN-1 open reading frame with a one base substitution to create an NcoI restriction site (a fragment of the *M. jannaschi* genome that contains the gene encoding *M. jannaschi* (Mja) FEN-1 is available from GenBank as accession # U67585). The 3'-end primer (SEQ ID NO:73) is complementary to a sequence about 15 base pairs downstream from the 3' end of the Mja FEN-1 open reading frame with 2 base substitutions to create a SalI restriction enzyme site. The sequences of the 5'-end and 3'-end primers are: 5'-GGGATACCA TGGGAGTGCAGTTTGG-3' (SEQ ID NO:72) and 5'-GGTAAATTTTTCTCGTCGA CATCCCAC-3' (SEQ ID NO:73), respectively. The PCR reaction resulted in the amplification (i.e., production) of a single major band about 1 kilobase in length. The open reading frame (ORF) encoding the Mja FEN-1 endonuclease is provided in SEQ ID NO:74; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:75.

[0951] Following the PCR amplification, the entire reaction was electrophoresed on a 1.0% agarose gel and the major band was excised from the gel and purified using the Geneclean II kit (Bio101, Vista, Calif.) according to manufacturer's instructions. Approximately 1 µg of the gel-purified Mja FEN-1 PCR product was digested with NcoI and SalI. After digestion, the DNA was purified using the Geneclean II kit according to manufacturer's instructions. One microgram of the pTrc99a vector (Pharmacia) was digested with NcoI and SalI in preparation for ligation with the digested PCR product. One hundred nanograms of digested pTrc99a vector and 250 ng of digested Mja FEN-1 PCR product were combined and ligated to create pTrc99-

MJFEN1. pTrc99-MJFEN1 was used to transform competent *E. coli* JM109 cells (Promega) using standard techniques.

[0952] b) Cloning and Expression of a FEN-1 Endonuclease from *Pyrococcus furiosus*

[0953] DNA encoding the *Pyrococcus furiosus* (*P. furiosus*) FEN-1 endonuclease was obtained by PCR amplification using a plasmid containing DNA encoding the *P. furiosus* (Pfu) FEN-1 endonuclease (obtained from Dr. Frank Robb, Center of Marine Biotechnology, Baltimore, Md.). DNA sequences encoding a portion of the Pfu FEN-1 endonuclease can be obtained from GenBank as accession Nos. AA113505 and W36094. The amplified Pfu FEN-1 gene was inserted into the pTrc99a expression vector (Pharmacia) to place the Pfu FEN-1 gene under the transcriptional control of the inducible trc promoter. The PCR amplification was conducted as follows. One hundred microliter reactions contained 50 mM Tris HCl, pH 9.0, 20 mM $(NH_4)_2SO_4$, 2 mM $MgCl_2$, 50 μM dNTPs, 50 pmole each primer, 1 U Tfl polymerase (Epicentre Technologies, Madison, Wis.) and 1 ng of FEN-1 gene-containing plasmid DNA. The 5'-end primer (SEQ ID NO:76) is complementary to the 5' end of the Pfu FEN-1 open reading frame but with two substitutions to create an NcoI site and the 3'-end primer (SEQ ID NO:77) is complementary to a region located about 30 base pairs downstream of the FEN-1 open reading frame with two substitutions to create a PstI site. The sequences of the 5'-end and 3'-end primers are: 5'-GAGGTGATACCATG GGTGTCC-3' (SEQ ID NO:76) and 5'-GAAACTCTGCAGCGCGTCAG-3' (SEQ ID NO:77), respectively. The PCR reaction resulted in the amplification of a single major band about 1 kilobase in length. The open reading frame (ORF) encoding the Pfu FEN-1 endonuclease is provided in SEQ ID NO:78; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:79.

[0954] Following the PCR amplification, the entire reaction was electrophoresed on a 1.0% agarose gel and the major band was excised from the gel and purified using the Geneclean II kit (Bio101) according to manufacturer's instructions. Approximately 1 μg of gel purified Pfu FEN-1 PCR product was digested with NcoI and PstI. After digestion, the DNA was purified using the Geneclean II kit according to manufacturer's instructions. One microgram of the pTrc99a vector was digested with NcoI and PstI prior to ligation with the digested PCR product. One hundred nanograms of digested pTrc99a and 250 ng of digested Pfu FEN-1 PCR product were combined and ligated to create pTrc99-PFFEN1. pTrc99-PFFEN1 was used to transform competent *E. coli* JM109 cells (Promega) using standard techniques.

[0955] c) Cloning and Expression of a FEN-1 Endonuclease from *Pyrococcus woesei*

[0956] For the cloning of DNA encoding the *Pyrococcus woesei* (Pwo) FEN-1 endonuclease, DNA was prepared from lyophilized *P. woesei* bacteria (DSMZ # 3773) as described (Zwickl et al., J. Bact., 172:4329 [1990]) with several changes. Briefly, one vial of *P. woesei* bacteria was rehydrated and resuspended in 0.5 ml of LB (Luria broth). The cells were centrifuged at 14,000×g for 1 min and the cell pellet was resuspended in 0.45 ml of TE. Fifty microliters of 10% SDS was added and the mixture was incubated at RT for 5 min. The cell lysate was then extracted three time with 1:1 phenol:chloroform and three times with chloroform. Five hundred microliters of isopropanol was added to the extracted lysate and the DNA was pelleted by centrifugation at 14,000×g for 10 min. The DNA pellet was washed in 0.5 ml of 70% ethanol and the DNA was pelleted again by centrifugation at 14,000×g for 5 min. The DNA pellet was dried and resuspended in 100 μl of TE and used for PCR reactions without further purification.

[0957] To generate a *P. woesei* FEN-1 gene fragment for cloning into an expression vector, low stringency PCR was attempted with primers complementary to the ends of the *P. furiosus* FEN-1 gene open reading frame. The sequences of the 5'-end and 3'-end primers are 5'-GATACCATGGGTGTCCCAATTGGTG-3' (SEQ ID NO:80) and 5'-TCGACGTCGACTTATCTCTTGAACCAACTTTCAAGGG-3' (SEQ ID NO:81), respectively. The high level of sequence similarity of protein homologs (i.e., proteins other than FEN-1 proteins) from *P. furiosus* and *P. woesei* suggested that there was a high probability that the *P. woesei* FEN-1 gene could be amplified using primers containing sequences complementary to the *P. furiosus* FEN-1 gene. However, this approach was unsuccessful under several different PCR conditions.

[0958] The DNA sequence of FEN-1 genes from *P. furiosus* and *M. jannaschi* were aligned and blocks of sequence identity between the two genes were identified. These blocks were used to design internal primers (i.e., complementary to sequences located internal to the 5' and 3' ends of the ORF) for the FEN-1 gene that are complementary to the *P. furiosus* FEN-1 gene in those conserved regions. The sequences of the 5'- and 3'-internal primers are 5'-AGCGAGGGAGAGGCCCAAGC-3' (SEQ ID NO:82) and 5'-GCCTATGCCCTTTATTCCTCC-3' (SEQ ID NO:83), respectively. A PCR employing these internal primers was conducted using the Advantage™ PCR kit and resulted in production of a major band of 300 bp.

[0959] Since the PCR with the internal primers was successful, reactions were attempted that contained mixtures of the internal (SEQ ID NOS:82 and 83) and external (SEQ ID NOS:80 and 81) primers. A reaction containing the 5'-end external primer (SEQ ID NO:80) and 3'-end internal primer (SEQ ID NO:83) resulted in the production of a 600 bp band and a reaction containing the 5'-end internal primer (SEQ ID NO:82) and 3'-end external primer (SEQ ID NO:81) resulted in the production of a 750 bp band. These overlapping DNA fragments were gel-purified and combined with the external primers (SEQ ID NOS:80 and 81) in a PCR reaction. This reaction generated a 1 kb DNA fragment containing the entire Pwo FEN-1 gene open reading frame. The resulting PCR product was gel-purified, digested, and ligated exactly as described above for the Mja FEN-1 gene PCR product. The resulting plasmid was termed pTrc99-PWFEN1. pTrc99-PWFEN1 was used to transform competent *E. coli* JM109 cells (Promega) using standard techniques.

[0960] d) Cloning and Expression of a FEN-1 Endonuclease from *Archaeoglobus fulgidus*

[0961] The preliminary *Archaeoglobus fulgidus* (Afu) chromosome sequence of 2.2 million bases was downloaded from the TIGR (The Institute for Genomic Research) world wide web site, and imported into a software program (MacDNAsis), used to analyze and manipulate DNA and protein sequences. The unannotated sequence was translated

into all 6 of the possible reading frames, each comprising approximately 726,000 amino acids. Each frame was searched individually for the presence of the amino acid sequence "VFDG" (valine, phenylalanine, aspartic acid, glycine), a sequence that is conserved in the FEN-1 family. The amino acid sequence was found in an open reading frame that contained other amino acid sequences conserved in the FEN-1 genes and that was approximately the same size as the other FEN-1 genes. The ORF DNA sequence is shown in SEQ ID NO:164, while the ORF protein sequence is shown in SEQ ID NO:165. Based on the position of this amino acid sequence within the reading frame, the DNA sequence encoding a putative FEN-1 gene was identified.

[0962] The sequence information was used to design oligonucleotide primers that were used for PCR amplification of the FEN-1-like sequence from *A. fulgidus* genomic DNA. Genomic DNA was prepared from *A. fulgidus* as described in Ex. 29a for *M. jannaschi*, except that one vial (approximately 5 ml of culture) of live *A. fulgidus* bacteria from DSMZ (DSMZ #4304) was used. One microliter of the genomic DNA was used for PCR reaction as described in Ex. 29a. The 5' end primer is complementary to the 5' end of the Afu FEN-1 gene except it has a 1 base pair substitution to create an Nco I site. The 3' end primer is complementary to the 3' end of the Afu FEN-1 gene downstream from the FEN-1 ORF except it contains a 2 base substitution to create a Sal I site. The sequences of the 5' and 3' end primers are 5'-CCGTCAACATTTACCATGGGTGCGGA-3' (SEQ ID NO:166) and 5'-CCGCCACCTCGTAGTCGACATC-CTTTTCGTG (SEQ ID NO:167), respectively.

[0963] Cloning of the resulting fragment was as described for the PfuFEN1 gene, above, to create the plasmid pTrc99-AFFEN1. The pTrcAfuHis plasmid was constructed by modifying pTrc99-AFFEN1, by adding a histidine tail to facilitate purification. To add this histidine tail, standard PCR primer-directed mutagenesis methods were used to insert the coding sequence for six histidine residues between the last amino acid codon of the pTrc99-AFFEN1 coding region and the stop codon. The resulting plasmid was termed pTrcAfuHis. The protein was then expressed as described in Example 28f), and purified by binding to a Ni++ affinity column, as described in Example 8.

[0964] e) Cloning and Expression of a FEN-1 Endonuclease from *Methanobacterium thermoautotrophicum*

[0965] A tentative listing of all open reading frames of the *Methanobacterium thermoautotrophicum* (Mth) genome on the Genome Therapeutics world wide web page was searched for amino acid sequences conserved in the FEN-1 genes. The amino acid sequence "VFDG" (valine, phenylalanine, aspartic acid, glycine) was found in an open reading frame that also contained other conserved FEN-1 sequences. SEQ ID NO:260 provides the Mth FEN-1 ORF DNA sequence as indicated by Genome Therapeutics, while SEQ ID NO:261 provides the Mth FEN-1 ORF protein sequence as indicated by Genome Therapeutics. However, this open reading frame was 259 amino acids in length, as compared to the other archael FEN-1 genes, which are approximately 325 amino acids long. To determine the cause of this discrepancy, the DNA sequence for Mth FEN-1 was obtained in an identical manner as described above for Afu FEN-1.

[0966] Upon examination of the sequence, it was apparent that the open reading frame could be extended to 328 amino acids by deletion of a single base at about position 750 of the open reading frame. The additional amino sequence added by deleting one base is 39% identical to the same region of the *P. furiosus* FEN-1 gene. The DNA sequence of the putative Mth FEN-1 gene was used to design oligonucleotide primers complementary to the 5' and 3' ends of the gene. The 5' oligonucleotide is complementary to the 5' end of the Mth FEN-1 gene except that it contains 2 substitutions which create an NcoI site. The 3' oligonucleotide is complementary to the 3' end of the gene about 100 base pairs downstream of where it is believed that the true open reading frame ends. This region contains a natural PstI site. The sequences of the 5' and 3' oligonucleotides are 5'-GGGT-GTTCCCATGGGAGTTAAACTCAGG-3' (SEQ ID NO:262) and 5'-CTGAATTCTGCAGAAAAAGGGG-3' (SEQ ID NO:263), respectively.

[0967] Genomic DNA was prepared from 1 vial of frozen *M. thermoautotrophicum* bacteria from ATCC (ATCC # 29096) as described in Ex. 28a. PCR, cloning, expression, and purification of Mth FEN-1 was done as described in Examples 28a and 28f, except PstI was used instead of SalI. The resulting plasmid was termed pTrc99-MTFEN1. Sequencing of the cloned Mth FEN-1 gene revealed the presence of additional "T" nucleotide when compared to the genome sequence published on the world wide web. This "T" residue at position 775 of the FEN-1 open reading frame causes a frame shift, creating the larger open reading frame that originally thought, based on comparison to the FEN genes from other organisms. SEQ ID NO:264 provides the sequence of the Mth ORF DNA sequence of the present invention, while SEQ ID NO:265 provides the sequence of the Mth FEN-1 protein sequence of the present invention.

[0968] f) Large Scale Preparation of Recombinant Thermostable FEN-1 Proteins

[0969] The Mja, Pwo and Pfu FEN-1 proteins were purified by the following technique, which is derived from a Taq DNA polymerase preparation protocol (Engelke et al., Anal. Biochem., 191:396 [1990]) as follows. *E. coli* cells (strain JM109) containing either pTrc99-PFFEN1, pTrc99-PW-FEN1, or pTrc99-MJFEN1 were inoculated into 3 ml of LB (Luria Broth) containing 100 μg/ml ampicillin and grown for 16 hrs at 37° C. The entire overnight culture was inoculated into 200 ml or 350 ml of LB containing 100 μg/ml ampicillin and grown at 37° C. with vigorous shaking to an A_{600} of 0.8. IPTG (1 M stock solution) was added to a final concentration of 1 mM and growth was continued for 16 hrs at 37° C.

[0970] The induced cells were pelleted and the cell pellet was weighed. An equal volume of 2×DG buffer (100 mM Tris-HCl, pH 7.6, 0.1 mM EDTA) was added and the pellet was resuspended by agitation. Fifty mg/ml lysozyme (Sigma, St. Louis, Mo.) was added to 1 mg/ml final concentration and the cells were incubated at room temperature for 15 min. Deoxycholic acid (10% solution) was added dropwise to a final concentration of 0.2% while vortexing. One volume of H_2O and 1 volume of 2×DG buffer was added and the resulting mixture was sonicated for 2 minutes on ice to reduce the viscosity of the mixture. After sonication, 3 M $(NH_4)_2SO_4$ was added to a final concentration of 0.2 M and the lysate was centrifuged at 14000×g for 20 min at 4° C. The supernatant was removed and incubated at 70° C. for 60 min at which time 10% polyethylimine (PEI) was added to 0.25%. After incubation on ice for 30 min., the

mixture was centrifuged at 14,000×g for 20 min at 4° C. At this point, the supernatant was removed and the FEN-1 proteins was precipitated by the addition of $(NH_4)_2SO_4$ as follows.

[0971] For the Pwo and the Pfu FEN-1 preparations, the FEN-1 protein was precipitated by the addition of 2 volumes of 3 M $(NH_4)_2SO_4$. The mixture was incubated overnight at room temperature for 16 hrs and the protein was centrifuged at 14,000×g for 20 min at 4° C. The protein pellet was resuspended in 0.5 ml of Q buffer (50 mM Tris-HCl, pH 8.0, 0.1 mM EDTA, 0.1% Tween 20). For the Mja FEN-1 preparation, solid $(NH_4)_2SO_4$ was added to a final concentration of 3 M (~75% saturated), the mixture was incubated on ice for 30 min, and the protein was spun down and resuspended as described above.

[0972] The resuspended protein preparations were quantitated by determination of the A_{279} and aliquots containing 2-41 g of total protein were electrophoresed on a 10% SDS polyacrylamide gel (29:1 acrylamide:bis-acrylamide) in standard Laemmli buffer [Laemmli, Nature 277:680 [1970]) and stained with Coomassie Brilliant Blue R; the results are shown in FIG. **64**.

[0973] In FIG. **64**, lane 1 contains molecular weight markers (Mid-Range Protein Molecular Weight Markers; Promega); the size of the marker proteins is indicated to the left of the gel. Lane 2 contains purified CLEAVASE BN nuclease; lanes 3-5 contain extracts prepared from *E. coli* expressing the Pfu, Pwo and Mja FEN-1 nucleases, respectively. The calculated (i.e., using a translation of the DNA sequence encoding the nuclease) molecular weight of the Pfu FEN-1 nuclease is 38,714 daltons and the calculated molecular weight for the Mja FEN-1 nuclease is 37,503 Daltons. The Pwo and Pfu FEN-1 proteins co-migrated on the SDS-PAGE gel and therefore, the molecular weight of the Pwo FEN-1 nuclease was estimated to be 38.7 kDa.

[0974] g) Activity Assays Using FEN-1 Endonucleases

[0975] i) Mixed Hairpin Assay

[0976] The CLEAVASE BN nuclease has an approximately 60-fold greater affinity for a 12 base pair stem-loop structure than an 8 base pair stem-loop DNA structure. As a test for activity differences between the CLEAVASE BN nuclease and the FEN-1 nucleases, a mixture of oligonucleotides having either a 8 or a 12 bp stem-loop (see FIG. **60**, which depicts the S-33 and 11-8-0 oligonucleotides) was incubated with an extract prepared from *E. coli* cells overexpressing the Mja FEN-1 nuclease (prepared as described above). Reactions contained 0.05 μM of oligonucleotides S-33 (SEQ ID NO:84) and 11-8-0 (SEQ ID NO:85) (both oligonucleotides contained 5'-fluorescein labels), 10 mM MOPS, pH 7.5, 0.05% Tween-20, 0.05% NP-40, 1 mM $MnCl_2$. Reactions were heated to 90° C. for 10 seconds, cooled to 55° C., then 1 μl of crude extract (Mja FEN-1) or purified enzyme (CLEAVASE BN nuclease) was added and the mixtures were incubated at 55° C. for 10 minutes; a no enzyme control was also run. The reactions were stopped by the addition of formamide/EDTA, the samples were electrophoresed on a denaturing 20% acrylamide gel and visualized on a Hitachi FMBIO 100 fluoroimager. The resulting image is shown in FIG. **65**.

[0977] In FIG. **65**, lane 1 contains the reaction products generated by the CLEAVASE BN nuclease, lane 2 contains the reaction products from the no enzyme control reaction and lane 3 contains the reaction products generated by the Mja FEN-1 nuclease. The data shown in FIG. **76** demonstrates that the CLEAVASE BN nuclease strongly prefers the S33 structure (12 bp stem-loop) while the Mja FEN-1 nuclease cleaves structures having either an 8 or a 12 bp stem-loop with approximately the same efficiency. This shows that the Mja FEN-1 nuclease has a different substrate specificity than the CLEAVASE BN nuclease, a useful feature for INVADER assays or CFLP® analysis as discussed in the Description of the Invention.

Example 29

Terminal Deoxynucleotidyl Transferase Selectively Extends the Products of INVADER-Directed Cleavage

[0978] The majority of thermal degradation products of DNA probes will have a phosphate at the 3'-end. To investigate if the template-independent DNA polymerase, terminal deoxynucleotide transferase (TdT) can tail or polymerize the aforementioned 3'-end phosphates (i.e., add nucleotide triphosphates to the 3' end) the following experiment was performed.

[0979] To create a sample containing a large percentage of thermal degradation products, the 5' fluorescein-labeled oligonucleotide 34-078-01 (SEQ ID NO:86) (200 pmole) was incubated in 100 μl 10 mM $NaCO_3$ (pH 10.6), 50 mM NaCl at 95° C. for 13 hours. To prevent evaporation, the reaction mixture was overlaid with 60 μl ChillOut™14 liquid wax. The reaction mixture was then divided into two equal aliquots (A and B). Aliquot A was mixed with one-tenth volume 3M NaOAc followed by three volumes ethanol and stored at −20° C. Aliquot B was dephosphorylated by the addition of 0.5 μl of 1M $MgCl_2$ and 1 μl of 1 unit/μl Calf Intestine Alkaline Phosphatase (CLAP) (Promega), with incubation at 37° C. for 30 minutes. An equal volume of phenol:chloroform:isomayl alcohol (24:24:1) was added to the sample followed by vortexing for one minute and then centrifugation 5 minutes at maximum speed in a microcentrifuge to separate the phases. The aqueous phase was removed to a new tube to which one-tenth volume 3M NaOAc, and three volumes ethanol was added followed by storage at −20° C. for 30 minutes. Both aliquots (A and B) were then centrifuged for 10 minutes at maximum speed in a microcentrifuge to pellet the DNA. The pellets were then washed two times each with 80% ethanol and then desiccated to dryness. The dried pellets were then dissolved in 70 μl ddH_2O each.

[0980] The TdT reactions were conducted as follows. Six mixes were assembled, all mixes contained 10 mM TrisOAc (pH 7.5), 10 mM MgOAc, 50 mM KCl, and 2 mM dATP. Mixes 1 and 2 contained one pmole of untreated 34-078-01 (SEQ ID NO:86), mixes 3 and 4 contained 2 μl of aliquot A (above), mixes 5 and 6 contained 2 μl of aliquot B (above). To each 9 μl of mixes 1, 3 and 5, 1 μl ddH_2O was added, to each 9 μl of mixes 2, 4, and 6, 1 μl of 20 units/μl TdT (Promega) was added. The mixes were incubated at 37° C. for 1 hour and then the reaction was terminated by the addition of 5 μl 95% formamide with 10 mM EDTA and 0.05% marker dyes. Five microliters of each mixture was resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer

containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA, and imaged using with the FMBIO Image Analyzer with a 505 nm filter. The resulting imager scan is shown in FIG. **66**.

[**0981**] In FIG. **66**, lanes 1, 3 and 5 contain untreated 34-078-01 (SEQ ID NO:86), heat-degraded 34-078-01, and heat-degraded, dephosphorylated, 34-078-01, respectively incubated in the absence of TdT. Lanes 2, 4 and 6 contain, untreated 34-078-01, heat-degraded 34-078-01, and heat-degraded, dephosphorylated, 34-078-01, respectively incubated in the presence of TdT.

[**0982**] As shown in FIG. **66**, lane 4, TdT was unable to extend thermal degradation products that contain a 3'-end phosphate group, and selectively extends molecules that have a 3'-end hydroxyl group.

Example 30

Specific TdT Tailing of the Products of INVADER-Directed Cleavage with Subsequent Capture and Detection on Nitrocellulose Supports

[**0983**] When TdT is used to extend the specific products of cleavage, one means of detecting the tailed products is to selectively capture the extension products on a solid support before visualization. This Example demonstrates that the cleavage products can be selectively tailed by the use of TdT and deoxynucleotide triphosphates, and that the tailed products can be visualized by capture using a complementary oligonucleotide bound to a nitrocellulose support.

[**0984**] To extend the cleavage product produced in an INVADER-directed cleavage reaction, the following experiment was performed. Three reaction mixtures were assembled, each in a buffer of 10 mM MES (pH 6.5), 0.5% Tween-20, 0.5% NP-40. The first mixture contained 5 fmols of target DNA-M13mp18, 10 pmols of probe oligo 32-161-2 (SEQ ID NO:87; this probe oligonucleotide contains 3' ddC and a Cy3 amidite group near the 3' end), and 5 pmols of INVADER oligonucleotide 32 161-1 (SEQ ID NO:88; this oligo contains a 3' ddC). The second mixture contained the probe and INVADER oligonucleotides without target DNA. The third mixture was the same as the first mixture, and contained the same probe sequence, but with a 5' fluorescein label (oligo 32-161-4 [SEQ ID NO:89; this oligo contains a 3' ddC, 5' fluorescein label, and a Cy3 dye group near the 3' end]), so that the INVADER-directed cleavage products could be detected before and after cleavage by fluorescence imaging. The probe only control sample contained 10 pmols of oligo 32-161-2 (SEQ ID NO:87). Each 3 μl of enzyme mix contained 5 ng of CLEAVASE DN nuclease in 7.5 mM $MgCl_2$. The TdT mixture (per each 4 μl) contained: 10 U of TdT (Promega), 1 mM $CoCl_2$, 50 mM KCl, and 100 μM of dTTP. The INVADER cleavage reaction mixtures described above were assembled in thin wall tubes, and the reactions were initiated by the addition of 3 μl of CLEAVASE DN enzyme mix. The reactions were incubated at 65° C. for 20 min. After cooling to 37° C., 4 μl of the TdT mix was added and the samples were incubated for 4 min at 37° C., Biotin-16-dUTP was then added to 100 μM and the samples were incubated for 50 min at 37° C. The reactions were terminated by the addition of 1 μl of 0.5 M EDTA.

[**0985**] To test the efficiency of tailing the products were run on an acrylamide gel. Four microliters of each reaction mixture was mixed with 2.6 μl of 95% formamide, 10 mM EDTA and 0.05% methyl violet and heated to 90° C. for 1 min, and 3 μl were loaded on a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. A marker (ΦX174-HinfI [fluorescein labeled]) also was loaded. After electrophoresis, the gel was analyzed using a FMBIO-100 Image Analyzer (Hitachi) equipped with a 505 nm filter. The resulting scan is shown in FIG. **67**.

[**0986**] In FIG. **67**, lane 1 contained the probe 32-161-2 only, without any treatment. Lanes 2 and 3 contained the products of reactions run without target DNA, without or with subsequent TdT tailing, respectively. Lanes 4 and 5 contained the products of reactions run with target DNA, probe oligo 32-161-2 (SEQ ID NO:87) and INVADER oligo 32-161-1 (SEQ ID NO:88), without or with subsequent TdT tailing, respectively. Lanes 6 and 7 show the products of reactions containing target DNA, probe oligo 32-161-4 (SEQ ID NO:89) and INVADER oligo 32-161-1 (SEQ ID NO:88), without or with subsequent TdT tailing, respectively. Lane M contains the marker ΦX174-HinfI.

[**0987**] The reaction products in lanes 4 and 5 are the same as those seen in lanes 6 and 7, except that the absence of a 5' fluorescein on the probe prevents detection of the released 5' product (indicated as "A" near the bottom of the gel) or the TdT extended 5' product (indicated as "B", near the top of the gel). The Cy3-labeled 3' portion of the cleaved probe is visible in all of these reactions (indicated as "C", just below the center of the gel).

[**0988**] To demonstrate detection of target-dependent INVADER-directed cleavage products on a solid support, the reactions from lanes 3 and 5 were tested on the Universal GENECOMB (Bio-Rad), which is a standard nitrocellulose matrix on a rigid nylon backing styled in a comb format, as depicted in FIG. **68**. Following the manufacturer's protocol, with one modification: 10 μl of the INVADER-directed cleavage reactions were used instead the recommended 10% of a PCR. To capture the cleavage products, 2.5 pmols of the capture oligo 59-28-1 (SEQ ID NO:90) were spotted on each tooth. The capture and visualization steps were conducted according to the manufacturer's directions. The results are shown in FIG. **68**.

[**0989**] In FIG. **68**, teeth numbered 6 and 7 show the capture results of reactions performed without and with target DNA present. Tooth 8 shows the kit positive control.

[**0990**] The darkness of the spot seen on tooth 7, when compared to tooth 6, clearly indicates that products of INVADER-directed cleavage assays may be specifically detected on solid supports. While the Universal GENECOMB was used to demonstrate solid support capture in this instance, other support capture methods known to those skilled in the art would be equally suitable. For example, beads or the surfaces of reaction vessels may easily be coated with capture oligonucleotides so that they can then be used in this step. Alternatively, similar solid supports may easily be coated with streptavidin or antibodies for the capture of biotin- or hapten-tagged products of the cleavage/tailing reaction. In any of these embodiments, the products may be appropriately visualized by detecting the resulting fluorescence, chemiluminescence, colorimetric changes, radioactive emissions, optical density change or any other distinguishable feature of the product.

Example 31

Comparison of the Effects of Invasion Length and 5' Label of the Probe on INVADER-Directed Cleavage by the CLEAVASE A/G and Pfu FEN-1 Nucleases

[0991] To investigate the effect of the length of invasion as well as the effect of the type of dye on ability of Pfu FEN-1 and the CLEAVASE A/G nuclease to cleave 5' arms, the following experiment was performed. Three probes of similar sequences labeled with either fluorescein, TET, or Cy3, were assembled in reactions with three INVADER oligonucleotides that created overlapping target hybridization regions of eight, five, and three bases along the target nucleic acid, M13mp18.

[0992] The reactions were conducted as follows. All conditions were performed in duplicate. Enzyme mixes for Pfu FEN-1 and the CLEAVASE A/G nuclease were assembled. Each 2 μl of the Pfu FEN-1 mix contained 100 ng of Pfu FEN-1 (prepared as described in Ex. 28) and 7.5 mM $MgCl_2$. Each 2 μl of the CLEAVASE A/G mix contained 5.3 ng of the CLEAVASE A/G nuclease and 4.0 mM $MnCl_2$. Six master mixes containing buffer, M13mp18, and INVADER oligonucleotides were assembled. Each 7 μl of mixes 1-3 contained 1 fmol M13mp18, 10 pmoles INVADER oligonucleotide (34-078-4 [SEQ ID NO:39], 24-181-2 [SEQ ID NO:91], or 24-181-1 [SEQ ID NO:92], in 10 mM MOPS (pH 7.5), 150 mM LiCl. Each 7 μl of mixes 4-6 contained 1 fmol of M13mp18, 10 pmoles of INVADER oligonucleotide [34-078-4 (SEQ ID NO:39), 24-181-2 (SEQ ID NO:91), or 24-181-1 (SEQ ID NO:92)] in 10 mM Tris (pH 8.0). Mixtures 1-6 were then divided into three mixtures each, to which was added either the fluorescein-labeled probe (oligo 34-078-01; SEQ ID NO:86), the Cy3-labeled probe (oligo 43-20; SEQ ID NO:93) or the TET-labeled probe (oligo 90; SEQ ID NO:32 containing a 5' TET label). Each 7 μl of all mixtures contained 10 pmoles of corresponding probe. The DNA solutions described above were covered with 10 μl of CHILLOUT evaporation barrier and brought to 68° C.

[0993] The reactions made from mixes 1-3 were started with 2 μl of the CLEAVASE A/G nuclease mix, and the reactions made from mixes 4-6 were started with 2 μl of the Pfu FEN-1 mix. After 30 minutes at 68° C., the reactions were terminated by the addition of 8 μl of 95% formamide with 10 mM EDTA and 0.05% marker dyes. Samples were heated to 90° C. for 1 minute immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. The products of the cleavage reactions were visualized following electrophoresis by the use of a Hitachi FMBIO fluorescence imager. Results from the fluorescein-labeled probe are shown in FIG. **69**, results from the Cy3-labeled probe in FIG. **70**, and results from the TET-labeled probe in FIG. **71**. In each of these Figures, the products of cleavage by CLEAVASE A/G are shown in lanes 1-6 and the products of cleavage by PfuFEN-1 are shown in lanes 7-12. In each in case the uncut material appears as a very dark band near the top of the gel, indicated by a "U" on the left. The products of cleavage directed by INVADER oligonucleotides with 8, 5 or 3 bases of overlap (i.e., the "X" region was 8, 5, or 3 nt long) are shown in the first, second and third pair of lanes in each set, respectively and the released labeled 5' ends from these reactions are indicated by the numbers 8, 5, and 3 on the left. Note that in the cleavage reactions shown in FIG. **70** the presence of the positively charged Cy3 dye causes the shorter products to migrate more slowly than the larger products. These products do not contain any additional positive charges (e.g., amino modifications as used in Example 23), and thus still carry a net negative charge, and migrate towards the positive electrode in a standard electrophoresis run.

[0994] It can be seen from these data that the CLEAVASE A/G and Pfu FEN-1 structure-specific nucleases respond differently to both dye identity and to the size of the piece to be cleaved from the probe. The Pfu FEN-1 nuclease showed much less variability in response to dye identity than did the CLEAVASE A/G nuclease, showing that any dye wold be suitable for use with this enzyme. In contrast, the amount of cleavage catalyzed by the CLEAVASE A/G nuclease varied substantially with dye identity. Use of the fluorescein dye gave results very close to those seen with the Pfu FEN-1 nuclease, while the use of either Cy3 or TET gave dramatically reduced signal when compared to the Pfu FEN-1 reactions. The one exception to this was in the cleavage of the 3 nt product carrying a TET dye (lanes 5 and 6, FIG. **71**), in which the CLEAVASE A/G nuclease gave cleavage at the same rate as the Pfu FEN-1 nuclease. These data indicate that, while CLEAVASE A/G may be used to cleave probes labeled with these other dyes, the Pfu FEN-1 nuclease is a preferred nuclease for cleavage of Cy3- and TET-labeled probes.

Example 32

Examination of the Effects of a 5' Positive Charge on the Rate of Invasive Cleavage Using the CLEAVASE A/G or Pfu FEN-1 Nucleases

[0995] To investigate whether the positive charges on 5' end of probe oligonucleotides containing a positively charged adduct(s) (i.e., charge reversal technology or CRT probes as described in Ex. 23 and 24 have an effect on the ability of the CLEAVASE A/G or Pfu FEN-1 nucleases to cleave the 5' arm of the probe, the following experiment was performed.

[0996] Two probe oligonucleotides having the following sequences were utilized in INVADER reactions: Probe 34-180-1: (N-Cy3)$T_{NH2}T_{NH2}$CCAGAGCCTAATTTGCCAGT(N-fluorescein)A, where N represents a spacer containing either the Cy3 or fluorescein group (SEQ ID NO:94) and Probe 34-180-2: 5'-(N-TET)TTCCAGAGCCTAATTTGCCAGT-(N-fluorescein)A, where N represents a spacer containing either the TET or fluorescein group (SEQ ID NO:95). Probe 34-180-1 has amino-modifiers on the two 5' end T residues and a Cy3 label on the 5' end, creating extra positive charges on the 5' end. Probe 34-180-2 has a TET label on the 5' end, with no extra positive charges. The fluorescein label on the 3' end of probe 34-180-1 enables the visualization of the 3' cleaved products and uncleaved probes together on an acrylamide gel run in the standard direction (i.e., with the DNA migrating toward the positive electrode). The 5' cleaved product of probe 34-180-1 has a net positive charge and will not migrate in the same direction as the uncleaved

probe, and is thus visualized by resolution on a gel run in the opposite direction (i.e.; with this DNA migrating toward the negative electrode).

[0997] The cleavage reactions were conducted as follows. All conditions were performed in duplicate. Enzyme mixes for the Pfu FEN-1 and CLEAVASE A/G nucleases were assembled. Each 2 μl of the Pfu FEN-1 mix contained 100 ng of Pfu FEN-1 (prepared as described in Ex. 28) and 7.5 mM $MgCl_2$. Each 2 μl of the CLEAVASE A/G nuclease mix contained 26.5 ng of CLEAVASE A/G nuclease and 4.0 mM $MnCl_2$. Four master mixes containing buffer, M13mp18, and INVADER oligonucleotides were assembled. Each 7 μl of mix 1 contained 5 fmol M13mp18, 10 pmoles INVADER oligonucleotide 123 (SEQ ID NO:96) in 10 mM HEPES (pH 7.2). Each 7 μl of mix 2 contained 1 fmol M13mp18, 10 pmoles INVADER oligonucleotide 123 in 10 mM HEPES (pH 7.2). Each 7 μl of mix 3 contained 5 fmol M13mp18, 10 pmoles INVADER oligonucleotide 123 in 10 mM HEPES (pH 7.2), 250 mM KGlu. Each 7 μl of mix 4 contained 1 fmol M13mp18, 10 pmoles INVADER oligonucleotide 123 in 10 mM HEPES (pH 7.2), 250 mM KGlu. For every 7 μl of each mix, 10 pmoles of either probe 34-180-1 (SEQ ID NO:94) or probe 34-180-2 (SEQ ID NO:95) was added. The DNA solutions described above were covered with 10 μl of CHILLOUT evaporation barrier and brought to 65° C. The reactions made from mixes 1-2 were started by the addition of 2 μl of the Pfu FEN-1 mix, and the reactions made from mixes 3-4 were started by the addition of 2 μl of the CLEAVASE A/G nuclease mix. After 30 minutes at 65° C., the reactions were terminated by the addition of 8 μl of 95% formamide containing 10 mM EDTA. Samples were heated to 90° C. for 1 minute immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA and a 20% native acrylamide gel (29:1 cross-linked) in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA.

[0998] The products of the cleavage reactions were visualized following electrophoresis by the use of a Hitachi FMBIO fluorescence imager. The resulting images are shown in FIG. **72**. FIG. **72**A shows the denaturing gel, which was run in the standard electrophoresis direction, and FIG. **72**B shows the native gel, which was run in the reverse direction. The reaction products produced by Pfu FEN-1 and CLEAVASE A/G nucleases are shown in lanes 1-8 and 9-16, respectively. The products from the 5 fmol M13mp18 and 1 fmol M13mp18 reactions are shown in lanes 1-4, 9-12 (5 fmol) and 5-8, 13-16 (1 fmol). Probe 34-180-1 is in lanes 1-2, 5-6, 9-10, 13-14 and probe 34-180-2 is in lanes 3-4, 7-8, 11-12, 15-16.

[0999] The fluorescein-labeled 3' end fragments from all cleavage reactions are shown in FIG. **72**A, indicated by a "3'" mark at the left. The 3 nt 5' TET-labeled products are not visible in this Figure, while the 5' Cy3-labeled products are shown in FIG. **72**B.

[1000] The 3' end bands in FIG. **72**A can be used to compare the rates of cleavage by the different enzymes in the presence of the different 5' end labels. It can be seen from this band that regardless of the amount of target nucleic acid present, both the Pfu FEN-1 and the CLEAVASE A/G nucleases show more product from the 5' TET-labeled probe. With the Pfu FEN-1 nuclease this preference is modest, with only an approximately 25 to 40% increase in signal. In the case of the CLEAVASE A/G nuclease, however, there is a strong preference for the 5' TET label. Therefore, although when the charge reversal method is used to resolve the products, a substantial amount of product is observed from the CLEAVASE A/G nuclease-catalyzed reactions, the Pfu FEN-1 nuclease is a preferred enzyme for cleavage of Cy3-labeled probes.

Example 33

The Use of Universal Bases in the Detection of Mismatches by INVADER Directed Cleavage

[1001] The term "degenerate base" refers to a base on a nucleotide that does not hydrogen bond in a standard "Watson-Crick" fashion to a specific base complement (i.e., A to T and G to C). For example, the inosine base can be made to pair via one or two hydrogen bonds to all of the natural bases (the "wobble" effect) and thus is called degenerate. Alternatively, a degenerate base may not pair at all; this type of base has been referred to as a "universal" base because it can be placed opposite any nucleotide in a duplex and, while it cannot contribute stability by base-pairing, it does not actively destabilize by crowding the opposite base. Duplexes using these universal bases are stabilized by stacking interactions only. Two examples of universal bases, 3-nitropyrrole and 5-nitroindole, are shown in FIG. **73**. In hybridization, placement of a 3-nitropyrrole three bases from a mismatch position enhances the differential recognition of one base mismatches. The enhanced discrimination seems to come from the destabilizing effect of the unnatural base (i.e., an altered T_m in close proximity to the mismatch). To test this same principle as a way of sensitively detecting mismatches using the INVADER-directed cleavage assay, INVADER oligonucleotides were designed using the universal bases shown in FIG. **73**, in the presence or absence of a natural mismatch. In these experiments, the use of single nitropyrrole bases or pairs of nitroindole bases that flank the site of the mismatch were examined.

[1002] The target, probe and INVADER oligonucleotides used in these assays are shown in FIG. **74**. A 43 nucleotide oligonucleotide (oligo 109; SEQ ID NO:97) was used as the target. The probe oligonucleotide (oligo 61; SEQ ID NO:50) releases a net positively charged labeled product upon cleavage. In FIG. **74**, the INVADER oligonucleotide is shown schematically above the target oligonucleotide as an arrow; the large arrowhead indicates the location of the mismatch between the INVADER oligos and the target. Under the target oligonucleotide, the completely complementary, all natural (i.e., no universal bases) INVADER oligo (oligo 67; SEQ ID NO:51) and a composite of INVADER oligos containing universal bases ("X") on either side of the mismatch ("M") are shown. The following INVADER oligos were employed: oligo 114 (SEQ ID NO:98), which contains a single nt mismatch; oligo 115 (SEQ ID NO:99), which contains two 5-nitroindole bases and no mismatch; oligo 116 (SEQ ID NO:100), which contains two 5-nitroindole bases and a single nt mismatch; oligo 112 (SEQ ID NO:101), which contains one 3-nitropyrrole base and no mismatch; oligo 113 (SEQ ID NO:102), which contains one 5-nitropyrrole base and a single nt mismatch; and oligo 67 (SEQ ID NO:51), which is completely complementary to the target.

[1003] The INVADER-directed cleavage reactions were carried out in 10 μl of 10 mM MOPS (pH 7.2), 100 mM KCl, containing 1 μM of the appropriate invading oligonucleotide (oligos 67, 112-116), 10 nM synthetic target 109, 1 μM Cy-3 labeled probe 61 and 2 units of CLEAVASE DV (prepared as described in Ex. 27). The reactions were overlayed with Chill-Out® liquid wax, brought to the appropriate reaction temperature, 52° C., 55° C., or 58° C. and initiated with the addition of 1 μl of 40 mM $MnCl_2$. Reactions were allowed to proceed for 1 hour and were stopped by the addition of 10 μl formamide. One fourth of the total volume of each reaction was loaded onto 20% non-denaturing polyacrylamide gels, which were electrophoresed in the reverse direction. The products were visualized using an Hitachi FMBIO-100 fluorescent scanner using a 585 nm filter. The resulting images are shown in FIGS. **75**A-C. In each panel, lanes 1-6 contain reactions products from reactions using INVADER oligo 67, 114, 115, 116, 112 and 113, respectively. Reactions run at 52° C., 55° C. and 58° C. are shown in Panels A, B and C, respectively.

[1004] These data show that two flanking 5-nitroindoles display a significantly greater differentiation then does the one 3-nitropyrrole system, or the all natural base hybridization, and this increased sensitivity is not temperature dependent. This demonstrates that the use of universal bases is a useful means of sensitively detecting single base mismatches between the target nucleic acid and the complex of detection oligonucleotides of the present invention.

Example 34

Detection of Point Mutations in the Human Ras Oncogene Using a Miniprobe

[1005] It is demonstrated herein that very short probes can be used for sensitive detection of target nucleic acid sequences (Ex. 37). In this Example, it is demonstrated that the short probes work very poorly when mismatched to the target, and thus can be used to distinguish a given nucleic acid sequence from a close relative with only a single base difference. To test this system synthetic human ras oncogene target sequences were created that varied from each other at one position. Oligonucleotide 166 (SEQ ID NO:103) provided the wild-type ras target sequence. Oligonucleotide 165 (SEQ ID NO:104) provided the mutant ras target sequence. The sequence of these oligonucleotides are shown in FIG. **76**, and the site of the sequence variation in the site corresponding to codon 13 of the ras gene is indicated. The INVADER oligonucleotide (oligo 162) has the sequence: 5'-$G_SC_ST_SC_SA_SA_SG_SG_SC_S$ACTCTTGCC TACGA-3' (SEQ ID NO:105), where the "S" indicates thiol linkages (i.e., these are 2'-deoxynucleotide-5'-O-(1-thiomonophates)). The miniprobe (oligo 161) has the sequence: 5'-(N-Cy3) $T_{NH2}T_{NH2}$CACCAG-3' (SEQ ID NO:106) and is designed to detect the mutant ras target sequence (i.e., it is completely complementary to oligo 165). The stacker oligonucleotide (oligo 164) has the sequence: 5'-$C_ST_SC_SC_SA_SA_SC_S$ T_SA_SCCACAAGTTTATATTCAG-3' (SEQ ID NO:107). A schematic showing the assembly of these oligonucleotides into a cleavage structure is depicted in FIG. **76**.

[1006] Each cleavage reaction contained 100 nM of both the invading (oligo 162) and stacking (oligo 164) oligonucleotides, 10 μM Cy3-labeled probe (oligo 161) and 100 pM of either oligo 165 or oligo 166 (target DNA) in 10 μl of 10 mM HEPES (pH 7.2), 250 mM KGlu, 4 mM $MnCl_2$. The DNA mixtures were overlaid with mineral oil, heated to 90° C. for 15 sec then brought to a reaction temperature of 47°, 50°, 53° or 56° C. Reactions were initiated by the addition of 1 μl of 100 ng/μl Pfu FEN-1. Reactions were allowed to proceed for 3 hours and stopped by the addition of 10 μl formamide. One fourth of the total volume od each reaction was loaded onto a 20% non-denaturing polyacrylamide gel, which was electrophoresed in the reverse direction. The gel was scanned using an Hitachi FMBIO-100 fluorescent scanner fitted with a 585 nm filter, and the resulting image is shown in FIG. **77**.

[1007] In FIG. **77**, for each reaction temperature tested, the products from reactions containing either the mutant ras target sequence (oligo 165) or the wild-type (oligo 166) are shown.

[1008] These data demonstrate that the miniprobe can be used to sensitively discriminate between sequences that differ by a single nucleotide. The miniprobe was cleaved to produce a strong signal in the presence of the mutant target sequence, but little or no miniprobe was cleaved in the presence of the wild-type target sequence. Furthermore, the discrimination between closely related targets is effective over a temperature range of at least 10° C., which is a much broader range of temperature than can usually be tolerated when the selection is based on hybridization alone (e.g., hybridization with ASOs). This suggests that the enzyme may be a factor in the discrimination, with the perfectly matched miniprobe being the preferred substrate when compared to the mismatched miniprobe. Thus, this system provides sensitive and specific detection of target nucleic acid sequences.

Example 35

Effects of 3' End Identity on Site of Cleavage of a Model Oligonucleotide Structure

[1009] As described in the Examples above, structure-specific nucleases cleave near the junction between single-stranded and base-paired regions in a bifurcated duplex, usually about one base pair into the base-paired region. It was shown in Example 10 that thermostable 5' nucleases, including those of the present invention (e.g., CLEAVASE BN nuclease, CLEAVASE A/G nuclease), have the ability to cleave a greater distance into the base paired region when provided with an upstream oligonucleotide bearing a 3' region that is homologous to a 5' region of the subject duplex, as shown in FIG. **26**. It has also been determined that the 3' terminal nucleotide of the INVADER oligonucleotide may be unpaired to the target nucleic acid, and still shift cleavage the same distance into the down stream duplex as when paired. It is shown in this Example that it is the base component of the nucleotide, not the sugar or phosphate, that is necessary to shift cleavage.

[1010] FIGS. **78**A and B shows a synthetic oligonucleotide that was designed to fold upon itself, and that consists of the following sequence: 5'-GTTCTCTGCTCTCTG-GTCGCTGTCTCGCTTGTGAAACAAGC-GAGACAGCGTGGTCTCTCG-3' (SEQ ID NO:29). This oligonucleotide is referred to as the "S-60 Hairpin." The 15 basepair hairpin formed by this oligonucleotide is further

stabilized by a "tri-loop" sequence in the loop end (i.e., three nucleotides form the loop portion of the hairpin) (Hiraro et al., Nucleic Acids Res., 22(4): 576 [1994]). FIG. **78**B shows the sequence of the P-15 oligonucleotide (SEQ ID NO:30) and the location of the region of complementarity shared by the P-15 and S-60 hairpin oligonucleotides. In addition to the P-15 oligonucleotide shown, cleavage was also tested in the presence of the P-14 oligonucleotide (SEQ ID NO:108) (P-14 is one base shorter on the 3' end as compared to P-15), the P-14 with an abasic sugar (P-14d; SEQ ID NO:109) and the P14 with an abasic sugar with a 3' phosphate (P-14dp; SEQ ID NO:110). A P-15 oligo with a 3' phosphate, P-15p (SEQ ID NO:11) was also examined. The black arrows shown in FIG. **78** indicate the sites of cleavage of the S-60 hairpin in the absence (top structure; A) or presence (bottom structure; B) of the P-15 oligonucleotide.

[**1011**] The S-60 hairpin molecule was labeled on its 5' end with fluorescein for subsequent detection. The S-60 hairpin was incubated in the presence of a thermostable 5' nuclease in the presence or the absence of the P-15 oligonucleotide. The presence of the full duplex that can be formed by the S-60 hairpin is demonstrated by cleavage with the CLEAVASE BN 5' nuclease, in a primer-independent fashion (i.e., in the absence of the P-15 oligonucleotide). The release of 18 and 19-nucleotide fragments from the 5' end of the S-60 hairpin molecule showed that the cleavage occurred near the junction between the single and double stranded regions when nothing is hybridized to the 3' arm of the S-60 hairpin (FIG. **27**, lane 2).

[**1012**] The reactions shown in FIG. **78**C were conducted in 10 μl 1×CFLP buffer with 1 mM $MnCl_2$ and 50 mM K-Glutamate, in the presence of 0.02 μM S-60, 0.5 μM INVADER oligonucleotide and 0.01 ng per μl CLEAVASE BN nuclease. Reactions were incubated at 40° C. for 5 minutes and stopped by the addition of 8 μl of stop buffer (95% formamide, 20 mM EDTA, 0.02% methyl violet). Samples were heated to 75° C. for 2 min immediately before electrophoresis through a 15% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Gels were then analyzed with a FMBIO-100 Image Analyzer (Hitachi) equipped with 505 nm filter. The resulting image is shown in FIG. **78**C.

[**1013**] In FIG. **78**C lane 1 contains products from the no enzyme control; lane 2 contains products from a reaction run in the absence of an INVADER oligo; lanes 3-6 contain products from reactions run the presence of the P-14d, P-14dp, P-15 and P-15p INVADER oligos, respectively.

[**1014**] From the data shown in FIG. **78**C, it can be seen that the use of the P-15 INVADER oligonucleotide produces a shift in the cleavage site, while the P14 INVADER oligonucleotide with either a ribose (P14d) or a phosphorylated ribose (P14dp) did not This indicates that the 15th residue of the INVADER oligonucleotide must have the base group attached to promote the shift in cleavage. Interestingly, the addition of phosphate to the 3' end of the P15 oligonucleotide apparently reversed the shifting of cleavage site. The cleavage in this lane may in fact be cleavage in the absence of an INVADER oligonucleotide as is seen in lane 2. In experiments with 5' dye-labeled INVADER oligonucleotides with 3' phosphate groups these oligonucleotides have been severely retarded in gel migration, suggesting that either the enzyme or another constituent of the reaction (e.g., BSA) is able to bind the 3' phosphate irrespective of the rest of the cleavage structure. If the INVADER oligonucleotides are indeed being sequestered away from the cleavage structure, the resulting cleavage of the S-60 hairpin would occur in a "primer-independent' fashion, and would thus not be shifted.

[**1015**] In addition to the study cited above, the effects of other substituents on the 3' ends of the INVADER oligonucleotides were investigated in the presence of several different enzymes, and in the presence of either Mn++ or Mg++. The effects of these 3' end modifications on the generation of cleaved product are summarized in the following table. All of modifications were made during standard oligonucleotide synthesis by the use of controlled pore glass (CPG) synthesis columns with the listed chemical moiety provided on the support as the synthesis starting residue. All of these CPG materials were obtained from Glen Research Corp. (Sterling, Va.).

[**1016**] FIG. **79** provides the structures for the 3' end substituents used in these experiments.

TABLE 4

Modification Studies At 3' End Of INVADER Oligo

3'-End Modification	Extension By Terminal Transferase	Effect on INVADER Rxn. (As INVADER) Enzyme:Condition - Effect
3' phosphate Glen part # 20-2900-42	no	A:5 - inhibits reaction, no detectable activity
3' acridine Glen part # 20-2973-42	yes, poorly	A:5 - decrease in activity, <10% B:5 - decrease in activity, <10% B:4 - decrease in activity, <10% C:1 - decrease in activity, <10% C:2 - decrease in activity, ~20% C:4 - decrease in activity, ~50% C:3 - decrease in activity, <5%
3' carboxylate Glen part # 20-4090-42	no	A:1 - decrease in activity, ~50% activity shift in cleavage site C:3 - reduces rate, <10% activity
3' nitropyrole Glen part # 20-2143-42	yes	A:5 - increase in activity, ~2×
3' nitroindole Glen part # 20-2144-42	yes	A:5 - decrease in activity, ~33% activity
3' arabinose Glen part # 10-4010-90	yes	A:5 - decrease in activity, ~50% activity
3'dideoxyUTP-flourescein	no	A:5 - decrease in activity, ~40% activity
3'-3' linkage Glen part # 20-0002-01	no	A:1 - equivalent cleavage activity shift in cleavage site C:3 - decrease in activity, ~25% activity
3' glyceryl Glen part # 20-2902-42	yes, very poorly	C:3 - decrease in activity, ~30% activity loss of specificity of cleavage (2 sites)
3' amino modifier C7 Glen part # 20-2957-42	yes	C:3 - decrease in activity, ~30% activity loss of specificity, multiple sites
3' phosphate Glen part # 20-2900-42	no	A:5 - inhibits reaction, no detectable activity

TABLE 4-continued

Modification Studies At 3' End Of INVADER Oligo

3'-End Modification	Extension By Terminal Transferase	Effect on INVADER Rxn. (As INVADER) Enzyme:Condition - Effect
3'deoxy, 2'OH Glen part # 20-2104-42	yes, very poorly	A:5 - decrease in activity, <20% activity B:5 - decrease in activity, <20% activity B:3 - decrease in activity, <20% activity C:1 - equivalent activity C:2 - equivalent activity C:4 - ? increase in activity C:3 - decrease in activity, ~40% activity

Enzymes:
A) CLEAVAGE DV nuclease
B) CLEAVAGE BN nuclease
C) Pfu FEN-1
Condition:
1) 4 mM $MnCl_2$, 150 mM LiCl
2) 4 mM $MnCl_2$, 50 mM KCl
3) 7.5 mM $MgCl_2$, no movement
4) 4 mM $MgCl_2$, 50 mM KCl
5) 10 mM MgOAc, 50 mM KCl

[1017] It can be seen from these data that many different modifications can be used on the 3' end of the INVADER oligonucleotide without detriment. In various embodiments of the present invention, such 3' end modifications may be used to block, facilitate, or otherwise alter the hybridization characteristics of the INVADER oligonucleotide, (e.g., to increase discrimination against mismatches, or to increase tolerance of mismatches, or to tighten the association between the INVADER oligonucleotide and the target nucleic acid). Some substituents may be used to alter the behavior of the enzyme in recognizing and cleaving within the assembled complex.

[1018] Altered 3' ends may also be used to prevent extension of the INVADER oligonucleotide by either template-dependent or template-independent nucleic acid polymerases. The use of otherwise unmodified dideoxynucleotides (i.e., without attached dyes or other moieties) are a particularly preferred means of blocking extension of INVADER oligonucleotides, because they do not decrease cleavage activity, and they are absolutely unextendable.

Example 36

Effect of Probe Concentration, Temperature and a Stacker Oligonucleotide on the Cleavage of Miniprobes by INVADER-Directed Cleavage

[1019] The stacker oligonucleotides employed to form cleavage structures may serve two purposes in the detection of a nucleic acid target using a miniprobe. The stacker oligonucleotide may help stabilize the interaction of the miniprobe with the target nucleic acid, leading to greater accumulation of cleaved probe. In addition, the presence of this oligo in the complex elongates the duplex downstream of the cleavage site, which may enhance the cleavage activity of some of the enzymes of the present invention. An example of different preferences for the length of this duplex by different structure-specific nucleases is seen in the comparison of the CLEAVASE BN nuclease and the Mja FEN-1 nuclease cleavage of 8 bp and 12 bp duplex regions in FIG. **65**. Increased affinity of the enzyme for the cleavage structure also results in increased accumulation of cleaved probe during reactions done for a set amount of time.

[1020] The amount of miniprobe binding to the target is also affected by the concentration of the miniprobe in the reaction mixture. Even when a miniprobe is only marginally likely to hybridize (e.g., when the reaction is performed at temperatures in excess of the expected melting temperature of the probe/target duplex), the amount of probe on the target at any given time can be increased by using high concentrations of the miniprobe.

[1021] The need for a stacker oligonucleotide to enhance cleavage of the miniprobe was examined at both low and high probe concentrations. The reactions were carried out in 10 μl of 10 mM HEPES (pH 7.2), 250 mM KGlu, 4 mM $MnCl_2$, containing 100 nM of both the invading (oligo 135; SEQ ID NO:112) and stacking oligonucleotides (oligo 147; SEQ ID NO:113) and 100 pM ssM13 DNA. The reactions were overlayed with mineral oil, heated to 90° C. for 15 sec then brought to the reaction temperature. Reactions were performed at 35°, 40°, 45°, 50°, 55°, 60°, and 65° C. The cleavage reactions were initiated by the addition of 1 μl of 100 ng/μl Pfu FEN-1 and 1 μl of varying concentrations of Cy-3 labeled 142 miniprobe oligonucleotide (SEQ ID NO:114). Reactions were allowed to proceed for 1 hour and stopped by the addition of 10 μl formaldehyde. One fourth of the total volume of each reaction was loaded onto 20% non-denaturing polyacrylamide gels, which were electrophoresed in the reverse direction. Gels were visualized using an Hitachi FMBIO-100 fluorescent scanner using a 585 nm filter. The fluorescence in each product band was measured and the graph shown in FIG. **80** was created using a Microsoft Excel spreadsheet.

[1022] The data summarized in FIG. **80** showed that the concentration of the miniprobe had a significant effect on the final measure of product, showing dramatic increases as the concentration was raised. Increases in the concentration of the miniprobe also shifted the optimum reaction temperature upward. It is known in the art that the concentration of the complementary strands in a hybridization will affect the apparent T_m of the duplex formed between them. More significantly to the methods and compositions of the present invention is the fact that the presence of the stacker oligonucleotide has a profound influence on the cleavage rate of the miniprobe at all probe concentrations. At each of the probe concentrations the presence of the stacker as much as doubled the signal from the cleavage product. This demonstrated the utility of using the stacker oligonucleotide in combination with the miniprobes described herein.

Example 37

The Presence of a Mismatch in the INVADER Oligonucleotide Decreases the Cleavage Activity of the CLEAVASE A/G Nuclease

[1023] In any nucleic acid detection assay it is of additional benefit if the assay can be made to sensitively detect minor differences between related nucleic acids. In the following experiment, model cleavage substrates were used

that were identical except for the presence or absence of a mismatch near the 3' end of the INVADER oligonucleotide when hybridized to the model target nucleic acid. The effect of a mismatch in this region on the accumulation of cleaved probe was then assessed.

[1024] To demonstrate the effect of the presence of a mismatch in the INVADER oligonucleotide on the ability of the CLEAVASE A/G nuclease to cleave the probe oligonucleotide in an INVADER assay the following experiment was conducted. Cleavage of the test oligonucleotide IT-2 (SEQ ID NO:115) in the presence of INVADER oligonucleotides IT-1 (SEQ ID NO:116) and IT-1A4 (SEQ ID NO:117). Oligonucleotide IT-1 is fully complementary to the 3' arm of IT-2, whereas oligonucleotide IT-1A4 has a T->A substitution at position 4 from the 3' end that results in an A/A mismatch in the INVADER-target duplex. Both the matched and mismatched INVADER oligonucleotides would be expected to hybridize at the temperature at which the following reaction was performed. FIG. **81** provides a schematic showing IT-1 annealed to the folded IT-2 structure and showing IT-1A4 annealed to the folded IT-2 structure.

[1025] The reactions were conducted as follows. Test oligonucleotide IT-2 (0.1 μM), labeled at the 5' end with fluorescein (Integrated DNA Technologies), was incubated with 0.26 ng/μl CLEAVASE AG in 10 μl of CFLP® buffer with 4 mM $MgCl_2$, in the presence of 1 μM IT-1 or IT-1A4 at 40° C. for 10 min; a no enzyme control was also run. Samples were overlaid with 15 μl Chill-Out® liquid wax to prevent evaporation. Reactions were stopped by addition of 4 μl stop buffer (95% formamide, 20 mM EDTA, 0.02% methyl violet). The cleavage products were separated on a 20% denaturing polyacrylamide gel and analyzed with the FMBIO-100 Image Analyzer (Hitachi) equipped with 505 nm filter. The resulting image is shown in FIG. **82**.

[1026] In FIG. **82**, lane 1 contains reaction products from the no enzyme control and shows the migration of the uncut IT-2 oligo; lanes 2-4 contain products from reactions containing no INVADER oligo, the IT-1 INVADER oligo and the IT-1 A4 INVADER oligo, respectively.

[1027] These data show that cleavage is markedly reduced by the presence of the mismatch, even under conditions in which the mismatch would not be expected to disrupt hybridization. This demonstrates that the INVADER oligonucleotide binding region is one of the regions within the complex in which can be used for mismatch detection, as revealed by a drop in the cleavage rate.

Example 38

Comparison of the Activity of the Pfu FEN-1 and Mja EN-1 Nucleases in the INVADER Reaction

[1028] To compare the activity of the Pfu FEN-1 and the Mja FEN-1 nucleases in INVADER reaction the following experiment was performed. A test oligonucleotide IT3 (SEQ ID NO:118) that forms an INVADER-Target hairpin structure and probe oligonucleotide PR1 (SEQ ID NO:119) labeled at the 5' end with fluorescein (Integrated DNA Technologies) were employed in INVADER assays using either the Pfu FEN-1 or the Mja FEN-1 nucleases.

[1029] The assays were conducted as follows. Pfu FEN-1 (13 ng/μl) and Mja FEN-1 (10 ng/μl) (prepared as described in Ex. 28) were incubated with the IT3 (0.1 nM) and PR1 (2 and 5 μM) oligonucleotides in 10 μl CFLP® buffer, 4 mM $MgCl_2$, 20 mg/ml tRNA at 55° C. for 41 min. Samples were overlaid with 15 μl Chill-Out® evaporation barrier to prevent evaporation. Reactions were stopped by addition of 70 μl stop buffer (95% formamide, 20 mM EDTA, 0.02% methyl violet). Reaction products (1 μl) were separated on a 20% denaturing polyacrylamide gel, visualized using a fluoroimager and the bands corresponding to the probe and the product were quantitated. The resulting image is shown in FIG. **83**. In FIG. **83**, the turnover rate per target per minute is shown below the image for each nuclease at each concentration of probe and target tested.

[1030] It was demonstrated in Example 32 that the use of the Pfu FEN-1 structure-specific nuclease in the INVADER-directed cleavage reaction resulted in a faster rate of product accumulation than did the use of the CLEAVASE A/G. The data presented here demonstrates that the use of Mja FEN-1 nuclease with the fluorescein labeled probe further increases the amount of product generated by an average of about 50%, demonstrating that, in addition to the Pfu FEN-1 nuclease, the Mja FEN-1 nuclease is a preferred structure-specific nuclease for the detection of nucleic acid targets by the method of the present invention.

Example 39

Detection of RNA Target Nucleic Acids Using Miniprobe and Stacker Oligonucleotides

[1031] In addition to the detection of the M13 DNA target material described above, a miniprobe/stacker system was designed to detect the HCV-derived RNA sequences described in Example 19. A probe of intermediate length, either a long mid-range or a short standard probe, was also tested. The miniprobe used (oligo 42-168-1) has the sequence: 5'-TET-CCGGTCGTCCTGG-3' (SEQ ID NO:120), the stacker oligonucleotide used (oligo 32-085) with this miniprobe has the sequence: 5'-CAATTCCGGT-GTACTACCGGTTCC-3' (SEQ ID NO:121). The slightly longer probe, used without a stacker (oligo 42-088), has the sequence: 5'-TET-CCGGTCGTCCTGGCAA-3' (SEQ ID NO:122). The INVADER oligonucleotide used with both probes has the sequence: 5'-GTTTATCCAAGAAAGGAC-CCGGTC-3' (SEQ ID NO:47). The reactions included 50 fmole of target RNA, 10 pmole of the INVADER oligonucleotide and 5 pmole of the miniprobe oligonucleotide in 10 μl of buffer containing 10 mM MES, pH 6.5 with 150 mM LiCl, 4 mM $MnCl_2$, 0.05% each Tween-20 and NP-40, and 39 units of RNAsin (Promega). When used, 10 pmoles of the stacker oligonucleotide was added. These components were combined, overlaid with CHILLOUT evaporation barrier, and warmed to 50° C.; the reactions were started by the addition of 5 polymerase units of DNAPTth, to a final reaction volume of 10 μl. After 30 minutes at 50° C., reactions were stopped by the addition of 8 μl of 95% formamide, 10 mM EDTA and 0.02% methyl violet. The samples were heated to 90° C. for 1 minute and 2.5 μl of each of these reactions were resolved by electrophoresis through a 20% denaturing polyacrylamide (19:1 cross link) with 7M urea in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA, and the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi). The resulting image is shown in FIG. **84**.

[1032] In FIG. **84**, lanes 1 and 2 show the products of reactions containing the HCV INVADER oligonucleotide and the longer probe (oligo 42-088), without and with the target RNA present, respectively. Lanes 3, 4, and 5 show the products of reactions containing the INVADER oligonucleotide and the shorter probe (oligo 42-168-1). Lane 3 is a control reaction without target RNA present, while lanes 4 and 5 have the target, but are without or with the stacker oligonucleotide, respectively.

[1033] Under these conditions the slightly longer (16 nt) probe oligonucleotide was cleaved quite easily without the help of a stacker oligonucleotide. In contrast, the shorter probe (13 nt) required the presence of the stacker oligonucleotide to produce detectable levels of cleavage. These data show that the miniprobe system of target detection by INVADER-directed cleavage is equally applicable to the detection of RNA and DNA targets. In addition, the comparison of the cleavage performance of longer and shorter probes in the absence of a stacker oligonucleotide give one example of the distinction between the performance of the miniprobe/stacker system and the performance of the mid-range and long probes in the detection of nucleic acid targets.

Example 40

Effect of an Unpaired 3' Tail on Transcription from a Complete (Un-Nicked) Promoter

[1034] In designing the method of transcription-based visualization of the products of INVADER-directed cleavage, it was first necessary to assess the effect of a 3' tail on the efficiency of transcription from a full length promoter. The duplexes tested in this Example are shown at the bottom of FIG. **93**, and are shown schematically in FIGS. **85**A-C.

[1035] Transcription reactions were performed using the MEGAshortscript™ system from Ambion, Inc. (Austin, Tex.), in accordance with the manufacturer's instructions with the exception that a fluorescein labeled ribonucleotide was added. Each DNA sample was assembled in 4 μl of RNAse-free dH_2O. Reactions 1-3 each contained 10 pmole of the copy template oligo 150 (SEQ ID NO:123); reaction 2 contained 10 pmole of the promoter oligo 151 (SEQ ID NO:124); sample 3 contained 10 pmole of the 3' tailed promoter oligo 073-065 (SEQ ID NO:125); sample 4 had no added DNA. To each sample, 6 μl of a solution containing 1 μl of 10× Transcription Buffer, 7.5 mM each rNTP, 0.125 mM fluorescein-12-UTP (Boehringer) and 1 μl T7 MEGAshortscript™ Enzyme Mix was added. The samples were then incubated at 37° C. for 1 hour. One microliter of RNase-free DNase 1 (2 U/μl) was added to each sample and the samples were incubated an additional 15 minutes at 37° C. The reactions were then stopped by the addition of 10 μl of a solution of 95% formamide, 5 mM Na_2EDTA, with loading dyes. All samples were heated to 95° C. for 2 minutes and 4 μl of each sample were resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. The gel was analyzed with a FMBIO II fluorescence image analyzer, and the resulting image is shown in FIG. **93**. The RNA produced by successful transcription appears near the middle of the panel, as indicated ("RNA").

[1036] Examination of the products of transcription shown in lanes 2 and 3 show that the presence of the 3' tail on the full-length promoter has an adverse affect on the efficiency of transcription, but does not shut it off completely. Because the objective of the transcription-based visualization assays of the present invention is to discriminate between uncleaved probe and the shorter products of the invasive cleavage assay (cut probe), these data indicate that production of a full-length promoter in the cleavage reaction would be difficult to resolve from the background created by transcription from promoters containing the uncleaved probe if no other oligonucleotides were included in the assay. Means of suppressing transcription from such a branched promoter are discussed in the Description of the Invention and discussed below in Ex. 43.

Example 41

Examination of the Influence of the Position of the Nick on the Efficiency of Transcription from Partial and Complete Composite Bacteriophage T7 Promoters

[1037] In the Description of the Invention, the procedure for testing prospective promoter pieces for suitability in an invasive cleavage-linked assay is described. One aspect of the test is to examine the effect a chosen nick site has on the efficiency of transcription from the final composite promoter. In addition, the individual pieces of nicked promoter are tested for transcription activity in the presence of the full-length un-nicked strand. In this experiment, a comparison on these points is made between a composite promoter having a nick in the non-template strand between nucleotides −11 and −10 relative to the initiation site (+1), and a promoter having a nick on the same strand, but positioned between nucleotides −8 and −7. The Figure numbers for the schematic representations of the contents of each reaction are indicated below each lane (e.g., **85**A=FIG. **85**A). The site where the nick would be in a fully assembled composite promoter using the reaction oligonucleotides is also indicated below each lane ("−11/−10" and "−8/−7").

[1038] Transcription reactions were performed using the MEGAshortscript™ system, in accordance with the manufacturer's instructions, but with the exception that a fluorescein labeled ribonucleotide was added. Each DNA sample was assembled in 4 μl of RNAse-free dH_2O. Reaction 1 had no added DNA. Reactions 2-9 each contained 10 pmole of the copy template oligo 150 (SEQ ID NO:123). Reactions 3 and 4 contained 10 pmole of the −11 "cut" probe (oligo 073-061-01; SEQ ID NO:127) or 20 pmole of the −10 partial promoter oligo 073-061-02 (SEQ ID NO:130), respectively, and reaction 5 contained both. Reactions 6 and 7 contained either the 10 pmole of the −8 "cut" probe (oligo 073-062-01; SEQ ID NO:126) or 20 pmoles of the −7 partial promoter oligo 073-062-02 (SEQ ID NO:129), respectively, and reaction 8 contained them both. Reaction 9 contained 10 pmole of the intact promoter oligo 151 (SEQ ID NO:124).

[1039] The transcription reactions were initiated, incubated, terminated and the reaction products were resolved and imaged as described in Ex. 40. The resulting image is shown in FIG. **92**. The reaction numbers correspond to the lane numbers above the image. The RNA created by successful transcription appears in the upper third of the image. Comparison to the positive control reaction (r×n. 9) shows that the full-length RNA produced by each of the composite

promoters is the same size as that produced in the control reaction, indicated that transcription initiated at the same site in each reaction.

[1040] In FIG. **92**, lanes 3, 4, and 5 compare transcription from the two species of partially assembled promoters (see schematics in FIGS. **86**A and B) and the fully assembled composite promoter (FIG. **88**B) having a nick between nucleotides −11 and −10 relative to the start of transcription. It can be seen from these data that neither partial promoter (lanes 3 and 4) is able to support transcription of the copy template, but that the composite promoter (lane 5) with this nick site is strongly transcribed. Surprisingly, comparison to the control reaction (lane 9) shows that the presence of a nick at this site (−11/−10) actually enhances transcription. While not limiting the present invention to any particular mechanism, it is believed that the enhancement of transcription is a result of both suppressing the formation of the shorter abortive transcripts and by allowing greater accumulation of the full length product. This result is highly reproducible.

[1041] In FIG. **92**, lanes 6, 7, and 8 compare transcription a similar set of partial and complete promoters in which the nick is shifted 3 residues closer to the transcription start site. Examination of lane 6 shows that the presence of 3 extra bases on the −8"cut" probe (compared to the −11 "cut" probe in lane 3) allow this partial promoter to initiate transcription. This indicates that the −8/−7 site would be a poor choice for use in this embodiment of the present invention.

[1042] This experiment demonstrates the process for determining the suitable placement of a nick within a promoter assembly to achieve the desired result. Similar tests can easily be designed for testing other nicks within the bacteriophage T7 promoter tested in this Example, or for testing suitable nick placement in any desired phage, prokaryotic or eukaryotic promoter.

Example 42

Detection of the Products of INVADER-Directed Cleavage Through Transcription from a Composite Promoter

[1043] The Examples described above indicate that a small oligonucleotide can be used to complete assembly of a composite T7 promoter, thereby enabling transcription from that promoter. Earlier Examples demonstrate that the invasive cleavage reaction can be used release specific small oligonucleotide products from longer probe oligonucleotides. In this Example, it is demonstrated that these two observations can be combined, and that the products of the invasive cleavage reaction can be used to complete a promoter and enable subsequent transcription. The schematic representations of the composite promoters tested in this Example are shown in FIG. **88**.

[1044] Two invasive cleavage reactions were set up, one without (r×n. 1) and one with (r×n. 2) input target DNA. The reactions (1 and 2) comprised 10 mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40 and 20 pmoles probe oligo 073-067-01 (SEQ ID NO:132) and 10 pmoles INVADER oligo 073-073-02 (SEQ ID NO:134) in a volume of 14 μl. Reaction 2 also included 100 fmoles M13mp18 ssDNA. The samples were placed at 60° C. and 6 μl of a solution containing 20 ng of Mja FEN-1 and 40 mM Mg_2Cl were added to each sample to start the reactions. The samples were incubated at 60° C. for 30 minutes and stopped by the addition of 3 μl of 2.5M NaOAc, 83 mM Na_2EDTA (pH 8.0). Each sample was transferred to a 1.5 ml microcentrifuge tube and then the DNAs were precipitated by the addition of 60 μl of chilled 100% ethanol, and were stored at −20° C. for 20 minutes. The pellets were collected by microcentrifugation, washed once with 80% ethanol to remove excess salt, then dried under vacuum. The product of this invasive cleavage reaction is a 12 nt oligonucleotide having the sequence: 5'-CGAAATTAATAC-3' (SEQ ID NO:128), termed the −12 cut probe (same sequence as oligo 073-073-03).

[1045] For transcription, the dried samples were each dissolved in 4 μl of a solution containing 1 pmole copy template oligo 150 and 2 pmoles −11 partial promoter oligo 073-073-012 (SEQ ID NO:131). Control samples 3 and 4 each contained 1 pmole of the copy template oligo 150; sample 3 also contained 1 pmole probe oligo 073-067-01 (SEQ ID NO:132) and 2 pmoles −11 partial promoter oligo 073-073-012 (see structure **88**A); sample 4 contained 1 pmole −12 "cut" probe oligo 073-073-03 (SEQ ID NO:128) and 2 pmoles −11 partial promoter oligo 073-073-012 (see structure **88**B). These are the structures that would be expected to exist in the transcription reactions from the two invasive cleavage reactions described above.

[1046] The transcription reactions were initiated, incubated, terminated and the products were resolved and imaged as described in Ex. 40. The resulting image is shown in the right half of FIG. **89** (lanes 6-9). Samples 3 and 4 appear in lanes 6 and 7, respectively, and the reactions 1 and 2 from the invasive cleavage reaction products (indicated by the use of the lower case "i"), appear in lanes 8 and 9, respectively. The number of the FIG. showing the schematic representation of the expected promoter structure in each reaction is indicated above each lane, and the placement of the nick is also indicated. The uppercase letters indicate which structure in the particular Figure to examine for each reaction. The lowercase "i" above lanes 8 and 9 indicate that these transcriptions were derived from actual invasive cleavage reactions. These products are compared to the RNA produced in the control reaction in lane 5, the procedure for which is described in Ex. 44. The RNA created by successful transcription appears in the upper third of the panel (indicated by "RNA").

[1047] The reaction shown in lane 6 shows no transcription. This demonstrates that a nick between nucleotides −12 and −11 in the on-template strand of the T7 promoter eliminates transcription if the promoter is assembled from uncut probe such as the 3' end of the probe forms a branch within the promoter sequence. This is in contrast to the results seen with the −11/−10 nick examined below. Further, the transcript apparent in lane 7 shows that an unbranched promoter with a nick at the same site (−12/−11) produces the correct RNA, with few abortive initiation products (see lanes 2 and 5 of FIG. **89**, described in Ex. 44). The reactions in lanes 8 and 9 demonstrate that the same effect is observed when the invasive cleavage reaction is the sole source of the upstream piece (−12 cut probe) of the T7 promoter. It is worthy of note that the promoter that is transcribed in lane 8 is made complete by the presence of 1 pmole of a synthetic "cut" probe oligo, without any uncut probe in the mixture, while the promoter that is transcribed in lane 9 is completed

by the product of an invasive cleavage reaction that had only 100 fmole of target DNA in it. This reaction also included the residual uncut probe (up to approx. 10 pmoles), which may compete for binding at the same site. Nonetheless, the transcriptions from the invasive cleavage reaction products are only slightly reduced in efficiency, and are just as free of background as is the "no target" sample (lane 8). This Example clearly demonstrates that the cleavage products from the invasive cleavage reaction can be used in combination with a partial promoter oligo to promote the production of RNA, without background transcription generated by the presence of the uncut probe. This RNA product is clearly dependent on the presence of the target material in the invasive cleavage reaction.

Example 43

Shutting Down Transcription from a "Leaky" Branched T7 Composite Promoter Through the Use of a Downstream Partial Promoter Oligonucleotide Having a 5' Tail

[1048] The previous Example demonstrated that placement of a nick in the non-template strand of a bacteriophage T7 promoter between the −12 and −11 nucleotides, relative to the transcription start site, prevents transcription of the branched promoter while allowing transcription when the composite promoter is assembled using the cut probe. When the nick is placed in other locations in the T7 promoter, transcription may be initiated from either promoter, although it is usually less efficient from the branched promoter. This Example demonstrates that the addition of a 5' tail that can base pair to the uncut probe (FIG. **90**A) to the downstream partial promoter piece effectively blocks transcription from that promoter, but does not prevent transcription when a cut probe completes the promoter (FIG. **90**B).

[1049] Two invasive cleavage reactions were set up, one without (r×n. 7) and one with (r×n. 8) input target DNA. The reactions (7 and 8) comprised 10 mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40 and 20 pmoles probe oligo 073-067-01 (SEQ ID NO:132) and 10 pmoles INVADER oligo 073-067-02 (SEQ ID NO:133) in a volume of 14 μl. Reaction 8 also included 100 fmoles M13mp18 ssDNA. The samples were placed at 60° C. and 6 μl of a solution containing 20 ng of Mja FEN-1 and 40 mM Mg_2Cl were added to each sample to start the reactions. The samples were incubated at 60° C. for 30 minutes and then stopped by the addition of 3 μl of 2.5M NaOAc, 83 mM Na_2EDTA (pH.8.0). Each sample was transferred to a 1.5 ml microcentrifuge tube and the DNAs were precipitated, washed and dried as described in Ex. 42. The product of this invasive cleavage reaction is 13 nt oligonucleotide sequence, 5'-CGAAATTAATACG-3' (SEQ ID NO:127), termed the −11 cut probe (same sequence as oligo 073-061-01 which is referred to as the −11 "cut" probe to indicate it was not generated in an invasive cleavage reaction).

[1050] In the transcription reactions, all of the DNAs were dissolved in 4 μl of RNase-free dH_2O, Sample 1 had no added DNA, samples 2-8 contained 1 pmole of the copy template oligo 150 (SEQ ID NO:123). In addition, sample 3 contained 1 pmole of −11 "cut" probe oligo 073-061-01 (SEQ ID NO:127) and 2 pmoles of −10 partial promoter oligo 073-061-02 (SEQ ID NO:130), sample 4 contained 1 pmole of probe oligo 073-067-01 and 2 pmoles of −10 partial promoter oligo 073-061-02. Control sample 5 contained 1 pmole of probe oligo 073-067-01 and 2 pmoles of partial promoter w/5' tail oligo 073-074 (5'-TACTGACTCACTATAGGGTCTTCTATGGAG GTC-3' (SEQ ID NO:146) (see structure in FIG. **90**A) and sample 6 contained 1 pmole of −11 "cut" probe oligo 073-061-01 and 2 pmoles of partial promoter w/5' tail oligo 073-074 (see structure in FIG. **90**B). These are the structures (i.e., **90**A and **90**B) that would be expected to exist in the transcription reactions from the two invasive cleavage reactions described above.

[1051] The dried samples 7 and 8 from the invasive cleavage (above) were each dissolved in 4 μl of dH_2O containing 1 pmole copy template oligo 150 and 2 pmoles partial promoter w/5' tail oligo 073-074. The transcription reactions were initiated, incubated, terminated and the reaction products were resolved and imaged as described in Ex. 40. The resulting image is shown in FIG. **91**.

[1052] In FIG. **91** the lane numbers correspond to the sample numbers; the number of the Figure showing the schematic representation of the expected promoter structure in each reaction is indicated above each lane ("88" and "90"), and the placement of the nick is also indicated ("−11/−10"). The upper-case letters indicate which structure in the particular Figure to examine for each reaction. The lower case "i" above lanes 7 and 8 indicates that these transcriptions were derived from actual invasive cleavage reactions. The RNA created by successful transcription appears in the upper third of the panel, as indicated ("RNA").

[1053] The control reactions in lanes 1 and 2, having either no DNA or having the only the copy template, produced no RNA as expected. The product in lane 4 demonstrates that the branched T7 promoter with a nick in the non-template strand between nucleotides −11 and −10 can support transcription, albeit not as efficiently as the un-branched promoter with the nick at the same site (lane 3). Examination of lane 5 shows that the use of a partial promoter oligonucleotide with a short 5' tail that can basepair to the uncut probe as depicted in FIG. **90**A, effectively suppresses this transcription but allows transcription when the probe does not have a 3' tail (lane 6; schematic FIG. **90**B). The reactions in lanes 7 and 8 demonstrate that the same effect as observed when the invasive cleavage reaction is the sole source of the upstream piece (−11 cut probe, SEQ ID NO:127) of the T7 promoter. It is worthy of note that the promoter that is transcribed in sample 6 is made complete by the presence of 1 pmole of a synthetic "cut probe", without any uncut probe in the mixture, while the promoter that is transcribed in sample 8 is completed by the product of an invasive cleavage reaction that had only 100 fmole of target DNA in it. This reaction also included the residual uncut probe (up to approximately 19 pmoles), which may compete for binding at the same site. Nonetheless, the transcriptions from the invasive cleavage reaction products are just as strong and just as free of background in the "no target" samples.

[1054] This Example clearly demonstrates that the cleavage products from the invasive cleavage reaction can be used in combination with a partial promoter oligonucleotide having a 5' tail to promote the production of RNA, without background transcription generated by the uncut probe. This RNA product is clearly dependent on the presence of the target material in the invasive cleavage reaction.

Example 44

Creation of a Complete Bacteriophage T7 Promoter by DNA Polymerase-Mediated Extension of a Cut Probe Comprising a Partial T7 Promoter

[1055] As demonstrated in the Examples above, transcription cannot occur from the T7 promoter unless a complete promoter region is present. In the above Examples, a complete promoter containing a nick in one strand was created by annealing a cut probe generated from an invasive cleavage reaction to a copy template that was annealed to a partial promoter oligo. An alternative means of creating a complete promoter in a manner dependent upon detection of a target sequence in an invasive cleavage reaction is to anneal the cut probe to a copy template devoid of a partial promoter oligo. The 3'-OH present at the end of the annealed cut probe is then extended by a DNA polymerase to create a complete and un-nicked promoter that is transcription-competent.

[1056] In this Example, the promoter was made complete through the use of primer extension, rather that by the co-hybridization of another oligonucleotide. The reaction steps are diagrammed schematically in FIG. **87**. Two invasive cleavage reactions were set up, one without (r×n. 1) and one with (r×n. 2) input target DNA. The reactions (1 and 2) comprised 10 mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40 and 20 pmoles probe oligo 073-067-01 (SEQ ID NO:132) and 10 pmoles INVADER oligo 073-073-02 (SEQ ID NO:134) in a volume of 14 μl. Reaction 2 also included 100 fmoles M13mp18 ssDNA. The samples were placed at 60° C. and 6 μl of a solution containing 20 ng of Mja FEN-1 and 40 mM Mg_2Cl were added to each sample to start the reactions. The samples were incubated at 60° C. for 30 minutes and stopped by the addition of 3 μl of 2.5M NaOAc, 83 mM Na_2EDTA (pH 8.0). Each sample was transferred to a 1.5 ml microcentrifuge tube and then the DNAs were precipitated, washed and dried as described in Ex. 42. The product of this invasive cleavage reaction is the 12 nt oligonucleotide sequence: 5'-CGAAATTAATAC-3' (SEQ ID NO:128), termed the −12 cut probe (same sequence as oligo 073-073-03 which is referred to as the −12 "cut" probe to indicate it was not generated in an invasive cleavage reaction).

[1057] To allow extension of these products using a template-dependent DNA polymerase, a 20 μl solution containing 20 mM Tris-HCl (pH 8.5), 1.5 mM Mg_2Cl, 50 mM KCl, 0.05% Tween-20, 0.05% NP-40, 25 μM each dNTP, 0.25 units Taq DNA polymerase (Boehringer) and 2 μM copy template oligo 150 (SEQ ID NO:123) was added to each of the dried cleavage samples. The samples were incubated at 30° C. for 1 hr. The primer extension reactions were stopped by the addition of 3 μl of 2.5M NaOAc with 83 mM Na_2EDTA (pH 8.0)/sample. Each sample was transferred to a 1.5 ml microcentrifuge tube and the DNAs were precipitated, washed and dried as described in Ex. 42.

[1058] Samples 1 and 2 were then dissolved in 4 μl RNase-free dH_2O, Samples 3, 4 and 5 are control reactions: sample 3 was 4 μl of RNase-free dH_2O without added DNA, sample 4 contained 1 pmole of the copy template oligo 150 (SEQ ID NO:123) in 4 μl of RNase-free dH_2O, and sample 5 contained 1 pmole of the same copy template and 1 pmole of the complete promoter oligo 151 (SEQ ID NO:124) in RNase-free dH_2O.

[1059] Transcription reactions were performed using the MEGAshortscript™ system, in accordance with the manufacturer's instructions, but with the addition of a fluorescein labeled ribonucleotide. To each sample, 6 μl of a solution containing 1 μl of 10× Transcription Buffer, 7.5 mM each rNTP, 0.125 mM fluorescein-12-UTP (Boehringer) and 1 μl T7 MEGAshortscript™ Enzyme Mix was added. The samples were incubated at 37° C. for 1 hour. One μl of RNase-free DNase 1 (2 U/μl) was added to each sample and they were incubated an additional 15 minutes at 37° C. The reactions were stopped by the addition of 10 μl of a solution of 95% formamide, 5 mM NaEDTA, with loading dyes. All samples were heated to 95° C. for 2 minutes and four μl of each sample were resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, with excitation at 488 nm and, emission detected at 530 nm.

[1060] The resulting image is shown in lanes 1 through 5 of FIG. **89**; the lane numbers correspond to the sample numbers. The Figure numbers corresponding to the schematic representations of the promoters transcribed in each reaction as indicated above the lanes. The RNA product from successful transcription appears in the upper third of the panel, as indicated ("RNA"). Unincorporated labeled nucleotide appears as a dense signal near the bottom ("NTPs"). Short transcription products caused by aborted initiation events (Milligan and Uhlenbeck, Methods Enzymol., 180:51 [1989]) appear as bands just above the free nucleotide in the lanes showing active transcription (i.e., lanes 2 and 5).

[1061] It can clearly be seen from the data in lanes 1 and 2 that the transcription is dependent on the presence of the target material in the invasive cleavage reaction. It is shown elsewhere (see lane 3, FIG. **92**) that the product of the cleavage reaction is not in itself sufficient to allow transcription from the copy template. Thus, the action of the DNA polymerase in extending the hybridized cut probe across the promoter is a necessary step in enabling the transcription in this embodiment. These data clearly demonstrate that both template-dependent extension by DNA polymerase, and extension followed by transcription are suitable methods of visualizing the products of the invasive cleavage assay. As discussed in the Description of the Invention, the products of thermal breakdown that possess 3' terminal phosphates would not be extended, and would thus be precluded from contributing to background transcription.

Example 45

Test for the Dependence of an Enzyme on the Presence of an Upstream Oligonucleotide

[1062] When choosing a structure-specific nuclease for use in a sequential invasive cleavage reaction it is preferable that the enzyme have little ability to cleave a probe 1) in the absence of an upstream oligonucleotide, and 2) in the absence of overlap between the upstream oligonucleotide and the downstream labeled probe oligonucleotide. FIGS. **99***a-e* depicts the several structures that can be used to examine the activity of an enzyme that is confronted with each of these types of structures. The structure a (FIG. **99***a*) shows the alignment of a probe oligonucleotide with a target

site on bacteriophage M13 DNA (M13 sequences shown in FIG. **99** are provided in SEQ ID NO:163) in the absence of an upstream oligonucleotide. Structure b (FIG. **99***b*) is provided with an upstream oligonucleotide that does not contain a region of overlap with the labeled probe (the label is indicated by the star). In structures c, d and e (FIGS. **99***c-e*) the upstream oligonucleotides have overlaps of 1, 3 or 5 nucleotides, respectively, with the downstream probe oligonucleotide and each of these structures represents a suitable invasive cleavage structure. The enzyme Pfu FEN-1 was tested for activity on each of these structures and all reactions were performed in duplicate.

[**1063**] Each reaction comprised 1 μM 5' TET labeled probe oligonucleotide 89-15-1 (SEQ ID NO:152), 50 nM upstream oligonucleotide (either oligo 81-69-2 [SEQ ID NO:153], oligo 81-69-3 [SEQ ID NO:154], oligo 81-69-4 [SEQ ID NO:155], oligo 81-69-5 [SEQ ID NO:156], or no upstream oligonucleotide), 1 fmol M13 target DNA, 10 mg/ml tRNA and 10 ng of Pfu FEN-1 in 10 μl of 10 mM MOPS (pH 7.5), 7.5 mM $MgCl_2$ with 0.05% each of Tween 20 and Nonidet P-40.

[**1064**] All of the components except the enzyme and the $MgCl_2$ were assembled in a final volume of 8 μl and were overlaid with 10 μl of Chill-Out™ liquid wax. The samples were heated to the reaction temperature of 69° C. The reactions were started by the addition of the Pfu FEN-1 and $MgCl_2$, in a 2 μl volume. After incubation at 69° C. for 30 minutes, the reactions were stopped with 10 μl of 95% formamide, 10 mM EDTA, 0.02% methyl violet. Samples were heated to 90° C. for 1 min immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Gels were then analyzed with a FMBIO-100 Hitachi FMBIO fluorescence imager. The resulting image is displayed in FIG. **100**.

[**1065**] In FIG. **100**, lanes labeled "a" contain the products generated from reactions conducted without an upstream oligonucleotide (structure a), lanes labeled "b" contain an upstream oligonucleotide that does not invade the probe/target duplex (structure b). Lanes labeled "c", "d" and "e" contain the products generated from reactions conducted using an upstream oligonucleotide that invades the probe/target duplex by 1, 3 or 5 bases, respectively. The size (in nucleotides) of the uncleaved probe and the cleavage products is indicated to the left of the image in FIG. **100**.

[**1066**] As shown in FIG. **100**, cleavage of the probe was not detectable when structures a and b were utilized. In contrast, cleavage products were generated when invasive cleavage structures were utilized (structures c-e). These data show that the Pfu FEN-1 enzyme requires an overlapping upstream oligonucleotide for specific cleavage of the probe.

[**1067**] Any enzyme may be examined for its suitability for use in a sequential invasive cleavage reaction by examining the ability of the test enzyme to cleave structures a-e (it is understood by those in the art that the specific oligonucleotide sequences shown in FIGS. **99***a-e* need not be employed in the test reactions; these structures are merely illustrative of suitable test structures). Desirable enzymes display little or no cleavage of structures a and b and display specific cleavage of structures c-e (i.e., they generate cleavage products of the size expected from the degree of overlap between the two oligonucleotides employed to form the invasive cleavage structure).

Example 46

Use of the Products of a First Invasive Cleavage Reaction to Enable a Second Invasive Cleavage Reaction with a Net Gain in Sensitivity

[**1068**] As discussed in the Description of The Invention above, the detection sensitivity of the invasive cleavage reaction can be increased by the performing a second round of invasive cleavage using the products of the first reaction to complete the cleavage structure in the second reaction (shown schematically in FIG. **96**). In this Example, the use of a probe that, when cleaved in a first invasive cleavage reaction, forms an integrated INVADER oligo and target molecule for use in a second invasive cleavage reaction, is illustrated (shown schematically in FIG. **97**).

[**1069**] A first probe was designed to contain some internal complementarity so that when cleaved in a first invasive cleavage reaction the product ("Cut Probe 1") could form a target strand comprising an integral INVADER oligonucleotide, as depicted in FIG. **97**. A second probe was provided in the reaction that would be cleaved at the intended site when hybridized to the newly formed target/INVADER (FIG. **97**). To demonstrate the gain in signal due to the performance of sequential invasive cleavages, a standard invasive cleavage assay, as described above, was performed in parallel.

[**1070**] All reactions were performed in duplicate. Each standard (i.e., non-sequential) invasive cleavage reaction comprised 1 μM 5' fluorescein-labeled probe oligo 073-182 (5' Fl-AGAAAGGAAGGGAAGAAAGCGAA-3'; SEQ ID NO:157), 10 nM upstream oligo 81-69-4 (5'-CT-TGACGGGGAAAGCCGGCGAACGTGGCGA-3'; SEQ ID NO:155), 10 to 100 attomoles of M13 target DNA, 10 mg/ml tRNA and 10 ng of Pfu FEN-1 in 10 μl of 10 mM MOPS (pH 7.5), 8 mM $MgCl_2$ with 0.05% each of Tween 20 and Nonidet P-40. All of the components except the enzyme and the $MgCl_2$ were assembled in a volume of 7 μl and were overlaid with 10 μl of Chill-Out™ liquid wax. The samples were heated to the reaction temperature of 62° C. The reactions were started by the addition of the Pfu FEN-1 and $MgCl_2$, in a 2 μl volume. After incubation at 62° C. for 30 minutes, the reactions were stopped with 10 μl of 95% formamide, 10 mM EDTA, 0.02% methyl violet.

[**1071**] Each sequential invasive cleavage reaction comprised 1 μM 5' fluorescein-labeled oligonucleotide 073-191 (the first probe or "Probe 1", 5' Fl-TGGAGGTCAAAA-CATCGATAAGTCGAAGAAAGGAAGGGAAGAAAT-3'; SEQ ID NO:158), 10 nM upstream oligonucleotide 81-69-4 (5'-CTTGACGGGGAAA GCCGGCGAACGTGGCGA-3'; SEQ ID NO:155), 1 μM of 5' fluorescein labeled oligonucleotide 106-32 (the second probe or "Probe 2", 5' Fl-TGTTTTGACCT CCA-3'; SEQ ID NO:159), 1 to 100 amol of M13 target DNA, 10 mg/ml tRNA and 10 ng of Pfu FEN-1 in 10 μl of 10 mM MOPS (pH 7.5), 8 mM $MgCl_2$ with 0.05% each of Tween 20 and Nonidet P-40. All of the components except the enzyme and the $MgCl_2$ were assembled in a volume of 8 μl and were overlaid with 10 μl of Chill-Out™ liquid wax. The samples were heated to the reaction temperature of 62° C. (this temperature is the optimum temperature for annealing of Probe 1 to the first target). The reactions were started by the addition of Pfu FEN-1 and $MgCl_2$, in a 2 μl volume. After incubation at 62°

C. for 15 minutes, the temperature was lowered to 58° C. (this temperature is the optimum temperature for annealing of Probe 2 to the second target) and the samples were incubated for another 15 min. Reactions were stopped by the addition of 10 μl of 95% formamide, 20 mM EDTA, 0.02% methyl violet.

[1072] Samples from both the standard and the sequential invasive cleavage reactions were heated to 90° C. for 1 min immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The gel was then analyzed with a Molecular Dynamics FluorImager 595. The resulting image is displayed in FIG. **101***a*. A graph showing measure of fluorescence intensity for each of the product bands is shown in FIG. **101***b*.

[1073] In FIG. **101***a*, lanes 1-5 contain the products generated in standard invasive cleavage reactions that contained either no target (lane 1), 10 amol of target (lanes 2 and 3) or with 100 amol of target (lanes 4 and 5). The uncleaved probe is seen as a dark band in each lane about half way down the panel and the cleavage products appear as a smaller black band near the bottom of the panel, the position of the cleavage product is indicated by an arrow head to the left of FIG. **101***a*. The gray ladder of bands seen in lanes 1-5 is due to the thermal degradation of the probe as discussed above and is not related to the presence or absence of the target DNA. The remaining lanes display products generated in sequential invasive cleavage reactions that contained 1 amol of target (lanes 6 and 7), 10 amol of target (lanes 8 and 9) and 100 amol of target (lanes 10 and 11). The uncleaved first probe (Probe 1; labeled "1 uncut") is seen near the top of the panel, while the cleaved first probe is indicated as "1: cut". Similarly, the uncleaved and cleaved second probe are indicated as "2: uncut" and 2: cut," respectively.

[1074] The graph shown in FIG. **101***b* compares the amount of product generated from the standard reaction ("Series 1") to the amount of product generated from the second step of the sequential reaction ("Series 2"). The level of background fluorescence measured from a reaction that lacked target DNA was subtracted from each measurement. It can be seen from the table located below the graph that the signal from the standard invasive cleavage assay that contained 100 attomoles of target DNA was nearly identical to the signal from the sequential invasive cleavage assay in which 1 attomole of target was present, indicating that the inclusion of a second cleavage structure increases the sensitivity of the assay 100 to 200-fold. This boost in signal allows easy detection of target nucleic acids at the sub attomole level using the sequential invasive cleavage assay, while the standard assay, when performed using this enzyme for only 30 minutes, does not generate detectable product in the presence of 10 attomoles of target.

[1075] When the amount of target was decreased by 10 or 100 fold in the sequential invasive cleavage assay, the intensity of the signal was decreased by the same proportion. This indicates that the quantitative capability of the invasive cleavage assay is retained even when reactions are performed in series, thus providing a nucleic acid detection method that is both sensitive and quantitative.

[1076] While in this Example, the two probes used had different optimal hybridization temperatures (i.e., the temperature empirically determined to give the greatest turnover rate in the given reaction conditions), the probes may also be selected (i.e., designed) to have the same optimal hybridization temperature so that a temperature shift during incubation is not necessary.

Example 47

The Products of a Completed Sequential Invasive Cleavage Reaction cannot Cross Contaminate Subsequent Similar Reactions

[1077] As discussed in the Description of the Invention, the serial nature of the multiple invasive cleavage events that occur in the sequential invasive cleavage reaction, in contrast to the reciprocating nature of the polymerase chain reaction and similar doubling assays, means that the sequential invasive cleavage reaction is not subject to contamination by the products of like reactions because the products of the first cleavage reaction do not participate in the generation of new signal in the second cleavage reaction. If a large amount of a completed reaction were to be added to a newly assembled reaction, the background that would be produced would come from the amount of target that was also carried in, combined with the amount of already-cleaved probe that was carried in. In this Example, it is demonstrated that a very large portion of a primary reaction must be introduced into the secondary reaction to create significant signal.

[1078] A first or primary sequential invasive cleavage reaction was performed as described above using 100 amol of target DNA. A second set of 5 reactions were assembled as described in Ex. 46 with the exception that portions of the first reaction were introduced and no additional target DNA was included. These secondary reactions were initiated and incubated as described above, and included 0, 0.01, 0.1, 1, or 10% of the first reaction material. A control reaction including 100 amol of target was included in the second set also. The reactions were stopped, resolved by electrophoresis and visualized as described above, and the resulting image is displayed in FIG. **102**. The primary probe, uncut second probe and the cut 2nd probe are indicated on the left as "1: cut", 2: uncut" and 2: cut", respectively.

[1079] In FIG. **102**, lane 1 shows the results of the first reaction with the accumulated product at the bottom of the panel, and lane 2 show a 1:10 dilution of the same reaction, to demonstrate the level of signal that could be expected from that level of contamination, without further amplification. Lanes 3 through 7 show the results of the secondary cleavage reactions that contained 0, 10, 1, 0.1 or 0.01% of the first reaction material added as contaminant, respectively and lane 8 shows a control reaction that had 100 amol of target DNA added to verify the activity of the system in the secondary reaction. The signal level in lane 4 is as would be expected when 10% of the pre-cleaved material is transferred (as in lane 2) and 10% of the transferred target material from the lane 1 reaction is allowed to further amplify. At all levels of further dilution the signal is not readily distinguished from background. These data demonstrate that while a large-scale transfer from one reaction to another may be detectable, cross contamination by the minute quantities that would be expected from aerosol or from equipment contamination would not be easily mistaken for a false positive result. These data also demonstrate that when the products of one reaction are deliberately carried over into a fresh sample, these products do not participate in

the new reaction, and thus do not affect the level of target-dependent signal that may be generated in that reaction.

Example 48

Detection of Human Cytomegalovirus Viral DNA by Invasive Cleavage

[1080] The previous Example demonstrates the ability of the invasive cleavage reaction to detect minute quantities of viral DNA in the presence of human genomic DNA. In this Example, the probe and INVADER oligonucleotides were designed to target the 3104-3061 region of the major immediate early gene of human cytomegalovirus (HCMV) as shown in FIG. **103**. In FIG. **103**, the INVADER oligo (89-44; SEQ ID NO:160) and the fluorescein (Fl)-labeled probe oligo (89-76; SEQ ID NO:161) are shown annealed along a region of the HCMV genome corresponding to nucleotides 3057-3110 of the viral DNA (SEQ ID NO:162). The probe used in this Example is a poly-pyrimidine probe and as shown herein the use of a poly-pyrimidine probe reduces background signal generated by the thermal breakage of probe oligos.

[1081] The genomic viral DNA was purchased from Advanced Biotechnologies, Incorporated (Columbia, Md.). The DNA was estimated (but not certified) by personnel at Advanced Biotechnologies to be at a concentration of 170 amol (1×10^8 copies) per microliter. The reactions were performed in quadruplicate. Each reaction comprised 1 μM 5' fluorescein labeled probe oligonucleotide 89-76 (SEQ ID NO:161), 100 nM INVADER oligonucleotide 89-44 (SEQ ID NO:160), 1 ng/ml human genomic DNA, and one of five concentrations of target HCMV DNA in the amounts indicated above each lane in FIG. **104**, and 10 ng of Pfu FEN-1 in 10 μl of 10 mM MOPS (pH 7.5), 6 mM $MgCl_2$ with 0.05% each of Tween 20 and Nonidet P-40. All of the components except the labeled probe, enzyme and $MgCl_2$ were assembled in a final volume of 7 μl and were overlaid with 10 μl of Chill-Out™ liquid wax. The samples were heated to 95° C. for 5 min, then reduced to 62° C. The reactions were started by the addition of probe, Pfu FEN-1 and $MgCl_2$, in a 3 μl volume. After incubation at 62° C. for 60 minutes, the reactions were stopped with 10 μl of 95% formamide, 10 mM EDTA, 0.02% methyl violet. Samples were heated to 90° C. for 1 min immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Gels were then analyzed with a Molecular Dynamics FluorImager 595.

[1082] The resulting image is displayed in FIG. **104**. The replicate reactions were run in groups of four lanes with the target HCMV DNA content of the reactions indicated above each set of lanes (0-170 amol). The uncleaved probe is seen in the upper third of the panel ("Uncut 89-76") while the cleavage products are seen in the lower two-thirds of the panel ("Cut 89-76"). It can be seen that the intensity of the accumulated cleavage product is proportional to the amount of the target DNA in the reaction. Furthermore, it can be clearly seen in reactions that did not contain target DNA ("no target") that the probe is not cleaved, even in a background of human genomic DNA. While 10 ng of human genomic DNA was included in each of the reactions shown in FIG. **104**, inclusion of genomic DNA up to 200 ng has slight impact on the amount of product accumulated. The data did not suggest that 200 ng per 10 μl of reaction mixture represented the maximum amount of genomic DNA that could be tolerated without a significant reduction in signal accumulation. For reference, this amount of DNA exceeds what might be found in 0.2 ml of urine (a commonly tested amount for HCMV in neonates) and is equivalent to the amount that would be found in about 5 μl of whole blood.

[1083] These results demonstrate that the standard (i.e., non-sequential) invasive cleavage reaction is a sensitive, specific and reproducible means of detecting viral DNA. It can also be seen from these data that the use of a poly-pyrimidine probe reduces the background from thermal breakage of the probe, as discussed in Example 22. Detection of 1.7 amol of target is roughly equivalent to detection of 106 copies of the virus. This is equivalent to the number of viral genomes that might be found in 0.2 mls of urine from a congenitally infected neonate (102 to 106 genome equivalents per 0.2 mls; Stagno et al., J. Infect. Dis., 132:568 [1975]). Use of the sequential invasive cleavage assay would permit detection of even fewer viral DNA molecules, facilitating detection in blood (10^1 to 10^5 viral particles per ml; Pector et al., J. Clin. Microbiol., 30:2359 [1992]), which carries a much larger amount of heterologous DNA.

[1084] From the above it is clear that the invention provides reagents and methods to permit the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. The INVADER-directed cleavage reaction and the sequential INVADER-directed cleavage reaction of the present invention provide ideal direct detection methods that combine the advantages of the direct detection assays (e.g., easy quantification and minimal risk of carry-over contamination) with the specificity provided by a dual or tri oligonucleotide hybridization assay.

[1085] As indicated in the Description of the Invention, the use of sequential invasive cleavage reactions can present the problem of residual uncut first, or primary, probe interacting with the secondary target, and either competing with the cut probe for binding, or creating background through low level cleavage of the resulting structure. This is shown diagrammatically in FIGS. **105** and **106**. In FIG. **105**, the reaction depicted makes use of the cleavage product from the first cleavage structure to form an INVADER oligonucleotide for a second cleavage reaction. The structure formed between the secondary target, the secondary probe and the uncut primary probe is depicted in FIG. **105**, as the right hand structure shown in step 2a. This structure is recognized and cleaved by the 5' nucleases, albeit very inefficiently (i.e., at less than about 1% in most reaction conditions). Nonetheless, the resulting product is indistinguishable from the specific product, and thus may lead to a false positive result. The same effect can occur when the cleaved primary probe creates and integrated INVADER/target (IT) molecule, as described in Example 46; the formation of the undesirable complex is depicted schematically in FIG. **106**, as the right hand structure shown in step 2a.

[1086] The improvements provided by the inclusion of ARRESTOR oligonucleotides of various compositions in each of these types of sequential INVADER assays are demonstrated in the following Examples. These ARRESTOR oligonucleotides are configured to bind the residual uncut probe from the first cleavage reaction in the series, thereby increasing the efficacy of and reducing the non-specific background in the subsequent reaction(s).

Example 49

"ARRESTOR" Oligonucleotides Improve Sensitivity of Multiple Sequential Invasive Cleavage Assays

[1087] In this Example, the effect of including an ARRESTOR oligonucleotide on the generation of signal using the IT probe system depicted in FIGS. **97** and **106** is demonstrated. The ARRESTOR oligonucleotide hybridizes to the primary probe, mainly in the portion that recognizes the target nucleic acid during the first cleavage reaction. In addition to examining the effects of adding an ARRESTOR oligonucleotide, the effects of using ARRESTOR oligonucleotides that extended in complementarity different distances into the region of the primary probe that composes the secondary IT structure were also investigated. These effects were compared in reactions that included the target DNA over a range of concentrations, or that lacked target DNA, in order to demonstrate the level of nonspecific (i.e., not related to target nucleic acid) background in each set of reaction conditions.

[1088] The target DNA for these reactions was a fragment that comprised the full length of the hepatitis B genome from strain of serotype adw. This material was created using the polymerase chain reaction from plasmid pAM6 (ATCC #45020D). The PCRs were conducted using a vector-based forward primer, oligo # 156-022-001 (5'-ggcgaccacacccgtcctgt-3'; SEQ ID NO:168) and a reverse primer, oligo #156-022-02 (5'-ccacgatgcgtccggcgtag-3'; SEQ ID NO:169) to amplify the full length of the HBV insert, an amplicon of about 3.2 kb. The cycling conditions included a denaturation of the plasmid at 95° C. for 5 minutes, followed by 30 cycles of 95° C., 30 seconds; 60° C., 40 seconds; and 72° C., 4 minutes. This was followed by a final extension at 72° C. for 10 minutes. The resulting amplicon, termed pAM6#2, was adjusted to 2 M NH_4OAc, and collected by precipitation with isopropanol. After drying in vacuo, DNA was dissolved in 10 mM Tris pH 0.0, 0.1 mM EDTA. The concentration was determined by OD_{200} measurement, and by INVADER assay with comparison to a standard of known concentration.

[1089] The INVADER reactions were conducted as follows. Five master mixes, termed "A," "B," "C," "D," and "E," were assembled; all mixes contained 12.5 mM MOPS, pH 7.5, 500 fmoles primary INVADER oligo #218-55-05 (SEQ ID NO:171), 10 ng human genomic DNA (Novagen) and 30 ng AfuFEN1 enzyme, for every 8 μl of mix. Mix A contained no added HBV genomic amplicon DNA; mix B contained 600 molecules of HBV genomic amplicon DNA pAM6 #2; mix C contained 6,000 molecules pAM6 #2; mix D contained 60,000 molecules pAM6 #2; and mix E contained 600,000 molecules pAM6 #2. The mixes were aliquotted to the reaction tubes, 8 μl/tube: mix A to tubes 1, 2, 11, 12, 21 and 22; mix B to tubes 3, 4, 13, 14, 23 and 24; mix C to tubes 5, 6, 15, 16, and 26; mix D to tubes 7, 8, 17, 18, 27 and 28; and mix E to tubes 9, 10, 19, 20, 29 and 30. The samples were incubated at 95° C. for 4 minutes to denature the HBV genomic amplicon DNA. The reactions were then cooled to 67° C., and 2 μl of a mix containing 37.5 mM $MgCl_2$ and 2.5 pmoles 218-95-06 (SEQ ID NO:183) for every 2 μl, was added to each sample. The samples were incubated at 67° C. for 60 minutes. Three secondary reaction master mixes were prepared, all mixes contained 10 pmoles of secondary probe oligonucleotide #228-48-04 (SEQ ID NO:173) for every 2 μl of mix. Mix 2A contained no additional oligonucleotide, mix 2B contained 5 pmoles "ARRESTOR" oligo # 218-95-03 (SEQ ID NO:184) and mix 2C contained 5 pmoles of "ARRESTOR" oligo # 218-95-01 (SEQ ID NO:174). After the 60 minute incubation at 67° C. (the primary reaction described above), 2 μl of the secondary reaction mix was added to each sample: Mix 2A was added to samples #1-10; Mix 2B was added to samples #11-20; and Mix 2C was added to samples #21-30. The temperature was adjusted to 52° C. and the samples were incubated for 30 minutes at 52° C. The reactions were then stopped by the addition of 10 μl of a solution of 95% formamide, 5 mM EDTA and 0.02% crystal violet. All samples were heated to 95° C. for 2 minutes, and 4 μl of each sample were resolved by electrophoresis through 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH8.3) and 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, excitation 488, emission 530. The resulting images are shown in FIG. **107**.

[1090] In FIG. **107**, Panel A shows the results of the target titration when no ARRESTOR oligonucleotide was included in the secondary reaction; Panel B shows the results of the same target titration using an ARRESTOR oligonucleotide that extended 2 nt into the non-target complementary region of the primary probe; and Panel C shows the results of the same target titration using an ARRESTOR oligonucleotide that extended 4 nt into the non-target complementary region of the primary probe. The product of the secondary cleavage reaction is seen as a band near the bottom of each panel. The first two lanes of each panel (i.e., 1 and 2, 11 and 12, 21 and 22) lacked target DNA, and the signal the co-migrates with the product band represents the nonspecific background under each set of conditions.

[1091] It can be seen by visual inspection of these panels that the background signal is both reduced, and made more predictable, by the inclusion of either species of ARRESTOR oligonucleotides. In addition to reducing the background in the no-target control lanes, the background reduction in the reactions that had the more dilute amounts of target included is reduced, leading to a signal that is a more accurate reflection of the target contained within the reaction, thus improving the quantitative range of the multiple, sequential invasive cleavage reaction.

[1092] To quantify the impact of including the ARRESTOR oligonucleotide in the secondary cleavage reaction under these conditions, the average product band signal from the reactions having the largest amount of target (i.e., averages of the signals from lanes 9 and 10, lanes 19 and 20, and lanes 29 and 30), were compared to the averaged signal from the no-target control lanes for each panel, determine the "fold over background," the factor of signal amplification over background, under each set of conditions. For the reactions without the ARRESTOR oligonucleotide, Panel A, the fold over background was 5.3; for Panel B, the fold over background was 12.7; and for Panel C, the fold over background was 13.4, indicating that in this system inclusion of any ARRESTOR oligonucleotide at least doubled the specificity of the signal over the ARRESTOR oligonucleotide-less reactions, and that the ARRESTOR oligonucleotide that extended slightly farther into the non-target complementary region may be slightly more effective, at

least in this embodiment of the system. This clearly shows the benefits of using an ARRESTOR oligonucleotide to enhance the specificity of these reactions, an advantage that is of particular benefit at low levels of target nucleic acid.

Example 50

"ARRESTOR" Oligonucleotides Allow Use of Higher Concentrations of Primary Probe without Increasing Background Signal

[1093] It was demonstrated in Example 36, that increasing the concentration of the probe in the invasive cleavage reaction could dramatically increase the amount of signal generated for a given amount of target DNA. While not intending to limit the explanation to any specific mechanism, this is believed to be caused by the fact that increased concentration of probe increases the rate at which the cleaved probe is supplanted by an uncleaved copy, thereby increasing the apparent turnover rate of the cleavage reaction. Unfortunately, this effect could not heretofore be applied in the primary cleavage reaction of a multiple sequential INVADER assay because the residual uncleaved primary probe can hybridize to the secondary target, in competition with the cleaved molecules, thereby reducing the efficacy of the secondary reaction. Elevated concentrations of primary probe exacerbate this problem. Further, the resulting complexes, as described above, can be cleaved at a low level, contributing to background. Therefore, increasing the primary probe can have the double negative effect of both slowing the secondary reaction and increasing the level of this form of non target-specific background. The use of an ARRESTOR oligonucleotide to sequester or neutralize the residual primary probe allows this concentration-enhancing effect to be applied to these sequential reactions.

[1094] To demonstrate this effect, two sets of reactions were conducted. In the first set of reactions, the reactions were conducted using a range of primary probe concentrations, but no ARRESTOR oligonucleotide was supplied in the secondary reaction. In the second set of reactions, the same probe concentrations were used, but an ARRESTOR oligonucleotide was added for the secondary reactions.

[1095] All reactions were performed in duplicate. Primary INVADER reactions were done in a final volume of 10 μl and contained: 10 mM MOPS, pH 7.5, 7.5 mM $MgCl_2$, 500 fin of primary INVADER (218-55-05; SEQ ID NO:171); 30 ng of AfuFEN1 enzyme and 10 ng of human genomic DNA. 100 zeptomoles of HBV pAM6 #2 amplicon was included in all even numbered reactions (by reference to FIGS. **108**A and B). Reactions included 10 pmoles, 20 pmoles, 50 pmoles, 100 pmoles or 150 pmoles of primary probe (218-55-02; SEQ ID NO:170). MOPS, target and INVADER oligonucleotides were combined to a final volume of 7 μl. Samples were heat denatured at 95° C. for 5 minutes, then cooled to 67° C. During the 5 minute denaturation, $MgCl_2$, probe and enzyme were combined. The primary INVADER reactions were initiated by the addition of 3 μl of $MgCl_2$, probe and enzyme mix, to the final concentrations indicated above. Reactions were incubated for 30 minutes at 67° C. The reactions were then cooled to 52° C., and each primary INVADER reaction received the following secondary reaction components in a total volume of 4 μl: 2.5 pmoles secondary target (oligo number 218-95-04; SEQ ID NO:172); 10 pmoles secondary probe (oligo number 228-48-04; SEQ ID NO:173). The reactions that included the ARRESTOR oligonucleotide had either 40 pmoles, 80 pmoles, 200 pmoles, 400 pmoles or 600 pmoles of ARRESTOR oligonucleotide (oligo number 218-95-01; SEQ ID NO:174), added at a 4-fold molar excess over the primary probe amount for each reaction, with this mix. Reactions were then incubated at 52° C. for 30 minutes. The reactions were stopped by the addition of 10 μl of a solution of 95% formamide, 10 mM EDTA and 0.02% crystal violet. All samples were heated to 95° C. for 1 minute, and 4 μl of each sample were resolved by electrophoresis through 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH8.3) and 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, excitation 488, emission 530. The resulting images for the reactions either without or with an ARRESTOR oligonucleotide are shown in FIGS. **108**A and **108**B, respectively. The products of cleavage of the secondary probe are seen as a band near the bottom of each panel.

[1096] In FIG. **108**A, lane sets 1 and 2 show results with 10 pmoles of primary probe; 3 and 4 had 20 pmoles; 5 and 6 had 50 pmoles; 7 and 8 had 100 pmoles; and 9 and 10 had 150 pmoles. It can be seen by visual examination, that the increases in the amount of primary probe have the combined effect of slightly increasing the background in the no-target lanes (odd numbers) while reducing the specific signal in the presence of target (even numbered lanes), and therefore the reducing the specificity of the reaction if viewed as the measure of "fold over background," demonstrating that the approach of increasing signal by increasing probe cannot be applied in these sequential reactions.

[1097] In FIG. **108**B, lane sets 1 and 2 show results with 10 pmoles of primary probe; while 3 and 4 had 20 pmoles; 5 and 6 had 50 pmoles; 7 and 8 had 100 pmoles; and 9 and 10 had 150 pmoles. In addition, each reaction included 4-fold molar excess of the ARRESTOR oligonucleotide added before the secondary cleavage reaction. It can be seen by visual examination that the background in the no-target lanes (odd numbers) is lower in all cases, while the specific signal in the presence of target (even numbered lanes) increases with increased amounts of primary probe, leading to a greater "fold over background" sensitivity at this target level.

[1098] To quantitatively compare these effects, the fluorescence signal from the products of both non-specific and specific cleavage were measured. The results are depicted graphically in FIG. **108**C, graphed as a measure of the percentage of the secondary probe cleaved during the reaction, compared to the amount of primary probe used. Examination of the plots from the no-target reactions confirms that the background in the absence of the ARRESTOR oligonucleotide is, in general, roughly two-fold higher, and that both increase slightly with the increasing probe amounts. The specific signals however, diverge between the two sets of reaction more dramatically. While the signal in the no-ARRESTOR oligonucleotide reactions decreases steadily as primary probe was increased, the signal in the ARRESTOR oligonucleotide reactions continued to increase. At the highest primary probe concentrations tested, the no-ARRESTOR oligonucleotide reactions had specific signal that was only 1.7 fold over background, while the ARRESTOR oligonucleotide reactions detected the 100

zmoles (60,000 copies) of target with a signal 6.5 fold over background, thus demonstrating the improvement in the sequential invasive cleavage reaction when an ARRESTOR oligonucleotide is included.

Example 51

Modified Backbones Improve Performance of ARRESTOR Oligonucleotides all Natural "ARRESTOR" Oligo with no 3'-Amine

[1099] The reactions described in the previous two Examples used ARRESTOR oligonucleotides that were constructed using 2' O-methyl ribose backbone, and that included a positively charged amine group on the 3' terminal nucleotide. The modifications were made specifically to reduce enzyme interaction with the primary probe/ARRESTOR oligonucleotide complex. During the development of the present invention, it was determined that the 2' O-methyl modified oligonucleotides are somewhat resistant to cleavage by the 5' nucleases, just as they are slowly degraded by nucleases when used in antisense applications (See e.g., Kawasaki et al., J. Med. Chem., 36:831 [1993]).

[1100] Further, as demonstrated in Example 35, the presence of an amino group on the 3' end of an oligonucleotide reduces its ability to direct invasive cleavage. To reduce the possibility that the ARRESTOR oligonucleotide would form a cleavage structure in this way, an amino group was included in the design of the experiments described in this and other Examples.

[1101] Initial designs of the ARRESTOR oligonucleotides (sometimes referred to as "blockers") did not include these modifications, and these molecules were found to provide no benefit in reducing background cleavage in the sequential invasive cleavage assay and, in fact, sometimes contributed to background by inducing cleavage at an unanticipated site, presumably by providing some element to an alternative cleavage structure. The effects of natural and modified ARRESTOR oligonucleotide on the background noise in these reactions are examined in this Example.

[1102] The efficacy of an "all-natural ARRESTOR oligonucleotide (i.e., an ARRESTOR oligonucleotide that did not contain any base analogs or modifications) was examined by comparison to an identical reactions that lacked ARRESTOR oligonucleotide. All reactions were performed in duplicate, and were conducted as follows. Two master mixes were assembled, each containing 12.5 mM MOPS, pH 7.5, 500 fmoles primary INVADER oligonucleotide #218-55-05 (SEQ ID NO:171), 10 ng human genomic DNA (Novagen) and 30 ng AfuFEN1 enzyme for every 8 μl of mix. Mix A contained no added HBV genomic amplicon DNA, mix B contained 600,000 molecules of HBV genomic amplicon DNA, pAM6 #2. The mixes were distributed to the reaction tubes, in aliquots of 8 μl/tube as follows: mix A to tubes 1, 2, 5 and 6; and mix B to tubes 3, 4, 7 and 8. The samples were incubated at 95° C. for 4 minutes to denature the HBV genomic amplicon DNA. The reactions were then cooled to 67° C. and 2 ul of a mix containing 37.5 mM $MgCl_2$ and 10 pmoles 218-55-02B (SEQ ID NO:185) for every 2 μl, was added to each sample. The samples were then incubated at 67° C. for 30 minutes. Two secondary reaction master mixes were prepared, each containing 10 pmoles of secondary probe oligo #228-48-04N (SEQ ID NO:178) and 2.5 pmoles of secondary target oligonucleotide #218-95-04 (SEQ ID NO:172) for every 3 μl of mix. Mix 2A contained no additional oligonucleotide, while mix 2B contained 50 pmoles of the natural "ARRESTOR" oligonucleotide #241-62-02 (SEQ ID NO:186). After the initial 30 minute incubation at 67° C., the temperature was adjusted to 52° C., and 3 μl of a secondary reaction mix was added to each sample, as follows: Mix 2A was added to samples #1-4; and Mix 2B was added to samples #5-8. The samples were then incubated for 30 minutes at 52° C. The reactions were then stopped by the addition of 10 μl of a solution of 95% formamide, 10 mM EDTA and 0.02% crystal violet.

[1103] All of the samples were heated to 95° C. for 2 minutes, and 4 μl of each sample were resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH8.3) and 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, excitation 488, emission 530. The resulting image is shown in FIG. **109**A.

[1104] To compare the effects of the various modifications made to the ARRESTOR oligonucleotides, reactions were performed using ARRESTOR oligonucleotides having all natural bases, but including a 3' terminal amine; ARRESTOR oligonucleotide having the 3' portion composed of 2' O-methyl nucleotides, plus the 3' terminal amine; and ARRESTOR oligonucleotide composed entirely of 2' O-methyl nucleotides, plus the 3' terminal amine. These were compared to reactions performed without an ARRESTOR oligonucleotide. The reactions were conducted as follows. Two master mixes were assembled, all mixes contained 14.3 mM MOPS, pH 7.5, 500 fmoles primary INVADER oligo #218-55-05 (SEQ ID NO:171) and 10 ng human genomic DNA (Novagen) for every 7 μl of mix. Mix A contained no added HBV genomic amplicon DNA, mix B contained 600,000 molecules of HBV genomic amplicon DNA, pAM6 #2. The mixes were distributed to the reaction tubes, at 7 μl/tube: mix A to tubes 1, 2, 5, 6, 9, 10, 13 and 14; and mix B to tubes 3, 4, 7, 8, 11, 12, 15 and 16. The samples were warmed to 95° C. for 4 minutes to denature the HBV DNA. The reactions were then cooled to 67° C. and 3 μl of a mix containing 25 mM $MgCl_2$, 25 pmoles 218-55-02B (SEQ ID NO:185) and 30 ng AfuFEN1 enzyme per 3 μl, were added to each sample. The samples were then incubated at 67° C. for 30 minutes. Four secondary reaction master mixes were prepared; all mixes contained 10 pmoles of secondary probe oligonucleotide #228-48-04B (SEQ ID NO:190) and 2.5 pmoles of secondary target oligonucleotide #218-95-04 (SEQ ID NO:172) for every 3 μl of mix. Mix 2A contained no additional oligonucleotide, while mix 2B contained 100 pmoles of the natural+amine ARRESTOR oligonucleotide # 241-62-01 (SEQ ID NO:187), mix 2C contained 100 pmoles of partially O-methyl+amine oligonucleotide # 241-62-03 (SEQ ID NO:188) and mix 2D contained 100 pmoles of all O-methyl+amine oligonucleotide # 241-64-01 (SEQ ID NO:189). After the initial 30 minute incubation at 67° C., the temperature was adjusted to 52° C. and 3 μl of a secondary reaction mix was added to each sample, as follows: mix 2A was added to samples #1-4; mix 2B was added to samples #5-8; mix 2C was added to samples #9-12; and mix 2D was added to samples #13-16. The samples were incubated for 30 minutes at 52° C., then stopped by the addition of 10 μl of a solution of 95% formamide, 10 mM NaEDTA, and 0.2% crystal violet.

[1105] All samples were heated to 95° C. for 2 minutes, and 4 μl of each sample were resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH8.3) and 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, excitation 488, emission 530. The resulting image is shown in FIG. **109**B.

[1106] In FIG. **109**A, the left hand panel shows the reactions that lacked an ARRESTOR oligonucleotide, while the right hand panel shows the data from reactions that included the all natural ARRESTOR oligonucleotide. The first two lanes of each panel are from no-target controls, the second set of lanes contained target. The products of cleavage are visible in the bottom one/fourth of each panel. The position at which the specific reaction products should run is indicated by arrows on left and right.

[1107] It can be seen by examination of these data, that the reactions run in the absence of ARRESTOR oligonucleotide show reproducible quality between the replicates, and show significant cleavage only when target is present. In contrast, the addition of another unmodified oligonucleotide into the reactions causes great variation between the replicate lanes (e.g., lanes 5 and 6 were provided with the same reactants, but produced markedly different results). The introduction of the all natural ARRESTOR oligonucleotide produced, rather than reduced, background in these no-target lanes, and increased cleavage at other sites (i.e., the bands other that those indicated by the arrows flanking the panels). For these reasons the modifications that are described above, the effects of which are shown on FIG. **109**B, were incorporated.

[1108] The first 4 lanes of FIG. **109**B show the products of duplicate reactions without an ARRESTOR oligonucleotide, plus or minus the HBV target (lanes 1, 2, and lanes 3, 4, respectively); The next 4 lanes, 5, 6 and 7, 8 used a natural ARRESTOR oligonucleotide having a 3' terminal amine; lanes 9, 10 and 11, 12 used the ARRESTOR oligonucleotide with a 3' portion composed of 2' O-methyl nucleotides, and having a 3' terminal amine; lanes 13, 14 and 15, 16 used the ARRESTOR oligonucleotide composed entirely of 2' O-methyl nucleotides and having a 3' terminal amine. The products of cleavage of the secondary probe are visible in the lower one third of each panel.

[1109] Visual inspection of these data shows that the addition of the 3' terminal amine to the natural ARRESTOR oligonucleotide suppresses the aberrant cleavage seen in FIG. **109**A, but this ARRESTOR oligonucleotide does not improve the performance of the reaction, as compared to the no-ARRESTOR oligonucleotide controls. In contrast, the use of the 2' O-methyl nucleotides in the body of the ARRESTOR oligonucleotide does reduce background, whether partially or completely substituted. To quantify the relative effects of these modifications, the fluorescence from each of the co-migrating product bands was measured, the signals from the duplicate lanes were averaged and the "fold over background" was calculated for each reaction containing target nucleic acid.

[1110] When ARRESTOR oligonucleotide was omitted, the target specific signal (lanes 3, 4) was 27-fold over the no target background; the natural ARRESTOR oligonucleotide+amine gave a signal of 17-fold over background; the partial 2' O-methyl+amine gave a signal of 47-fold over background; and the completely 2' O-methyl+amine gave a signal of 33 fold over background.

[1111] These Figures show that both modifications can have a beneficial effect on the specificity of the multiple, sequential invasive cleavage assay. They also show that the use of the 2' O-methyl substituted backbone, either partial or entire, markedly improves the specificity of these reactions. It is intended that in various embodiments of the present invention, that any number of modifications that make either the ARRESTOR oligonucleotide or the complex it forms with the primary target resistant to nucleases will provide similar enhancement.

Example 52

Effect of ARRESTOR Oligonucleotide Length on Signal Enhancement in Multiple Sequential Invasive Cleavage Assays

[1112] As noted in the Description of the Invention, the optimal length for an ARRESTOR oligonucleotide depends upon the design of the other nucleic acid elements of the INVADER reaction, particularly on the design of the primary probe. In this Example, the effects of varying the length of the ARRESTOR oligonucleotide were explored in systems using two different secondary probes. A schematic diagram showing these ARRESTOR oligonucleotides aligned as they would hybridize to the primary probe oligonucleotide is provided in FIG. **110**C. In this Figure, the region of the primary probe that recognizes the target nucleic acid is shown underlined; the non-underlined portion, plus the first underlined base is the portion that is released by the first cleavage, and goes on to participate in the second or subsequent cleavage structure.

[1113] All reactions were performed in duplicate. The INVADER reactions were done in a final volume of 10 μl final volume containing 10 mM MOPS, pH 7.5, mM $MgCl_2$, 500 fmoles of primary INVADER 241-95-01, (SEQ ID NO:176), 25 pmoles of primary probe 241-95-02 (SEQ ID NO:175), 30 ng of AfuFEN1 enzyme, and 10 ng of human genomic DNA, and if included, 1 amoles of HBV amplicon pAM 6 #2. MOPS, target DNA, and INVADER oligonucleotides were combined to a final volume of 7 μl. Samples were heat denatured at 95° C. for 5 minutes, then cooled to 67° C. During the 5 minute denaturation, $MgCl_2$, probe and enzyme were combined. The primary INVADER reactions were initiated by the addition of 3 μl of $MgCl_2$, probe and enzyme mix, to the final concentrations indicated above. Reactions were incubated for 30 minutes at 67° C. The reaction were then cooled to 52° C., and each primary INVADER reaction received the following secondary reaction components in a total volume of 3 μl: 2.5 pmoles secondary target 241-95-07 (SEQ ID NO:177), 10 pmoles of either secondary probe 228-48-04 (SEQ ID NO:173), or 228-48-04N (SEQ ID NO:178) and 100 pmoles of an ARRESTOR oligonucleotide, either 241-95-03 (SEQ ID NO:179), 241-95-04 (SEQ ID NO:180), 241-95-05 (SEQ ID NO:181) or 241-95-06 (SEQ ID NO:182). The ARRESTOR oligonucleotide were omitted from some reactions as controls for ARRESTOR oligonucleotide effects.

[1114] The reactions were incubated at 52° C. for 34 minutes, and were then stopped y the addition of 10 μl of

95% formamide, 10 mM EDTA, and 0.02% crystal violet. All samples were heated to 95° C. for 1 minute, and 4 μl of each sample were resolved by electrophoresis through 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH8.3) and 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, excitation 488, emission 530. The resulting images for the reactions with the shorter and longer secondary probes are shown in FIGS. **110**A and **110**B, respectively.

[**1115**] In each Figure, the products of cleavage are visible as bands in the bottom half of each lane. The first 4 lanes of each Figure show the products of duplicate reactions without an ARRESTOR oligonucleotide, plus or minus the HBV target (lanes sets 1 and 2 respectively); in the next 4 lanes, sets 3 and 4 used the shortest ARRESTOR 241-95-03 (SEQ ID NO:179); lanes 5 and 6 used 241-95-04 (SEQ ID NO:180); lanes 7 and 8 used 241-95-05 (SEQ ID NO:181); and lanes 9 and 10 used 241-95-06 (SEQ ID NO:182).

[**1116**] The principal background of concern is the band that appears in the "no target" control lanes (odd numbers; this band co-migrates with the target-specific signal near the bottom of each gel panel). Visual inspection shows that the shortest ARRESTOR oligonucleotide was the least effective at suppressing this background, and that the efficacy was increased when the ARRESTOR oligonucleotide extended further into the portion that participates in the subsequent cleavage reaction. Even with this difference in effect, it can be seen from these data that there is much latitude in the design of the ARRESTOR oligonucleotide. The choice of lengths will be influenced by the temperature at which the reaction making use of the ARRESTOR oligonucleotide is performed, the lengths of the duplexes formed between the primary probe and the target, the primary probe and the secondary target, and the relative concentrations of the different nucleic acid species in the reactions.

Example 53

Effect of ARRESTOR Oligonucleotide Concentration on Signal Enhancement in Multiple Sequential Invasive Cleavage Assays

[**1117**] In examining the effects of including ARRESTOR oligonucleotides in these cleavage reactions, it was of interest to determine if the concentration of the ARRESTOR oligonucleotide in excess of the primary probe concentration would have an effect on yields of either non-specific or specific signal, and if the length of the ARRESTOR oligonucleotide would be a factor. These two variable were investigated in the following Example.

[**1118**] All reactions were performed in duplicate. The primary INVADER reactions were done in a final volume of 10 μl and contained 10 mM MOPS, pH 7.5; 7.5 mM $MgCl_2$, 500 fmoles of primary INVADER 241-95-01 (SEQ ID NO:176), 25 pmoles of primary probe 241-95-02 (SEQ ID NO:175), 30 ng of AfuFEN1 enzyme, and 10 ng of human genomic DNA. Where included, the target DNA was 1 amole of HBV amplicon pAM 6 #2, as described above. MOPS, target and INVADER were combined to a final volume of 7 μl. The samples were heat denatured at 95° C. for 5 minutes, then cooled to 67° C. During the 5 minute denaturation, $MgCl_2$, probe and enzyme were combined. The primary INVADER reactions were initiated by the addition of 3 μl of $MgCl_2$, probe and enzyme mix. The reactions were incubated for 30 minutes at 67° C. The reactions were then cooled to 52° C. and each primary INVADER reaction received the following secondary reaction components: 2.5 pmoles secondary target 241-95-07 (SEQ ID NO:177), 10 pmoles secondary probe 228-48-04 (SEQ ID NO:173); and, if included, 50, 100 or 200 pmoles of either ARRESTOR oligonucleotide 241-95-03 (SEQ ID NO:179) or 241-95-05 (SEQ ID NO:181), in a total volume of 3 μl. Reactions were then incubated at 52° C. for 35 minutes. Reactions were stopped by the addition of 10 μl of 95% formamide, 10 mM EDTA, and 0.02% crystal violet. All of the samples were heated to 95° C. for 1 minute, and 4 μl of each sample were resolved by electrophoresis through 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH8.3), and 1.4 mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, excitation 488, emission 530. The resulting images are shown as a composite image in FIG. **111**.

[**1119**] Each of the duplicate reactions were loaded on the gel in adjacent lanes and are labeled with a single lane number. All odd numbered lanes were no-target controls. Lanes 1 and 2 had no ARRESTOR oligonucleotide added; lanes 3-8 show results from reactions containing the shorter ARRESTOR oligonucleotide, 241-95-03 (SEQ ID NO:179); lanes 9-14 show results from reactions containing the longer ARRESTOR oligonucleotide, 241-95-05 (SEQ ID NO:181). The products of cleavage from the secondary reaction are visible in the bottom one third of each panel. Visual inspection of these data (i.e., comparison of the specific products to the background bands) shows that both ARRESTOR oligonucleotides have some beneficial effect at all concentration.

[**1120**] To quantify the relative effects of ARRESTOR oligonucleotide length and concentration, the fluorescence from each of the co-migrating product bands was measured, the signals from the duplicate lanes were averaged and the "fold over background" (signal+target/signal-target) was calculated for each reaction containing target nucleic acid. The reaction lacking an ARRESTOR oligonucleotide yielded a signal approximately 27-fold over background. Inclusion of the shorter ARRESTOR oligonucleotide at 50, 100 or 200 pmoles produced products at 42, 51 and 60-fold over background, respectively. This shows that while the short arrestor at the lowest concentration seems to be less effective than the longer ARRESTOR oligonucleotides (See, previous Example) this can be compensated for by increasing the concentration of ARRESTOR oligonucleotide, and thereby the ARRESTOR oligonucleotide:primary probe ratio.

[**1121**] In contrast, inclusion of the longer ARRESTOR oligonucleotide at 50, 100 or 200 pmoles produced products at 60, 32 and 24 fold over background, respectively. At the lowest concentration, the efficacy of this longer ARRESTOR oligonucleotide relative to the shorter ARRESTOR oligonucleotide is consistent with the previous Example. Increasing the concentration, however, decreased the yield of specific product, suggesting a competition effect with some element of the secondary cleavage reaction.

[**1122**] These data show that the ARRESTOR oligonucleotides can be used to advantage in a number of specific

reaction designs. The choice of concentration will be influenced by the temperature at which the reaction making use of the ARRESTOR oligonucleotide is performed, the lengths of the duplexes formed between the primary probe and the target, the primary probe and the secondary target, and between the primary probe and the ARRESTOR oligonucleotide.

[1123] Selection of oligonucleotides for target nucleic acids other than the HBV shown here, (e.g., oligonucleotide composition and length), and the optimization of cleavage reaction conditions in accord with the models provided here follow routine methods and common practice well known to those skilled in the methods of molecular biology.

[1124] Example 45 demonstrated that some enzymes require an overlap between an upstream INVADER oligonucleotide and a downstream probe oligonucleotide to create a cleavage structure (FIG. **100**). It has also been determined that the 3' terminal nucleotide of the INVADER oligonucleotide need not be complementary to the target strand, even if it is the only overlapping base in the INVADER oligonucleotide (e.g., as with the HCMV probes shown in FIG. **103**). The requirement for an overlap can serve as a convenient basis for detecting single base polymorphisms (SNPs) or mutations in a nucleic acid sample.

[1125] For detection of single base variations, at least two oligonucleotides (e.g., a probe and an INVADER oligonucleotide) hybridize in tandem to the target nucleic acid to form the overlapping structure recognized by the CLEAVASE enzyme to be used in the reaction. An unpaired "flap" is included on the 5' end of the probe. The enzyme recognizes the overlap and cleaves off the unpaired flap, releasing it as a target-specific product. Enzymes that have a strong preference for an overlapping structure, i.e., that cleave the overlapping structure at a much greater rate than they cleave a non-overlapping structure include the FEN-1 enzymes from *Archaeoglobus fulgidus* and *Pyrococcus furiosus* and such enzymes are particularly preferred in the detection of mutations and SNPs. In the secondary reaction, the released flap serves as an INVADER oligonucleotide to create another overlapping cleavage structure (e.g., as shown in FIG. **96**). In the following examples, the released flap creates this overlapping structure in conjunction with a FRET cassette, a single oligonucleotide having a region of self-complementarity to form a hairpin (FIG. **112**A) When the FRET cassette is cleaved to release its 5' nucleotide, the fluorescent dye (F) and the quencher (Q) on the cassette are separated and a detectable fluorescence signal is produced. If the probe and the target sequence do not match perfectly at the cleavage site (e.g., as in FIG. **112**B), the overlapped structure does not form, cleavage is suppressed, and no fluorescence will be produced.

[1126] The reactions may be performed under conditions in which the probes and FRET cassettes turn over continuously without temperature cycling or cleavage. When an uncut probe hybridizes to the target next to an overlapping INVADER oligonucleotide, the probe can be cleaved to produce a target-specific product, which in turn enables the cleavage of many FRET cassettes.

[1127] The following eight examples demonstrate the design and application of the sequential INVADER assay with FRET cassette detection to analysis of SNPs and mutations in a variety of nucleic acid samples.

Example 54

Detection of Single Nucleotide Polymorphisms in the Human Apolipoprotein E Gene

[1128] This Example describes an assay for the detection of SNPs in the human Apolipoprotein E gene. Probe and INVADER oligonucleotides were designed to target single nucleotide polymorphisms (SNPs) at two positions in the human apolipoprotein E (apoE) gene. Three different alleles exist for the apoE gene, epsilon 2, epsilon 3, and epsilon 4, which code for 3 different isoforms of the apoE protein, termed E2, E3 and E4. The different isoforms vary in at amino acid positions 112 or 158 (see Table A), and each variation is caused by a single base change in the corresponding codon.

TABLE A

	112		158	
ISOFORM	codon	amino acid	codon	amino acid
E2	TGC	cys	TGC	cys
E3	TGC	cys	CGC	arg
E4	CGC	arg	CGC	arg

[1129] INVADER and probe oligonucleotides were designed using the algorithm described above (detailed description of the invention), with the probe set selected to operate at 63° C. As shown in FIGS. **113** A-D, one INVADER oligonucleotide and two unlabelled, probe oligonucleotides, one for each variant at a given locus, were designed for each codon. For codon 112, the probes were designed to detect either the C nucleotide (to code for arginine; SEQ ID NO:197) or a T nucleotide (to code for cysteine; SEQ ID NO:198). For codon 158, the probes were designed to detect either a C nucleotide (to code for arginine; SEQ ID NO:199) or a T nucleotide (to code for cysteine; SEQ ID NO:200). A FRET cassette to be used with all of the probe sets was also synthesized (SEQ ID NO:201, FIG. **113**). In this Example and in the following Examples, all oligonucleotides were synthesized using standard phosphoramidite chemistries. Primary probe oligonucleotides were unlabeled. The FRET cassettes were labeled by the incorporation of Cy3 phosphoramidite and fluorescein phosphoramidite (Glen Research). While designed for 5' terminal use, the Cy3 phosphoramidite has an additional monomethoxy trityl (MMT) group on the dye that can be removed to allow further synthetic chain extension, resulting in an internal label with the dye bridging a gap in the sugar-phosphate backbone of the oligonucleotide (as diagrammed in the panels of FIG. **113**). While a nucleotide may be omitted at this position to accommodate the dye, we have determined it is not necessary, and no nucleotides were omitted from the FRET cassettes used in these examples. Amine or phosphate modifications, where indicated, were used on the 3' ends of the primary probes and the FRET cassettes to prevent their use as invasive oligonucleotides. 2'-O-methyl bases in the secondary target oligonucleotides are indicated by underlining and were also used to minimize enzyme recognition of 3' ends. In addition, reactions having synthetic target DNAs were used as positive controls to verify the activity of the reaction components. The control targets are illustrated in FIGS. **113** A-D. The 112 arg, 112

cys, 158 arg, and 158 cys control oligonucleotides are SEQ ID NOS:191-194, respectively.

[1130] Genomic DNA sample AG09714 was purchased from Coriell. This sample was quantitated via Pico Green and diluted with Tris with 0.1 mM EDTA to a concentration of approximately 100 ng/μl. This sample (9714 in FIG. **114**A) was used to test for the 112 mutation. Samples 39634, 32435 and 31071 were purchased as whole blood from Lampire Biological Labs., Inc. Samples 511, 537, 538 and 539 were whole blood samples donated by the Blood Center of Southeast Wisconsin (Milwaukee, Wis.). Genomic DNA was prepared via the PUREGENE Blood Kit (Gentra) according to the manufacturer's instructions. Samples 39634 and 32435 were used to test for the 112 mutation, and sample 31071, 511, 537, 538 and 539 were used to test for the 158 mutation. One μl of genomic DNA was used per reaction, with 9 μl of water, for a final volume of 10 μl. Although determination of the full genotype for any one sample generally requires analysis of both loci, the samples listed above were selected to show representative signals from, and thus the functioning of, each probe set. Complete genotyping requires each sample to be tested with both probe sets.

[1131] The experiment comprised testing each genomic DNA for the indicated alleles, along with reactions having no target DNA to allow measurement of any background signal not attributable to the presence of a target sequence. Reactions testing the 112 locus were done in quadruplicate, reactions testing the 158 locus were done in triplicate.

[1132] Reaction components were prepared as batch mixes for dispensing to the individual test reactions. Batches of INVADER mix for each allele were prepared, comprising for each planned reaction: 4 μl of 16% PEG 8000/50 mM MOPS pH 7.5 and 1 μl of 1 μM INVADER oligonucleotide (either the 112 or the 158). Batches of CLEAVASE enzyme/Mg^{2+}/probe mix for each allele were prepared, comprising for each planned reaction: 2 μl of 75 mM $MgCl_2$, 1 μl of 10 μM FRET cassette, 1 μl 10M probe oligonucleotide (any one of the 112 or the 158 T or C probe oligonucleotides), and 1 μl of 200 ng/μl Afu FEN-1 enzyme.

[1133] For each reaction, 5 μl of INVADER reaction mix were aliquoted into each well of a 96-well Low Profile Polypropylene Microplate (MJ Research). Ten μl of each control DNA or genomic sample (approximately 100 ng-190 ng) were added and mixed by pipetting up and down. The no-target controls received 1 μg of yeast tRNA instead of target DNA. The reactions comprising the synthetic targets as positive controls included either 150 or 100 zeptomoles (zmoles) of the 112 or 158 synthetic targets, respectively, and 1 μg of yeast tRNA. Each reaction was overlaid with 20 μl of clear CHILLOUT liquid wax, and incubated at 95° C. for 5 minutes. The reaction temperature was then lowered to 63° C., 5 μl of the appropriate CLEAVASE enzyme/Mg^{2+}/Probe reaction mix was added to each reaction and mixed by pipetting up and down 3-5 times, and the reactions were further incubated for 4 hours at 63° C., and were read directly on a CYTOFLUOR Series 4000 Fluorescence Multi-well Plate Reader, (PerSeptive Biosystems), using the following settings: Excitation (wavelength/bandwidth): 485/20 nm; Emission (wavelength/bandwidth): 530/25 nm; Gain: 37. The net averaged fluorescence signal was calculated by subtracting the averaged no-target signal (background) from the corresponding averaged target DNA reaction signal and the data were plotted using Excel spreadsheet software (Microsoft).

[1134] Results for the ApoE 112 and ApoE 158 loci are shown graphically in FIGS. **114**A and **114**B, respectively, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net averaged signal from the "C" probe, while the dark bars represent the net averaged signal from the "T" probe. The reactions having synthetic targets are indicated as Syn C and Syn T for the C and T controls, respectively. At both loci, the samples that are homozygous for either the C or T allele are easily identified by having a strong signal from only one probe or the other, while the heterozygous samples, are easily identified by having strong signals from both the C and T probes.

Example 55

Detection of Mutations in the Human Hemochromatosis (HFE) Gene

[1135] The human hemochromatosis (HFE gene) gene is located in the MHC region of chromosome 6, and was initially named HLA-H. It was later renamed the HFE gene, in accordance with the WHO Nomenclature Committee for Factors of the HLA System. Two different, single-base variations in the HFE gene are responsible for the vast majority of the cases of hereditary hemochromatosis, or iron overload disease. The most common variant, termed C282Y, is caused by a change from the wild type (WT) adenine (A) to the mutant (MT) guanine (G) at codon 282 that causes an amino acid change from a cysteine to a tyrosine residue. The second variation commonly detected in individuals suffering from iron overload disorder is termed H63D, and is caused by a WT cytosine (C) to a MT guanine (G) change at codon 63 that causes an amino acid change from a histidine to an aspartic acid residue in the expressed protein.

[1136] INVADER and probe oligonucleotide sets were designed as described above to detect both the WT and MT alleles for both the C282Y and H63D sites and are shown in FIGS. **115** A-D. Detection of the C282 polymorphism used one INVADER oligonucleotide (SEQ ID NO:202), one probe specific for each variant of the allele (WT and MT, SEQ ID NOS:208 and 209, respectively) and a first FRET cassette (SEQ ID NO:210). Oligonucleotides for the H63 locus included an INVADER oligonucleotide (SEQ ID NO:203), one probe specific for each variant of the allele (WT and MT, SEQ ID NOS:211 and 212, respectively), and a second FRET cassette (SEQ ID NO:213). In addition, reactions having synthetic target DNAs were used as positive controls to verify the activity of the reaction components. The control targets are illustrated in FIGS. **115** A-D. The C282 WT, C282 MT, H63 WT and H63 MT control oligonucleotides are SEQ ID NOS:204-207, respectively. Human genomic DNA samples 14640, 14641, 14646, 14690, and 14691 were purchased from Coriell Cell Repositories (Catalog #s NA14640, NA14641, NA1446, NA14690, and NA14691).

[1137] Reactions were performed and analyzed as described in Example 54. The reactions comprising the synthetic targets as positive controls included 100 zmoles of the synthetic target and 1 μg of yeast tRNA.

[1138] Results are shown graphically in FIG. **116**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net signal from the wild-type probe, while the dark bars represent the net signal from the mutant probe. The left half of the graph indicates samples tested for the C282Y polymorphism, while the right half of the graph indicates samples tested for the H63D polymorphism. No target controls are indicated as "NT" and the synthetic targets are indicated as SynWT and SynMT for wild-type and mutant controls, respectively. At both loci, the samples that are homozygous for either WT or MT are easily identified by having a strong signal from only one probe or the other, while the heterozygous samples, are easily identified by having strong signals from both the WT and MT probes.

Example 56

Detection of Mutations in the Human MTHFR

[1139] Human 5,10-methylene-tetrahydrofolate reductase (MTHFR) is a major enzyme in the folate-dependent regulation of methionine and homocysteine concentrations. The wild-type protein plays a critical role in the conversion of homocysteine to methionine. A particular variation in the MTHFR protein, termed C677T and caused by a C to T transition in the MTHFR gene, has been correlated with myriad diseases and defects, including cardiovascular and neurological disorders. This Example describes an assay for the detection of the WT and MT alleles for the MTHFR 677 SNP.

[1140] INVADER and probe oligonucleotide sets were designed as described above to detect both the WT and MT allele for the MTHFR 677 site (INVADER, WT probe, MT probe, and FRET cassette are SEQ ID NOS:216, 217, 218 and 225, respectively). Positive control targets were synthesized for the WT and MT alleles at the 677 site (SEQ ID NOS:214 and 215, respectively); oligonucleotides are shown in FIGS. **117**A and **117**B.

[1141] Human genomic DNA samples 01532 and 01560 were purchased from Coriell. These samples had been characterized by "PCR" at Coriell for the MTHFR genotype. They were also characterized in house by PCR/RFLP analysis for genotype confirmation. Human genomic sample 32435 was purchased as whole blood from Lampire Biological Labs., Inc. (Coopersberg, Pa.), and genomic DNA was prepared via the Gentra PUREGENE Blood Kit (Minneapolis, Minn.) according to the manufacturer's instructions. Samples were quantitated via PicoGreen (Molecular Probes, Eugene Oreg.) and diluted with TE to a concentration of approximately 10 ng/μl. 100 ng (10 μl) of each sample was used in each reaction.

[1142] Triplicate reactions were performed and analyzed as described in Example 54, except the INVADER mixes contained 1 μl of 0.5 μM INVADER oligonucleotide for each reaction. The reactions comprising the synthetic targets as positive controls included 50 zmoles of the synthetic target and 1 μg of yeast tRNA. Reactions simulating a heterozygous sample included 50 zmoles of each control target.

[1143] Results are shown graphically in FIG. **118**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net averaged signal from the wild-type probe, while the dark bars represent the net averaged signal from the mutant probe. The synthetic targets are indicated as SynWT and SynMT for wild-type and mutant controls, respectively and SynHET for a mixture of the two to simulate a heterozygous sample. At both loci, the samples that are homozygous for either WT or MT are easily identified by having a strong signal from only one probe or the other, while the heterozygous samples are easily identified by having strong signals from both the WT and MT probes.

Example 57

Detection of Mutations in the Human Prothrombin (Factor II) Gene

[1144] The prothrombin A20210G mutation has been determined to be a risk factor for thromboembolism. The mutation occurs in the 3' untranslated region of the prothrombin gene, replacing the WT adenine (A) at position 20210 with the MT guanine (G). This Example describes an assay for the detection of the WT and MT alleles of the prothrombin A20210G mutation

[1145] INVADER and probe oligonucleotide sets were designed as described above to detect both the WT and MT alleles at the prothrombin 20210 site (INVADER, WT probe, MT probe and FRET cassette are SEQ ID NOS: 222-225, respectively). Positive control targets were synthesized for the WT and MT alleles at the 20210 site (SEQ ID NOS:220 and 221, respectively); oligonucleotides are shown in FIGS. **119**A and **119**B.

[1146] Three patient samples of human genomic DNA were donated by the Blood Center of Southeast Wisconsin, identified as 2196, 2263 and 2265. These samples were purified at the Blood Center via QIAGEN BioRobot 9600 (QIAGEN # 900200), quantitated by Pico Green (Molecular Probes) and were found to be at a concentration of 30-50 ng/ul.

[1147] Duplicate reactions were performed and analyzed as described in Example 54, except the INVADER mixes contained 1 μl of 0.5 μM INVADER oligonucleotide for each reaction, and the mix was diluted with 1 volume of dH_2O (i.e., 5 μl per reaction) so that the INVADER mix was dispensed 10 μl aliquots, while the DNA was dispensed in 5 μl aliquots, adding 150-250 ng of genomic DNA per reaction. Each no target control reaction received 1 μg of yeast tRNA, and the reactions comprising the synthetic targets as positive controls included 300 zmoles of WT control or 50 zmoles of MT control and 1 μg of yeast tRNA.

[1148] Results are shown graphically in FIG. **120**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net averaged signal from the wild-type probe, while the dark bars represent the net averaged signal from the mutant probe. Synthetic targets are indicated as SynWT and SynMT for wild-type and mutant controls, respectively. Samples that are homozygous for the WT are easily identified by having a strong signal from only the WT probe, while the heterozygous sample is easily identified by having strong signals from both the WT and MT probes.

Example 58

Detection of the HR-2 Mutation in the Human Factor V Gene

[1149] This Example describes an assay for the detection of the R-2 polymorphism in the human factor V gene. The R-2 polymorphism in the human factor V gene is located in exon 13 of the factor V gene, and is the result of an A to G transition at base 4070, replacing the wild-type amino acid histidine with the mutant arginine in the mature protein. The R-2 polymorphism is one of a set of mutations termed collectively HR-2. The HR-2 haplotype is defined by 6 nucleotide base substitutions in exons 13 and 16 of the factor V gene, and is associated with an increased functional resistance to activated protein C both in normal subjects and in thrombophilic patients. When present as a compound heterozygote in conjunction with the Leiden mutation (see Example 60, below), clinical symptoms are comparable to those seen in patients homozygous for the Leiden mutation.

[1150] Within about a 600-base pair region surrounding the R2 allele, four sub-regions of DNA, each encompassing the sequence of the WT INVADER probe set, (approximately 22 bases in length), contain sequence similar to that immediately surrounding the R2 allele. These repeated sequences can be detected by an INVADER and probe oligonucleotide set designed for the wild-type R-2 sequence. Because of the repeated sequence, reactions with this VADER/probe set yield very high signal, even with genomic samples containing R-2 mutants, thus greatly increasing the risk of misinterpreting the data. In the example of an R-2 heterozygote, the signal generated by the R-2 mutant would be extremely low compared to the wild-type signal. It is thus possible that one might err and interpret the data as wild-type, not as heterozygous. The same would hold true even for a homozygous mutant R-2 sample. Therefore, instead of having an INVADER/probe set to detect the WT R-2 allele, an INVADER/probe set was developed to detect sequences in the single copy α-actin gene, thus providing an internal reaction control, as well as an internal signal intensity control. Since the α-actin gene is single copy, the signal levels generated in the detection of this sequence will be comparable to that generated in the detection of the R-2 mutant allele, and the probability of incorrect data interpretation due to WT signal overwhelming that generated by the MT is no longer an issue.

[1151] In the previous examples, each sample was assayed in two different reactions, one reaction tested for the presence of wild-type sequence and one reaction tested for the presence of mutant sequence. In this example, each sample is tested with both the α-actin internal control and the MT R-2 INVADER/probe sets. INVADER and probe oligonucleotide sets were designed as described above to detect both the MT R-2 and α-actin control sequence (MT R-2 INVADER and probe, and the FRET cassette are SEQ ID NOS:228, 229 and 230, respectively; α-actin INVADER and probe are SEQ ID NOS: 231 and 232, respectively). Positive control targets were synthesized for the Mutant R-2 allele and the α-actin gene (SEQ ID NOS:226 and 227, respectively); oligonucleotides are shown in FIGS. **121** A and B.

[1152] Human genomic DNA sample 39021 was obtained from Sigma (Catalog #D6537) and uncharacterized human genomic sample 15506 was obtained from Coriell(Catalog #NA15506, Camden, N.J. 08103) Samples were diluted to 10 ng/μl with Tris-EDTA, pH 8.0. Ten μl (100 ng) was used per reaction. No target controls received 1 μg of yeast tRNA instead of human genomic DNA. Reactions were performed and analyzed as described in Example 54, except the INVADER mixes contained 0.5 μl each of 2 μM R-2 INVADER oligonucleotide and 2.0 μM α-actin INVADER oligonucleotide. The probe master mixes contained 1 μl of either the 10 μM R-2 probe or 1 μl of 10 μM α-actin probe, 2 μl of 75 mM $MgCl_2$, 1 μl of 10 μM FRET cassette and 1 μl 200 ng/μl Afu FEN-1 enzyme per reaction. The reactions comprising the synthetic targets as positive controls included 100 zmoles of the synthetic target and 1 μg of yeast tRNA. The SynHET and SynMT reactions contained mixtures of synthetic targets at 2:1 and 1:1 of the α-actin:R-2 mutant targets, respectively.

[1153] Reactions were read directly on a CYTOFLUOR Multi-well Plate Reader Series 4000 (PerSeptive Biosystems) using the following parameters: Excitation wavelength/bandwidth 485 nm/20 nm, Emission wavelength/bandwidth 530 nm/255 nm, gain 36.

[1154] Results are shown graphically in FIG. **122**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net signal from the internal control probe, while the dark bars represent the net signal from the R-2 mutant probe. Synthetic targets are indicated as SynIC and SynMT for internal control and mutant R-2 controls, respectively and SynHET for a mixture of the two to simulate a sample that is heterozygous at the R-2 allele. The sample that does not have the MT R-2 allele is easily identified by having a strong signal from only the IC probe, while that which is heterozygous at the R-2 allele is identified by having signals from both the IC and the MT R-2 probes, but at a ratio near 2:1. A sample homozygous for the mutation at the R-2 allele (not shown) would show nearly equal signal from each probe, as shown with the SynMT control.

Example 59

Detection of Single Nucleotide Polymorphisms in the Human TNF-α Gene

[1155] The human cytokine tumor necrosis factor α (TNF-α) gene has been shown to be a major factor in graft rejection; the more TNF-α present in the system, the greater the rejection response to transplanted tissue. The mutation detected in this example is located in the promoter region of the TNF-α gene at position −308 (minus 308). The WT guanine (G) is replaced with a MT adenine (A). This result of this promoter mutation is the enhancement of transcription of TNF-α by 6 to 7 fold. This Example describes an assay for the detection of the −308 mutation in the promoter of the human TNF-α gene.

[1156] INVADER and probe oligonucleotide sets were designed as described above to detect both the WT and MT alleles at the −308 site (INVADER, WT probe, and MT probe are SEQ ID NOS:235, 236 and 237, respectively; FRET cassette is SEQ ID NO:225). Positive control targets were synthesized for the WT and MT alleles at the −308 site (SEQ ID NOS:233 and 234, respectively); oligonucleotides are shown in FIGS. **123**A and **123**B.

[1157] Purified human genomic DNA samples (M2, M3 and M4) were donated by the Mayo Clinic (Rochester Minn.).

[1158] Triplicate reactions were performed as described in Example 54, except they were stopped after the four hour incubation at 63° C. by the addition 100 μl of 100 mM EDTA. Reactions comprising the synthetic targets as positive controls included 100 zmoles of the synthetic target and 1 μg of yeast tRNA. No target controls received 1 μg of yeast tRNA instead of human genomic DNA. 100 μl of each stopped reaction was transferred to a Nunc 96 well Maxisorb plate (VWR Scientific) and read on a CYTOFLUOR Multi-well Plate Reader Series 4000 (PerSeptive Biosystems) using the following parameters: Excitation wavelength/bandwidth 485 nm/20 nm, Emission wavelength/bandwidth 530 nm/25 nm; gain 65.

[1159] Results are shown graphically in FIG. **124**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net averaged signal from the wild-type probe, while the dark bars represent the net averaged signal from the mutant probe. The synthetic targets are indicated as SynWT and SynMT for wild-type and mutant controls, respectively and SynHET for a mixture of the two to simulate a heterozygous sample. The samples that are homozygous for either WT or MT are easily identified by having a strong signal from only one probe or the other, while the heterozygous sample is easily identified by having signals from both the WT and MT probes.

Example 60

Detection of the Factor V Leiden Mutation

[1160] The "Leiden" mutation in blood coagulation factor V results from a cytosine "C" to a thymidine "T" base change in exon 1 of the factor V gene. The mutant protein has glutamine at amino acid position 506, instead of the wild-type arginine. This substitution prevents activated protein C from cleaving and inactivating factor V. The active form of the protein therefore remains abundant in the blood stream and continues to promote coagulation. This Example describes an assay for the detection of the Leiden mutation of the human factor V gene.

[1161] INVADER and probe oligonucleotide sets were designed as described above to detect both the WT and MT alleles at the 506 site (INVADER, WT probe, and MT probe are SEQ ID NOS:240, 241 and 242, respectively; the FRET cassette is SEQ ID NO:225). Positive control targets were synthesized for the WT and MT alleles at the 506 site (SEQ ID NOS:238 and 239, respectively); oligonucleotides are shown in FIGS. **125**A and **125**B.

[1162] Whole blood samples were obtained from the Midwest Hemostasis Center (Muncie, Ind.). Samples were characterized for the Factor V Leiden genotype by the Midwest Hemostasis Center via methods involving PCR. Buffy coats were isolated as previously described, and genomic DNA was purified using the QIAamp96 DNA Blood Kit (Qiagen, Valencia) according to the manufacturer's instructions, except that the samples were eluted in 200 μl of elution buffer. The purified DNA samples were quantitated by Pico Green (Molecular Probes) and were then diluted with TE to a concentration of 15-60 ng per μl. Single reactions were performed as described in Example 54. The no-target control reaction received 1 μg of yeast tRNA instead of DNA, and the reactions comprising the synthetic targets as positive controls included 200 zmoles of the synthetic target and 1 μg of yeast tRNA.

[1163] After the 4 hour incubation at 63° C., reactions were read directly on a CYTOFLUOR Multi-well Plate Reader Series 4000 (PerSeptive Biosystems) using the following parameters: Excitation wavelength/bandwidth 485 nm/20 nm, Emission wavelength/bandwidth 530 nm/25 mm, gain 65.

[1164] Results are shown graphically in FIG. **126**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net averaged signal from the wild-type probe, while the dark bars represent the net averaged signal from the mutant probe. The synthetic targets are indicated as SynWT and SynMT for wild-type and mutant controls, respectively and SynHET for a mixture of the two to simulate a heterozygous sample. The samples that are homozygous for either WT or MT are easily identified by having a strong signal from only one probe or the other, while the heterozygous samples are easily identified by having signals from both the WT and MT probes.

Example 61

Detection of Methicillin-Resistant *Staphylococcus aureus*

[1165] *Staphylococcus aureus* is recognized as one of the major causes of infections in humans occurring both in the hospital and in the community at large. One of the most serious concerns in treating any bacterial infection is the increasing resistance to antibiotics. The growing incidence of methicillin-resistant *S. aureus* (MRSA) infections worldwide has underscored the importance of both early detection of the infective agent, and defining a resistance profile such that proper treatment can be given. The primary mechanism for resistance to methicillin involves the production of a protein called PBP2a, encoded by the mecA gene. The mecA gene is not native to *Staphylococcus aureus*, but is of extra-species origin. The mecA gene is, however, indicative of methicillin resistance and is used as a marker for the detection of resistant bacteria. To identify methicillin resistant *S. aureus* via nucleic acid techniques, both the mecA gene and at least one species specific gene must be targeted. A particular species-specific gene, the nuclease or nuc gene is used in the following example. This Example describes an assay for the detection of MRSA.

[1166] INVADER and probe oligonucleotide sets were designed as described above to detect both the mecA gene and the nuc gene (meA INVADER and probe, are SEQ ID NOS:243 and 244, respectively; nuc INVADER and probe are SEQ ID NOS:246 and 247, respectively; the FRET cassette for both INVADER/probe sets is SEQ ID NO:245); oligonucleotides are shown in FIGS. **127**A and **127**B. The mecA and nuc target sequences shown are SEQ ID NOS:252 and 253, respectively. Samples of methicillin-resistant *Staphylococcus aureus* were purchased from American Type Culture Collection (ATCC, Catalog #33591). Samples of methicillin sensitive *Staphylococcus aureus* (MSSA) were obtained from Gene Trak, Inc. (GT#2431), and samples of

Staphylococcus haemolyticus were obtained from ATCC (ATCC#29970). The bacterial samples were streaked onto standard blood agar plates and grown at 37° C. for 14-18 hours. DNA samples from MRSA, MSSA, and *S. haemolyticus* were prepared as follows. A single colony was suspended in 50 μl of 10 mM TRIS pH 7.5 in a 1.5 ml microfuge tube. The sample was incubated at 65° C. for 5 minutes, and then micro-waved on the highest setting for 4 minutes. Ten μl of this preparation was used in each reaction.

[1167] Positive controls were created by polymerase chain reaction. A 533 base-pair DNA fragment of the mecA sequence and a 467 base pair DNA fragment of the nuc gene sequence were amplified and isolated as follows. PCR primer sequences used for mecA gene amplification were 5'-AAA ATC GAT GGT AAA GGT TGG C-3" (SEQ ID NO:248) and 5'-AGT TCT GCA GTA CCG GAT TTG C-3' (SEQ ID NO:249). PCR primer sequences used for nuc gene sequence amplification were 5'-TCGCTACTAGTTGCTTAGTG-3' (SEQ ID NO:250) and 5'-GTAAACATAAGCAACTTTAG-3' (SEQ ID NO:251). MRSA and MSSA target DNA was isolated as described above. PCR reactions were done using the AMPLITAQ DNA Polymerase Kit with GENEAMP (PE Corporation Catalog #N808-0152). Separate reactions were done for the mecA and nuc sequences, and were performed in a 100 μl final volume containing the following components: 10 μl of 10×PCR buffer, 2.5 μl of 10 μM upstream primer and downstream primer, 2 μl of 10 mM dNTP mix, 1.0 μl AMPLITAQ DNA polymerase, 2 μl (10-50 ng) of bacterial DNA (the MRSA or the MSSA), and 80 μl of water for a final volume of 100 μl. Reactions were covered with approximately 50 μl of CHILLOUT liquid wax (MJ Research) and cycled as follows: the mecA reactions were denatured at 97° C. for 3 minutes. Reactions were then cycled at 97° C. for 1 minute, 52° C. for 30 seconds, 72° C. for 1 minute. This was repeated 5 times. After the final 72° C. 1 minute incubation, reactions were again heated to 94° C. for 30 seconds, 52° C. for 30 seconds and 72° C. for 1 minute, for 30 cycles. mecA reactions were then incubated at 72° C. for 7 minutes, then held at 4° C. until purification.

[1168] The nuc amplification reactions were denatured at 97° C. for 3 minutes. Reactions were then cycled at 97° C. for 1 minute, 48° C. for 30 seconds, 72° C. for 1 minute. This was repeated for 5 cycles. After the final 72° C., 1 minute incubation, reactions were heated to 94° C. for 30 seconds, 48° C. for 30 seconds and 72° C. for 1 minute. This was repeated for 30 cycles. Reactions were then incubated at 72° C. for 7 minutes, and finally cooled to 4° C. and held until purification.

[1169] After amplification, reactions were run on a 1% agarose gel in 1% TBE buffer with 50-2000 base-pair markers (Novagen, Cat# 69278-3); bands were visualized via ethidium bromide staining followed by ultraviolet illumination. The appropriately sized bands were excised from the gel and purified by the QIAquick Gel Extraction Kit (QiagenCat# 28704) according to the manufacturer's protocol. Each column was eluted twice with 50 μl of elution buffer. The concentration of the purified PCR synthetic target DNA was determined by OD_{260}, and diluted to a stock concentration of 50 fmoles per microliter. Positive controls were used at a concentration of 10 amole per reaction with a 10 μl addition. Control reactions with no target were also performed, using human genomic DNA at 10 ng/μl in place of a bacterial sample. All samples were added in a volume of 10 μl.

[1170] INVADER reactions were performed in MJ 96 well Low Profile Polypropylene Microplates (MJ Research MLL-9601) in duplicate in a final volume of 15 μl. An INVADER reaction master mix was prepared and contained (per reaction) 1.5 μl water, 2.5 μl 100 mM MOPS, 5 μl of 20% PEG (8000 MW), 0.5 μl of 1 μM nuc INVADER oligonucleotide and 0.5 μl of mecA INVADER oligonucleotide. Five μl of the INVADER master mix were added to each sample and control well. 10 μl of the target bacterial DNA samples, prepared as described above, or 10 μl (10 amoles) of positive control target, or 10 μl (100 ng of human genomic DNA) of the no target control sample were added to each well. Samples were overlaid with 15 μl clear Chill-out wax (MJ Research) and incubated at 95° C. for 5 minutes in an MJ Research Thermocycler with Hot Bonnet. Two different probe master mixes were prepared, one containing the mecA probe oligonucleotide, one containing the nuc probe oligonucleotide. The probe master mixes contained (per reaction) 2 μl of 93.75 mM $MgCl_2$, 1 μl of 10 μM FRET oligonucleotide, 1 μl of either 10 μM mecA probe oligonucleotide or 10 μM nuc probe oligonucleotide, 1 μl of 100 ng/μl Afu FEN-1 enzyme (Third Wave Technologies, Cat # 96004D). The temperature was cooled to 64° C. and 5 μl of the appropriate probe master mix (such that each control or sample reaction is tested with both the mecA and the nuc probe) was added below the Chill-out wax layer to each well and mixed by pipetting up and down 5 times. The plate was covered with MICROSEAL 'A' Film (MJ Research) and incubated at 64° C. for 30 minutes. After the 30 minute incubation, reactions were cooled to room temperature, placed on a Perkin Elmer MICROAMP base (cat# N801-0531) and read on a CYTOFLUOR Multi-well Plate Reader Series 4000 (PerSeptive Biosystems) using the following parameters: Excitation wavelength/bandwidth 485 nm/20 nm, Emission wavelength/bandwidth 530 nm/25 nm, gain 40, 30 reads per well, temperature 25° C.

[1171] Results are shown graphically in FIG. **128**, with target DNAs indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. The white bars represent the net averaged signal from the mecA probe, while the dark bars represent the net averaged signal from the nuc probe.

Example 62

Construction of Chimerical Structure Specific Nucleases

[1172] FIG. **59** provides an alignment of the amino acid sequences of several structure-specific nucleases including several each of the FEN-1, XPG and RAD type nucleases. The numbers to the left of each line of sequence refers to the amino acid residue number; portions of the amino acid sequence of some of these proteins were not shown in order to maximize the alignment between proteins. Dashes represent gaps introduced to maximize alignment. From this alignment, it can be seen that the proteins can be roughly divided into blocks of conservation, which may also represent functional regions of the proteins. While not intended as a limitation on the chimeric nucleases of the present invention, these blocks of conservation may be used to select junction sites for the creation of such chimeric proteins.

[1173] The *Methanococcus jannaschi* FEN-1 protein (MJAFEN1.PRO), the *Pyrococcus furiosus* FEN-1 protein (PFUFEN1.PRO) are shown in the alignment in FIG. **59**. These two natural genes were used to demonstrate the creation of chimeric nucleases having different activities than either of the parent nucleases. As known to those of skill in the art, appropriately sited restriction cleavage and ligation would also be a suitable means of creating the nucleases of the present invention. The activities of the parent nucleases on two types of cleavage structures, namely folded structures (See e.g., FIG. **60**), and invasive structures (See e.g., FIG. **26**) are demonstrated in the data shown in FIGS. **129**A and **129**B, respectively. These test molecules were digested as described in Ex. 29 g. Lanes marked with "1" show cleavage by Pfu FEN-1, while lanes marked with "2" indicate cleavage by Maj FEN-1.

[1174] In this example, PCR was used to construct complete coding sequences for the chimeric proteins. This is a small subset of the possible combinations. It would also be within common practice in the art to design primers to allow the combination of any fragment of a gene for a nuclease with one or more other nuclease gene fragments, to create further examples of the chimeric nucleases of the present invention. The present invention provides methods, including an activity test, so that the activity of any such chimeric nuclease not explicitly described herein may be determined and characterized. Thus, it is intended that the present invention encompass any chimeric nuclease meeting the requirements of chimeric nucleases, as determined by methods such as the test methods described herein.

[1175] To make chimeric nucleases from the *M. jannaschi* and *P. furiosus* 5' nuclease genes, homologous parts were PCR amplified using sets of external and internal primers as shown in FIG. **130**. In the next step, 5' portions from one gene and a 3' portions from the other gene were joined in pairs by recombinant PCR, such that each combination created a different full size chimerical gene. The resulting coding regions were cloned into the pTrc99A vector and expressed to produce chimerical nucleases. The specific details of construction of each of the chimeric genes shown in FIG. **130** are described below.

[1176] a) Construction of chimerical 5' nuclease with *M. jannaschi* N-terminal portion and *P. furiosus* C-terminal portion with a junction point at codon 84 (FIG. **130***g*).

[1177] A fragment of the pTrc99A vector carrying the *M. jannaschi* 5' nuclease gene was PCR amplified with TrcFwd (SEQ ID NO:266) and 025-141-02 (SEQ ID NO:267) primers (5 pmole each) in a 50 μl reaction using the ADVANTAGE cDNA PCR kit (Clonetech), for 30 cycles (92° C., 30 s; 55° C., 1 min; 72° C. 1 min) to make an N-terminus-encoding gene fragment (SEQ ID NO:268). The TrcRev (SEQ ID NO:269) and 025-141-01 (SEQ ID NO:270) primers were used to amplify a fragment of the pTrc99A vector carrying the *P. furiosus* gene to produce a C-terminus encoding gene fragment (SEQ ID NO:271). The PCR products were cleaned with the High Pure PCR Product Purification kit (Boehringer Mannheim, Germany) as described in the manufacturer's protocol and eluted in 100 μl water.

[1178] The 025-141-02 (SEQ ID NO:267) primer and the 025-141-01 (SEQ ID NO:270) primer are complementary to each other, so that the PCR fragments created above had the corresponding regions of complementarity on one end. When these fragments are combined in an amplification reaction, the region of complementarity allows the parts to hybridize to each other, to be filled in with the DNA polymerase, and then to be amplified using the outer primer pair, TrcFwd (SEQ ID NO:266) and TrcRev (SEQ ID NO:269) in this case, to form one fragment (SEQ ID NO:272). Five pmole of each outer primer was then placed in 50 μl PCR reaction using the ADVANTAGE cDNA PCR kit (Clonetech) as described above. The full length PCR product (SEQ ID NO:272) including the chimerical coding region (positions 45-1067 of SEQ ID NO:272) was separated in 1% agarose gel by standard procedures and isolated using the Geneclean II Kit (Bio 101, Vista, Calif.). The isolated fragment was then cut with NcoI and PstI restriction enzymes and cloned in pTrc99A vector.

[1179] b) Construction of chimerical 5' nuclease with *P. furiosus* N-terminal portion and *M. jannaschi* C-terminal portion with a junction point at codon 84 (FIG. **130***f*).

[1180] A fragment of the pTrc99A vector carrying the *P. furiosus* 5' nuclease gene was PCR amplified with TrcFwd (SEQ ID NO:266) and 025-141-02 (SEQ ID NO:267) primers (5 pmole each) as described above to make an N-terminus-encoding gene fragment (SEQ ID NO:273). The TrcRev (SEQ ID NO:269) and 025-141-01 (SEQ ID NO:270) primers were used to amplify a fragment of the pTrc99A vector carrying the *M. jannaschi* gene to produce a C-terminus encoding gene fragment (SEQ ID NO:274). The fragments were purified and combined in a PCR, as described above to form one fragment (SEQ ID NO:275), containing the entire chimerical gene (positions 45-1025 of SEQ ID NO:275). This chimerical gene was cut with NcoI and PstI, and cloned into pTrc99A vector as described in a) above.

[1181] c) Construction of chimerical 5' nuclease with *P. furiosus* N-terminal portiono and *M. jannaschi* C-terminal portion with a junction point at codon 114 (FIG. **130***e*).

[1182] A fragment of the pTrcPfuHis plasmid was PCR amplified with TrcFwd (SEQ ID NO:266) and 025-164-04 (SEQ ID NO:277) primers (5 pmole each), as described above to make an N-terminus-encoding gene fragment (SEQ ID NO:276). The pTrcPfufHis plasmid was constructed by modifying pTrc99-PFFFEN1 (described in Ex. 28), by adding a histidine tail to facilitate purification. To add this histidine tail, standard primer directed mutagenesis methods were used to insert the coding sequence for six histidine residues between the last amino acid codon of the pTrc99-PFFFEN1 coding region and the stop codon. The resulting plasmid was termed pTrcPfuHis.

[1183] The 159-006-01 (SEQ ID NO:279) and 025-164-07 (SEQ ID NO:280) primers were used as described in section a) above, to amplify a fragment of the pTrcMjaHis plasmid to produce a C-terminus encoding gene fragment (SEQ ID NO:278). The pTrcMjaHis plasmid was constructed by modifying pTrc99-MJFEN1 (described in Ex. 28), by adding a histidine tail to facilitate purification. To add this histidine tail, standard PCR mutagenesis methods were used to insert the coding sequence for six histidine residues between the last amino acid codon of the pTrc99-MJFEN1 coding region and the stop codon. The resulting plasmid was termed pTrcMjaHis. The fragments were purified, and combined by PCR amplification with TrcFwd (SEQ ID NO:266) and 159-006-01 (SEQ ID NO:279) primers in one fragment (SEQ ID NO:281) containing the chimerical gene (positions

45-1043). This chimerical gene was cut with NcoI and PstI, and cloned into pTrc99A vector as described in a), above.

[1184] d) Construction of chimerical 5' nuclease with *M. jannaschi* N-terminal portion and *P. furiosus* C-terminal portion with a junction point at codon 148 (FIG. **130***d*).

[1185] A fragment of the pTrc99A vector carrying the *M. jannaschi* 5' nuclease gene was PCR amplified with TrcFwd (SEQ ID NO:266) and 025-119-05 (SEQ ID NO:283) primers, as described above, to make an N-terminus-encoding gene fragment (SEQ ID NO:282). The TrcRev (SEQ ID NO:269) and 025-119-04 (SEQ ID NO:285) primers were used to amplify a fragment of the pTrc99A vector carrying the *P. furiosus* gene to produce a C-terminus encoding gene fragment (SEQ ID NO:284). The fragments were purified as described above and combined by PCR amplification with the TrcFwd (SEQ ID NO:266) and TrcRev (SEQ ID NO:269) primers into one fragment (SEQ ID NO:286) containing the chimerical gene (positions 45-1067). This chimerical gene was cut with NcoI and PstI, and cloned into pTrc99A vector as described in a), above.

[1186] e) Construction of chimerical 5' nuclease with *P. furiosus* N-terminal portion and *M. jannaschi* C-terminal portion art with a junction point at codon 148 (FIG. **130***c*).

[1187] A fragment of the pTrcPfuHis plasmid was PCR amplified with TrcFwd (SEQ ID NO:266) and 025-119-05 (SEQ ID NO:283) primers as described above to make an N-terminus-encoding gene fragment (SEQ ID NO:287). The TrcRev (SEQ ID NO:269) and 025-119-04 (SEQ ID NO:285) primers were used to amplify a fragment of the pTrcMjaHis plasmid to produce a C-terminus encoding gene fragment (SEQ ID NO:288). The fragments were purified as described above and combined by PCR amplification with TrcFwd (SEQ ID NO:266) and TrcRev (SEQ ID NO:269) primers in one fragment (SEQ ID NO:289) containing the chimerical gene (positions 45-1025). This chimerical gene was cut with NcoI and PstI, and cloned into pTrc99A vector as described in a), above.

[1188] f) Expression and Purification of Chimeras.

[1189] All of the chimerical enzymes described above except *P. furiosus-M. jannaschi* construct containing a junction point at the codon 114 (i.e., Example 62c) were purified as described for Taq DN. The *P. furiosus-M. jannaschi* codon 114 chimera with His-tag was purified as described for the 5' nuclease domain BN of Taq Pol I.

[1190] g) Activity Characterization of Natural and Chimerical

[1191] Structure-Specific Nuclease.

[1192] All of the chimerical enzymes produced as described above were characterized. In one assay, the enzymes were tested using a mixture of long and short hairpin substrates in the assay system described in Example 28 g.

[1193] In these tests, reactions were done using 50 ng of each enzyme for 2 min., at 50° C. The results of the analysis are shown in FIG. **131**A. In this Figure, the lanes marked "1" and "2" in FIG. **131**A, indicate reactions with the Pfu and Maj parent enzymes, respectively. The remaining uncut hairpin molecules are visible as two bands at the top of each lane. Each chimeric enzyme tested is represented by reference in FIG. **130**. For example, the lane marked "130f" shows the cleavage of these test molecules by the chimerical 5' nuclease with the *P. furiosus* N-terminus and the *M. jannaschi* C-terminus joined at codon 84. The various products of cleavage are seen in the lower portion of each lane. These data show that the chimerical nucleases may display cleavage activities (i.e., substrate specificities) like either parent (e.g., 130c and parent Pfu FEN-1 show little cleavage in this test) or distinct from either parent (i.e., different product profiles).

[1194] Similarly, the chimerical enzymes were examined for invasive cleavage activity using the S-60 structure and the P15 oligonucleotide depicted in FIG. **26**, as described in Ex. 11. The results are shown in FIG. **131**B. The uncleaved labeled P15 oligonucleotide appears in the upper portion of each lane, while the labeled product of cleavage appears in the lower portion.

[1195] These results indicate that chimerical enzymes are different in activity and specificity from the original (i.e., wild-type) *M. jannaschi* and *P. furiosus* 5' nucleases.

Example 63

Comparison of Digestion of Folded Cleavage Structures with Chimeric Nucleases

[1196] CFLP analysis was applied to a PCR amplified segment derived from *E. coli* 16S rRNA genes. Although bacterial 16S rRNA genes vary throughout the phylogenetic tree, these genes contain segments that are conserved at the species, genus or kingdom level. These features have been exploited to generate primers containing consensus sequences which flank regions of variability. In prokaryotes, the ribosomal RNA genes are present in 2 to 10 copies, with an average of 7 copies in *Escherichia* strains. Any PCR amplification produces a mixed population of these genes and is in essence a "multiplex" PCR from that strain. CFLP analysis represents a composite pattern from the slightly varied rRNA genes within that organism, such that no one particular rRNA sequence is directly responsible for the entire "bar code." As a representative example of an amplicon as described below from the *E. coli* 16s rrsE gene is provided (SEQ ID NO:290). Despite the variable nature of these genes, amplification by PCR can be performed between conserved regions of the rRNA genes, so prior knowledge of the entire collection of rRNA sequences for any microbe of interest is not required (See e.g., Brow et al., J. Clin. Microbiol., 34:3129 [1996]).

[1197] In this Example, the 1638 (5'-AGAGTTTGATCCTGGCTCAG-3') (SEQ ID NO:291)/TET-1659 (5'-CTGCTGCCTCCCGTAGGAGT-3') (SEQ ID NO:292) primer pair was used to amplify an approximately 350 bp fragment of rrsE from genomic DNA derived from *E. coli* 0157: H7 (ATCC #43895). The PCR reactions contained 10 mM Tris-HCl (pH 8.3 at 25° C.), 50 mM KCl, 1.5 mM $MgCl_2$, 0.001% w/v gelatin, 60 μM each of dGTP, dATP, dTTP, and dCTP, 1 μM of each primer, 25 ng of genomic DNA, and 2.5 units AmpliTaq DNA polymerase, LD in a volume of 100 μl. Control reactions that contained no input bacterial genomic DNA were also run to examine the amount of 16S rRNA product produced due to contaminants in the DNA polymerase preparations. The reactions were subjected to 30 cycles of 95° C. for 30 sec; 60° C. for 1 min; 72° C. for 30 sec; after the last cycle the tubes were cooled to 4° C.

[1198] After thermal cycling, the PCR mixtures were treated with *E. coli* exonuclease I (Exo I, Amersham) to remove single-stranded partial amplicons and primers. One unit of ExoI was added directly to each PCR mixture, and the samples were incubated at 37° C. for 20 minutes. Then, the nuclease was inactivated by heating to 70° C. for 15 min. The reaction mixtures were brought to 2 M NH_4OAc, and the DNAs were precipitated by the addition of 1 volume of 100% ethanol.

[1199] Cleavage reactions comprising 1 μl of TET-labeled PCR products (approximately 100 fmoles) in a total volume of 10 μl containing 1×CFLP buffer (10 mM MOPS, pH 7.5; 0.5% each Tween 20 and NP-40) and 0.2 mM $MnCl_2$, were then conducted. All components except the enzyme were assembled in a volume of 9 μl. The reactions were heated to 95° C. for 15 sec., cooled to 55° C., and the cleavage reactions were started by the addition of 50 ng of enzyme. After 2 minutes at 55° C., the reactions were stopped by the addition of 6 μl of a solution containing 95% formamide, 10 mM EDTA and 0.02% methyl violet.

[1200] Reaction mixtures were heated at 85° C. for 2 min, and were then resolved by electrophoresis through a 10% denaturing polyacrylamide gel (19:1 cross link) with 7M urea in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA, and were visualized using the FMBIO-100 Image Analyzer (Hitachi). The resulting scanned image is shown in FIG. **132**. In this Figure, the enzymes used in each digest are indicated at the top of each lane. CLEAVASE BN is described in Ex. 2. Lane 2 shows the results of digestion with the Mja FEN-1 parent nuclease, while digests with the chimerical nucleases are indicated by reference to the diagrams in FIG. **130**. These data show that the use of each of these nucleases under identical reaction conditions (i.e., conditions in which the DNA assumes similar folded structures) can produce distinct pattern differences, indicating differences in the specificities of the enzymes. Thus, each enzyme can provide additional information about the folded structure assumed by a nucleic acid of interest, thereby allowing more accurate comparisons of molecules for identification, genotyping, and/or mutation detection.

[1201] These data show that the activities of these enzymes may vary substantially in similar reaction situations. The performance of an optimization panel for an unknown enzyme can help in selection of the optimal enzyme and conditions for a given application. For example, in the invasive cleavage reactions it is often desirable to choose a combination of nuclease and conditions that perform invasive cleavage, but that do not exhibit activity in the absence of the invader oligonucleotide (i.e., do not cut a hairpin type substrate). The optimization panel allows selection of conditions that do not favor hairpin cleavage, such as the use of the Pfu FEN-1 enzyme in a $MgCl_2$-containing solution. Conversely, hairpin cleavage is desirable for CFLP-type cleavage, so it is contemplated that reaction conditions be screened accordingly for strength in this activity.

Example 64

Characterization of Performance of Structure-Specific Nucleases

[1202] Two substrates were used to determine the optimal conditions for seven enzymes, Afu, Pfu, Mth and Mja FEN-1s, CLEAVASE BN, Taq DN and Tth DN. As shown in FIG. **140** Panel A, Substrate 25-65-1 (5'-Fluorescein-TTTTCGCTGTCTCGCTGAAAGCGAGACAGCGTTT-3'; SEQ ID NO:293) is a stem-loop structure with a 5' arm labeled at its 5' end with fluorescein. As shown in FIG. **140** Panel B, substrate 25-184-5 (INVADER-like "IT" test substrate") (5'-Fluorescein-TTTTCGCTGTCTCGCT-GAAAGCGAGACAGCGAAAGACGCTCGT-GAAACGAGCGTCTTTG-3'; SEQ ID NO:294) is a substrate with an upstream primer adjacent to the 5' fluoroscein labeled arm; this mimics an INVADER oligonucleotide and target ("IT"). Standard reactions contained 2 μM labeled substrate, 10 mM MOPS, pH7.5, 0.05% TWEEN 20, 0.05% NP-40, 20 μg/ml tRNA (Sigma # R-5636) and 2 mM $MgCl_2$ or 2 mM $MnCl_2$. Ten μl reactions were heated to 90° C. for 15 seconds in the absence of enzyme and divalent cation, after which the reactions were cooled to room temperature and enzyme was added. Reactions were heated to 50° C. for 20 seconds and divalent cation was then added to start the reaction. The incubation time varied from 1 minute to 1 hour depending on the particular enzyme/substrate combination. Reaction times were adjusted so that less than 25% of the substrate was cleaved during the incubation. Reactions were stopped with the addition of 10 μl of 95% formamide, 20 mM EDTA, methyl violet. One μl of each reaction was electrophoresed on a 20% denaturing acrylamide gel and then scanned on an FMBIO 100 scanner (Hitachi).

[1203] Divalent cation titrations varied $MgCl_2$ or $MnCl_2$ from 0.25 mM to 7 mM under otherwise standard conditions. Salt titrations varied KCl from 0 mM to 200 mM or 400 mM for salt tolerant enzymes under otherwise standard conditions. For temperature titrations, reactions with CLEAVASE BN and the FEN-1 enzymes contained 50 mM KCl and 4 mM $MgCl_2$ or $MnCl_2$. Temperature titrations with Taq DN and Tth DN contained 200 mM KCl and 4 mM $MgCl_2$ or $MnCl_2$. Temperature was varied from 40° C. to 85° C. in 5 or 10 degree increments depending on the particular enzyme used.

[1204] The results are shown in FIGS. **133-139**. FIG. **133** shows the results for CLEAVASE BN, while FIG. **134** shows the results for Taq DN, FIG. **135** shows the results for Tth DN, FIG. **136** shows the results for Pfu FEN-, FIG. **137** shows the results for Mja FEN-, FIG. **138** shows the results for Afu FEN-1, and FIG. **139** shows the results for Mth FEN-1. In each of the Panels within these Figures, the activity of the enzyme is defined as cleavages per molecule of enzyme per minute. Panels marked "IT" refer to cleavage of the 25-184-5 structure (SEQ ID NO:294; FIG. **140**B), which mimics an INVADER oligo/target DNA structure, while Panels marked with "hairpin" refer to cleavage of the 25-65-1 structure (SEQ ID NO:293; FIG. **140**A), which indicates activity on folded cleavage structures.

[1205] In each of these Figures, Panel A shows the results from reactions containing 2 mM $MgCl_2$ and the IT substrate as described in the text, with KCl varied as indicated; Panel B shows the results from reactions containing 2 mM $MnCl_2$ and the IT substrate as described in the text, with KCl varied as indicated; Panel C shows the results from reactions containing 2 mM $MgCl_2$ and the hairpin substrate as described in the text, with KCl varied as indicated; Panel D shows the results from reactions containing 2 mM $MnCl_2$ and the hairpin substrate as described in the text, with KCl

varied as indicated; Panel E shows the results from reactions containing the IT substrate as described in the text, with $MgCl_2$ varied as indicated; Panel F shows the results from reactions containing the IT substrate as described in the text, with $MnCl_2$ varied as indicated; Panel G shows the results from reactions containing the hairpin substrate as described in the text, with $MgCl_2$ varied as indicated; Panel H shows the results from reactions containing the hairpin substrate as described in the text, with $MnCl_2$ varied as indicated; Panel I shows the results from reactions containing the IT substrate, 4 mM $MgCl_2$, and 50 mM KCl (Afu FEN-1, Pfu FEN-1, Mja FEN-1, Mth FEN-1, and CLEAVASE FN) or 200 mM KCl (Taq DN and Tth DN) as described in the text, with the temperature varied as indicated; and Panel J shows the results from reactions containing the IT substrate, 4 mM $MnCl_2$, and 50 mM KCl (Afu FEN-1, Pfu FEN-1, Mja FEN-1, Mth FEN-1, and CLEAVASE BN) or 200 mM KCl (Taq DN and Tth DN) as described in the text, with the temperature varied as indicated. It is noted that some of these Figures (e.g., **134**, **135**, **136**, and **138**) do not show each of the above-named panels A-J.

[**1206**] From the above it is clear that the invention provides reagents and methods to permit the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. The INVADER-directed cleavage reaction of the present invention provides an ideal direct detection method that combines the advantages of the direct detection assays (e.g., easy quantification and minimal risk of carry-over contamination) with the specificity provided by a dual or tri oligonucleotide hybridization assay.

Example 65

Cloning and Expression of Unknown FEN1 Nucleases

[**1207**] A common method for cloning new members of a gene family is to run PCR reactions using degenerate oligonucleotides complementary to conserved amino acid sequences in that family, and then to clone and sequence the gene-specific PCR fragments. This sequence information can then be used to design sense and anti-sense gene-specific primers which can be used in PCR walking reactions (Nucleic Acids Res. 1995a. 23(6)1087-1088) to obtain the remainder of the gene sequence. The sequences obtained from the sense and anti-sense PCR walks can then be combined to generate the DNA sequence for the entire open reading frame (ORF) of the gene of interest. Once the entire ORF is know, primers specific to both the 5' and the 3' end of the gene can be designed, and PCR reactions can be performed on genomic DNA to amplify the gene in its entirety. This organism-specific, amplified fragment can then be cloned into an expression vector, and via methods know in the art, and detailed below, the protein of interest can be expressed and purified.

[**1208**] The following examples utilize this series of steps in the cloning and expression of 14 novel FEN-1 nucleases. The steps and reagents (such as cloning vectors, expression vectors, PCR kits or PCR walking kits, etc) are intended to be examples and not limitations to the current invention; those skilled in the art would know that different cloning vectors, expression vectors, PCR kits or PCR walking kits, etc. may be substituted for those exemplified.

[**1209**] The following example is divided into 2 main sections:

A. degenerate PCR and PCR walking to obtain the sequence of 14 novel FEN-1 nucleases

B. cloning and expression of 16 FEN-1 nucleases

A. Degenerate PCR and PCR Walking to Obtain the Sequence of 14 Novel FEN-1 Nucleases

[**1210**] The protein sequences of the FEN1 genes from *Pyrococcus furiosus* (SEQ ID NO:79) *Methanococcus jannaschi* (SEQ ID NO:75), *Methanobacterium thermoautotrophicum* (SEQ ID NO:265), and *Archaeoglobus fulgidus* (SEQ ID NO:165) were aligned and blocks of conserved amino acids were identified. The conserved sequence blocks VFDG (valine, phenylalanine, aspartic acid, glycine), EGEAQ (glutamic acid, glycine, glutamic acid, alanine, glutamine), SQDYD (serine, glutamine, aspartic acid, tyrosine, aspartic acid), and GTDYN/GTDFN (glycine, threonine, aspartic acid, tyrosine or phenylalanine, asparagine) were chosen as sequences that would likely be present in all Archaeal FEN1 genes. Degenerate oligonucleotides were designed for each of these conserved sequence blocks. In addition to the FEN1 gene specific portion of the oligonucleotides a 15 nucleotide tail was added to the 5' end of the oligonucleotides to enable nested PCR. A different tail sequence was used depending on whether the degenerate oligonucleotide targets the sense or antisense strand of the FEN1 gene.

[**1211**] Forward and/or reverse versions of the oligonucleotides were made and target the sense and antisense strands of the FEN1 gene respectively. The oligonucleotides are VFDG-Fwd (SEQ ID NO:295), EGEAQ-Fwd (SEQ ID NO:296) QDYD-Fwd (SEQ ID NO:297), EGEAQ-Rev (SEQ ID NO:298), SQDYD-Rev1 (SEQ ID NO:299), SQDYD-Rev2 (SEQ ID NO:300), and GTDYN-Rev (SEQ ID NO:301). Two oligonucleotides were made for the SQDYD-Rev sequence because serine is encoded by 6 different codons. For use in PCR, the SQDYD-Rev1 and SQDYD-Rev2 oligonucleotides were mixed in a ratio of 1:2. For the QDYD-Fwd oligonucleotide, the requirement for mixing was avoided by targeting only the last four amino acids of the conserved SQDYD sequence. The GTDYN-Rev oligonucleotide also recognizes the sequence GTDFN since the codons for tyrosine and phenylalanine share 2 of 3 nucleotides.

[**1212**] First, genomic DNA was prepared from 1 vial of the live bacterial strain as described below. All bacterial strains were obtained from the DSMZ (Deutsche Sammlung von Mikroorganismen und Zellkulturen, *Acidianus ambivalens*-DSM # 3772). When the cells were lyophilized, they were resuspended in 200 µl of TNE (10 mM TrisHCL, pH 8.0, 1 mM EDTA, 100 mM NaCl). When the cells were in liquid suspension, they were spun down at 20,000×G for 2 minutes and the cell pellets were resuspended in 200 µl of TNE. 20 µl of 20% SDS (sodium dodecylsulfate) and 2 µl of 1 mg/ml proteinase K were added and the suspension was incubated at 65° C. for 30 minutes. The lysed cell suspension was extracted in sequential order with buffered phenol, 1:1 phenol:chloroform, and chloroform. The nucleic acid was precipitated by the addition of on equal volume of cold 100% ethanol. The nucleic acid was pelleted by spinning at 20,000×G for 5 minutes. The nucleic acid pellet was washed with 70% ethanol, air dried and resuspended in 50 µl of TE (10 mM TrisHCL, pH 8.0, 1 mM EDTA). The final DNA pellet was re-suspended in 50 µl of TE (10 mM Tris HCl, pH 8.0, 1 mM EDTA).

[1213] Both reactions of the nested PCR were done using the Advantage cDNA PCR kit (Clontech) according to manufacturer's instructions using a final concentration of 1 μM for all oligonucleotides. The first reaction is done in a 20 μl volume with one of the 6 possible combinations of forward and reverse degenerate oligonucleotides, and includes either 1 μl of the genomic DNA preparation described above, or in the case of Tgo and Tzi, 1 μl (4 ng/μl stock and 6 ng/μl stock, respectively) of DNA purchased from ATCC (ATCC#s 700654D and 700529D, respectively). The cycling conditions were 20 cycles of 95° C. for 15 seconds, 50° C. or 55° C. for 15 seconds, and 68° C. for 30 seconds. The second reactions utilize primers that have the same sequence as the 5' tail sequence of the degenerate oligonucleotides described above. The two primers are 203-01-01 (SEQ ID NO:302) and 203-01-02 (SEQ ID NO:303). The second reaction is carried out exactly as described for the first reaction, except 30 cycles are done instead of 20 and the reaction volume is 25 μl. Following the second PCR, 5 μl of the reaction were loaded on a 2% or 4% agarose gel and the DNA was visualized by ethidium bromide staining. The expected product sizes based on the previously identified FEN1 sequences for all primer pairs are as follows: VFDG-Fwd and EGEAQ-Rev; 275 base pairs, VFDG-Fwd and SQDYD-Rev; 325 base pairs, VFDG Fwd and GTDYN-Rev; 510 base pairs, EGEAQ-Fwd and SQDYD-Rev; 100 base pairs, EGEAQ-Fwd and GTDYN-Rev; 290 base pairs, QDYD-Fwd and GTDYN-Rev; 230 base pairs. The primer pair, VFDG-Fwd and EGEAQ-Rev was able to generate a correctly sized DNA product for all samples attempted. The primer pair, VFDG-Fwd and GTDYN-Rev was able to generate a correctly sized DNA product for most of the DNA samples attempted.

[1214] When a DNA product of the expected size was made by the degenerate PCR, that DNA fragment was isolated and cloned into pGEM-T Easy (Promega) using the pGEM-T Easy ligation kit according to the manufacturer's instructions. The DNA sequence was determined and the sequence was used to generate sense and antisense genome walking oligonucleotides for cloning the remainder of the FEN1 genes. The oligonucleotides were designed according to the parameters of the GenomeWalker kit (Clontech) which was used prepare the various genomic DNA samples for the genome walking PCR reactions.

[1215] Since many of the organisms of interest cannot be easily cultured in a standard laboratory setting (due to requirements of very specialized temperature, pressure and medium conditions), quantities of genomic DNA were limiting. Therefore, the DNA was randomly amplified using a random 12-mer oligonucleotide. One hundred-μl PCR reactions were set up with the Advantage cDNA PCR kit (Clontech) and contained 10 μl of genomic DNA and 15 μM random 12-mer oligonucleotide. 50 cycles were carried out with the following parameters: 95° C. for 30 seconds, 50° C. for 30 seconds, 68° C. for 5 minutes. After the PCR reactions were complete, amplified DNA was purified with the High Pure PCR Product Purification kit (Boehringer Mannheim). The purified DNA was eluted into a total of 200 μl of 10 mM TrisHCL, pH 8.5.

[1216] The genome walking protocol consists of 3 steps. First, a genomic DNA sample is cut with 5 different blunt-end restriction enzymes in 5 separate reactions. Second, the cut DNA is ligated to an adapter that serves as a tag sequence and also is designed to prevent background amplification. Third, the ligated DNA is amplified with a gene-specific primer and a primer with the same sequence as a portion of the adapter sequence.

[1217] 50 μl restriction digests contained 30 μl of randomly amplified genomic DNA and one of the following enzymes: Dra I, Eco RV, Pvu II, Sca I or Stu I. After 4 hours at 37° C., the cut DNA was purified with either GENECLEANII (Bio 101) or QIAEX II (Qiagen) according to manufacturer's instructions. DNA was eluted into 10 μl of 10 mM Tris HCl, pH 8.5 in either case. 5.6 μl of this cut DNA was used in 10 μl ligation reactions containing 6 μM GenomeWalker adapter. Reactions were carried out at room temperature overnight followed by heating at 70° C. for 10 minutes to inactivate the T4 DNA ligase. The ligation reactions were then diluted with 70 μl of TE (10 mM Tris HCl, pH 8.0, 1 mM EDTA).

[1218] One μl of the diluted ligation mix was used in 25 μl PCR reactions with 0.2 μM gene-specific primer and 0.2 μM primer AP-1 (Clontech) which has the same sequence as the 5' portion of the GenomeWalker adapter. Ten reactions were done for each DNA sample. Five antisense walk PCR reactions (for the 5 different restriction enzymes used to cut the genomic sample) were done using the sense gene-specific primer and five sense walk PCR reactions were done using the antisense gene-specific primer for each DNA sample. The cycling parameters were as recommended by the Universal Genome Walking kit (Clontech) and were as follows: 7 cycles of 94° C. for 25 seconds and 72° C. for 3 minutes, 32 cycles of 94° C. for 25 seconds and 67° C. for 3 minutes, followed by 67° C. for 7 minutes. The source of DNA for the genome walking PCR reactions was, in most cases, genomic DNA which had been randomly amplified with a random 12-mer oligonucleotide, as described above. The exceptions were for *Sulfolobus solfataricus* (Sso), *Thermococcus gorgonarius* (Tgo), and *Thermococcus zilligii* (Tzi). Because we were able to grow, Sso, there was a large quantity of Sso genomic DNA, and the DNA was used directly. A 500 ml culture of *Sulfolobus solfataricus* (ATCC # 35091) was grown in DSM medium 182 at 75° C. for 48 hours. After growth, the cells were spun down for 10 minutes at 20,000×G at 4° C. The cell pellet was resuspended in 10 ml of TE (10 mM Tris HCL, 1 mM EDTA) and frozen in 1 ml aliquots at −70° C. DNA was prepared by the method described above using 1 ml aliquots, but all volumes were increased 10-fold. As noted above, the Tgo and Tzi genomic DNAs were purchased from ATCC.

[1219] After the PCR reactions were completed, 5 μl of each reaction was run on a 1% agarose gel and the DNA was visualized by ethidium bromide staining. The presence of a major product was used as an indication of a successful reaction. When a major product was made, it was gel purified with GENECLEAN II (Bio101) or QIAEX II (Qiagen) and ligated into pGEM-T Easy (Promega) according to manufacturer's instructions. The plasmids were sequenced with primers flanking the insert and the sequence obtained was compared to the sequence of the fragment generated by PCR with degenerate oligonucleotides from the same species. The sequences obtained for the degenerate PCR and the sense and antisense walks were combined to generate the DNA sequence for the entire FEN1 open

reading frame. Specific information regarding genome walking and cloning for each of the 14 novel FEN-1 nucleases is detailed below.

[1220] 1. *Acidianus ambivalens* (Aam)

[1221] The *Acidianus ambivalens* (Aam) genome walks were done as follows. The antisense primer was Aam 39AS (SEQ ID NO:304) and the sense primer was Aam 44S (SEQ ID NO:305). The antisense PCR walk on Sca I digested Aam genomic sample generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Dra I digested Aam genomic sample generated a 600 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1222] 2. The *Acidianus brierlyi* (Abr)

[1223] The *Acidianus brierlyi* (Abr) genome walks were done as follows. The antisense primer was Abr 39AS (SEQ ID NO:306) and the sense primer was Abr 40S (SEQ ID NO:307). The antisense PCR walk on Eco RV digested Abr genomic sample generated a 1.5 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Dra I digested Abr genomic sample generated a 600 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1224] 3. *Archaeoglobus profundus* (Apr)

[1225] The *Archaeoglobus profundus* (Apr) genome walks were done as follows. The antisense primer was Apr 35AS (SEQ ID NO:308) and the sense primer was Abr 63S (SEQ ID NO:309). The antisense PCR walk on Dra I digested Apr genomic sample generated a 1.8 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The antisense PCR walk on Pvu II digested Apr genomic sample generated a 2 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Dra I digested Apr genomic sample generated a 1 kilobase fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1226] 4. *Archaeoglobus veneficus* (Ave)

[1227] The *Archaeoglobus veneficus* (Ave) genome walks were done as follows. The primary antisense primer was Ave 34AS (SEQ ID NO:310) and the primary sense primer was Ave 65S (SEQ ID NO:311). For Ave, the primary genome walk PCR reactions generated a strong product for only the sense walk on the Dra I cut Ave DNA sample. Therefore, nested PCR reactions were done using the nested primer AP-2 and either the nested antisense primer Ave 32AS (SEQ ID NO:312) or the nested sense primer Ave 67S (SEQ ID NO:313). 25 μl nested reactions were done as described above for the primary PCR walk reactions. The primary reactions were diluted 1:50 in H_2O and 0.5 μl of those dilutions were added to the nested PCR reactions. The cycling parameters for the nested PCR reactions were as recommended by the Universal Genome Walking kit (Clontech) and are as follows: 5 cycles of 94° C. for 25 seconds and 72° C. for 3 minutes, 20 cycles of 94° C. for 25 seconds and 67° C. for 3 minutes, followed by 7 minutes at 67° C. The nested antisense PCR reaction on Stu I cut Ave genomic sample generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The nested sense PCR reaction on Eco RV cut Ave genomic sample generated a 1.1 kilobase product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1228] 5. *Desulfurococcus amylolyticus* (Dam)

[1229] The *Desulfurococcus amylolyticus* (Dam) genome walks were done as follows. The antisense primer was Dam 31AS (SEQ ID NO:314) and the sense primer was Dam 65S (SEQ ID NO:315). The antisense PCR walk on Stu I digested Dam genomic sample generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Pvu II digested Dam genomic sample generated a 800 base pair DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Stu I digested Dam genomic sample generated a 400 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1230] 6. *Desulfurococcus mobilis* (Dmo)

[1231] The *Desulfurococcus mobilis* (Dmo) genome walks were done as follows. The antisense primer was Dmo 31AS (SEQ ID NO:316) and the sense primer was Dmo 66S (SEQ ID NO:317). The antisense PCR walk on Eco RV digested Dmo genomic sample generated a 450 base pair DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Pvu II digested Dmo genomic sample generated a 1 kilobase fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1232] 7. *Methanococcus igneus* (Mig)

[1233] The *Methanococcus igneus* (Mig) genome walks were done as follows. The antisense primer was Mig 36AS (SEQ ID NO:318) and the sense primer was Mig 39S (SEQ ID NO:319). The antisense PCR walk on Dra I digested Mig genomic sample generated a 900 base pair DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Eco RV digested Mig genomic sample generated a 2.5 kilobase fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1234] 8. *Methanopyrus kandleri* (Mka)

[1235] The *Methanopyrus kandleri* (Mka) genome walks were done as follows. The antisense primer was Mka 31 AS (SEQ ID NO:320) and the sense primer was Mka 41S (SEQ ID NO:321). The antisense PCR walk on Eco RV digested Mka genomic sample generated a 500 base pair DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Eco RV digested Mka genomic sample generated a 1.6 kilobase fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1236] 9. *Pyrobaculum aerophilum* (Pae)

[1237] The *Pyrobaculum aerophilum* (Pae) genome walks were done as follows. The antisense primer was Pae 28AS (SEQ ID NO:322) and the sense primer was Pae 45S (SEQ ID NO:323). The antisense PCR walk on Eco RV digested Pae genomic sample generated a 400 base pair DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Pvu II digested Pae genomic sample generated a 700 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1238] 10. *Pyrodictium brockii* (Pbr)

[1239] The *Pyrodictium brockii* (Pbr) genome walks were done as follows. The antisense primer was Pbr 42AS (SEQ ID NO:324) and the sense primer was Pbr 56S (SEQ ID NO:325). The antisense PCR walk on Eco RV digested Pbr genomic sample generated a 650 base pair DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Pvu II digested Pbr genomic sample generated a 800 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1240] 11. *Sulfolobus solfataricus* (Sso)

[1241] The *Sulfolobus solfataricus* (Sso) genome walks were done as follows. The antisense primer was Sso 27AS (SEQ ID NO:326) and the sense primer was Sso 27S (SEQ ID NO:327). The antisense PCR walk on Pvu II digested Sso genomic DNA generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Dra I digested Sso genomic DNA generated a 750 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1242] 12. *Thermococcus gorgonarius* (Tgo)

[1243] The *Thermococcus gorgonarius* (Tgo) genome walks were done as follows. The antisense primer was Tgo 55AS (SEQ ID NO:330) and the sense primer was Tgo 67S (SEQ ID NO:331). The antisense PCR walk on Dra I digested Tgo genomic sample generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Stu I digested Tgo genomic sample generated a 850 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1244] 13. *Thermococcus litoralis* (Tli)

[1245] The *Thermococcus litoralis* (Tli) genome walks were done as follows. The antisense primer was Tli 28AS (SEQ ID NO:328) and the sense primer was Tli 48S (SEQ ID NO:329). The antisense PCR walk on Eco RV digested Tli genomic sample generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Eco RV digested Tli genomic sample generated a 1.9 kilobase fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

[1246] 14. *Thermococcus zilligii* (Tzi)

[1247] The *Thermococcus zilligii* (Tzi) genome walks were done as follows. The antisense primer was Tzi 55AS (SEQ ID NO:332) and the sense primer was Tzi 67S (SEQ ID NO:333). The antisense PCR walk on Dra I digested Tzi genomic sample generated a 1 kilobase DNA product which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced. The sense PCR walk on Stu I digested Tzi genomic sample generated a 850 base pair fragment which was cloned into pGEM-T Easy (Promega) following manufacturer's instructions and sequenced.

B. Cloning of 16 FEN-1 Nucleases

[1248] The previous section detailed the cloning and sequencing of novel FEN-1 nucleases. This section will describe the cloning of these novel FEN-1's into an expression vector, as well as the cloning of two additional, previously known FEN-1's, *Aeropymum pernix* (Ape) and *Pyrococcus horikoshii* (Pho). The process comprises either 4 or 5 steps, and is broadly outlined below.

[1249] The first step involves the design of 5' and 3' gene specific PCR primers. Since the complete sequence of all 16 FEN-1 genes has been determined, specific primers were designed to target and amplify the entire FEN-1 gene of interest. For each FEN1 endonuclease to be cloned, the 5'-end primer and the 3-end primer are mostly complementary to the 5' end and the 3' end of the FEN1 open reading frame. The first few nucleotides of the primer constitute a spacer and sequences necessary to introduce a restriction endonuclease site to facilitate cloning. The choice of restriction endonuclease sequence to incorporate into the primer is dependent on the sequence of the FEN-1 enzyme. Ideally, unique restriction sites are created at the 5' and 3' ends of the PCR product (they are not the same as any restriction sites that may be internal to the FEN-1 sequence). Also, the sites incorporated into the primers correspond to restriction enzyme sites that are commonly found on expression vectors used in the art. Examples of such enzymes are EcoRI, SalI, NcoI, XbaI and PstI.

[1250] Second, PCR reactions were performed using the primers designed above and genomic DNA from the organism of interest. Third, the PCR products were gel purified and then cut with restriction endonucleases corresponding to the sites incorporated in the PCR primers. The cut PCR products were then purified away from the smaller digest fragments and, fourth, these cut products were cloned into an expression vector. In some cases, this was the final step of the cloning process, prior to transformation and protein expression/purification. In some cases a fifth step was needed. In some cases, a mutagenesis step had to be performed to remove any nucleotides that were incorporated into the ORF as a result of primer sequences required for cloning.

[1251] Finally, a bacterial host (e.g., *E. coli* JM109) was transformed with the expression vector containing the cloned FEN-1, and protein expression and purification were done as detailed in Experimental Example 28f. Four of the isolated FEN gene constructs (Pae FEN-1, Pbr FEN-1, Mig FEN-1 and Mka FEN-1) produced little or no detectable protein in the host that was transformed.

[1252] The following section details the PCR, restriction digests, cloning, mutagenesis reactions (if required) and

transformation for each FEN-1 nuclease. The description is sub-divided in order to group the FEN-1 nucleases according to the restriction endonucleases used in cloning. The sub-divisions are as follows:

I. FEN-1 endonucleases cloned with restriction endonucleases NcoI/SalI

II. FEN-1 endonucleases cloned with restriction endonucleases EcoRI/SalI

III. FEN-1 endonucleases cloned with other restriction endonucleases

I. Cloning of FEN-1 Endonucleases Using the Restriction Endonucleases NcoI and SalI.

[1253] In this example, DNA encoding the FEN-1 endonuclease from *Acidianus ambivalens* (Aam), *Acidianus brierlyi* (Abr), *Aeropyrum pernix* (Ape), *Archaeaglobus profundus* (Apr), *Methanococcus igneus* (Mig), *Pyrococcus horikoshii* (Pho), *Sulfolobus solfataricus* (Sso), *Thermococcus gorgonarius* (Tgo), were isolated and inserted into a plasmid under the transcriptional control of an inducible promoter as follows.

1. Cloning of *Acidianus ambivalens* FEN-1 (Aam)

[1254] One microliter of the genomic DNA solution described above (in section 65A) was employed in a PCR using the ADVANTAGE cDNA PCR kit (Clonetech); the PCR was conducted according to manufacturer's recommendations. For each FEN1 endonuclease to be cloned, the 5'-end primer is mostly complementary to the 5' end of the FEN1 open reading frame. The first 6 nucleotides of the primer constitute a spacer and 2 bases of an Nco I site to facilitate cloning. An 'A' at position 3 of the Aam ORF sequence (SEQ ID NO: 336) was mutated to a 'G' in the 5' primer to create an ATP start codon. Likewise, the 3'-end primer is mostly complementary to the 3' end of the FEN-1 open reading frame. The first 10 nucleotides constitute a spacer and Sal I site to facilitate cloning. The PCR primers used for Aam are: Aam5'-5' GCAACCATGGGAGTAGACCTTGCTGATTTGG (SEQ ID NO:334) and Aam 3'-5' CCATGTCGACTAAAAC CACTGATCTAAACCGC (SEQ ID NO:335). The PCR reaction for each FEN1 resulted in the amplification (i.e. production) of a single major band about 1 kilobase in length. The open reading frame (ORF) encoding the Aam FEN-1 endonuclease is provided in SEQ ID NO:336; the amino acid sequence encoded by the Aam ORF is provided in SEQ ID NO:337.

[1255] Following the PCR amplification, the entire reaction was electrophoresed on a 1.0% agarose gel and the major band was excised from the gel and purified using the GENECLEAN II kit (Bio 101, Vista Calif.) according to manufacturer's instructions. Approximately 1 μg of the gel-purified FEN-1 PCR product was digested with NcoI and SalI. After digestion, the DNA was purified using the Geneclean II kit according to manufacturer's instructions. One microgram of the pTrc99a vector (Pharmacia) was digested with NcoI and SalI in preparation for ligation with the digested PCR product. One hundred nanograms of digested pTrc99a vector and 250 ng of digested FEN-1 PCR product were combined and ligated to create pTrc99-(enzyme TLA)FEN1. pTrc99-(enzyme TLA) FEN-1 was used to transform competent *E. coli* JM 109 cells (Promega) using standard techniques.

2. Cloning of a FEN-1 Endonuclease from *Acidianus brierlyi*

[1256] Cloning of the FEN-1 from *Acidianus brierlyi* (Abr) was performed as described above, except the DSM# is 1651 and the PCR primers used are Abr 5'-5' CATACCATGGGAGTAGATTTATCTGACTTAG (SEQ ID NO:338) and Abr 3'-5' CTTGGTCGACTTAAAACCATTGGTCAAGTCCAG (SEQ ID NO:339). A 'C' at position 3 of the Abr ORF sequence (SEQ ID NO: 338) was mutated to a 'G' in the 5' primer to create an ATP start codon. The open reading frame (ORF) encoding the Abr FEN-1 endonuclease is provided in SEQ ID NO:340; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:341.

3. Cloning of a FEN-1 Endonuclease from *Aeropyrum pernix*

[1257] Cloning of the FEN-1 from *Aeropyrum pernix* (Ape) was performed as described above, except the sequence of this enzyme was obtained from GENBANK (accession #H72765), the DSM# is 11879, and the PCR primers used are Ape 5'-5' TTAGCCATGGGAGTCAACCTTAGGGAG (SEQ ID NO:342) and Ape 3'-5' GTAAGTCGACTATCCGAACCACATGTCGAG (SEQ ID NO:343). An 'T' at position 1 of the Ape ORF sequence (SEQ ID NO: 344) was mutated to an 'A' in the 5' primer to create an ATP start codon. The open reading frame (ORF) encoding the Ape FEN-1 endonuclease is provided in SEQ ID NO:344; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:345.

4. Cloning of a FEN-1 Endonuclease from *Archaeaglobus profundus*

[1258] Cloning and expression of the FEN-1 from *Archaeaglobus profundus* (Apr) was performed as described above, except the DSM# is 5631 and the PCR primers used are Apr 5'-5' CTTACCATGGGCGCTGATATAGGAGAGC (SEQ ID NO:346) and Apr 3'-5' TGGAGTCGACTTAAAACCACCTGTCCAGAG (SEQ ID NO:347). The open reading frame (ORF) encoding the Apr FEN-1 endonuclease is provided in SEQ ID NO:348; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:349.

5. Cloning of a FEN-1 Endonuclease from *Methanococcus igneus*

[1259] Cloning and expression of the FEN-1 from *Methanococcus igneus* (Mig) was performed as described above except the DSM # is 5666 and the PCR primers used are Mig 5'-5' CATTCCATGGGAGTGCAGTTTAATG (SEQ ID NO:350) and Mig 3'-5' CGGAGTCGACTCATCTCCCAAACCATGC(SEQ ID NO:351). The open reading frame (ORF) encoding the Mig FEN-1 endonuclease is provided in SEQ ID NO:352; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:353.

6. Cloning of a FEN-1 Endonuclease from *Pyrococcus horikoshii*

[1260] Cloning and expression of the FEN-1 from Pho *Pyrococcus horikoshii* (Pho) was performed as described above except the sequence of this enzyme was obtained from GENBANK (accession #A71015), the DSM # is 12428, and the PCR primers used are Pho 5'-5' GATACCATGGGTGTTCCTATCGGTGAC (SEQ ID NO:354) Pho 3'-5' CTTGGTCGACTTAGGGTTTCTTTTTAACGAACC

(SEQ ID NO:355). The open reading frame (ORF) encoding the Pho FEN-1 endonuclease is provided in SEQ ID NO:356; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:357.

7. Cloning of a FEN-1 Endonuclease from *Sulfolobus solfataricus*

[1261] Cloning and expression of *Sulfolobus solfataricus* (Sso) FEN-1 was performed as described above except the bacterial stocks were obtained from the American Type Culture Collection (Manassas, Va.) ATCC # is 5091, and the PCR primers used are Sso 5'-5' TAAGCCATGGGTGTAGATTTAGGCGAAATAG (SEQ ID NO:358) Sso 3'-5' ACTAGTCGACTTAAAACCACTGATCAAGACCTGTC (SEQ ID NO:359). An 'A' at position 3 of the Sso ORF sequence (SEQ ID NO: 360) was mutated to a 'G' in the 5' primer to create an ATP start codon. The open reading frame (ORF) encoding the Sso FEN-1 endonuclease is provided in SEQ ID NO:360; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:361.

8. Cloning of a FEN-1 Endonuclease from *Thermococcus gorgonarius*

[1262] Cloning and expression of *Thermococcus gorgonarius* (Tgo) was performed as above except the ATCC # is 700653D, and the PCR primers used are Tgo 5'-5' CTAGCCATGGGAGTTCAGATAGGTGAGC (SEQ ID NO:362) and Tgo 3'-5' TGGAGTCGACTACCGTGTGAACCAGCTTTC (SEQ ID NO:363). The open reading frame (ORF) encoding the Tgo FEN-1 endonuclease is provided in SEQ ID NO:364; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:365.

II. Cloning of FEN-1 Endonucleases with EcoRI/SalI

[1263] The FEN-1's in this group were cloned as described above, except the restriction endonucleases used for the cloning step are EcoRI and SalI. This is due to the presence of an internal NcoI site in these FEN-1 sequences. EcoRI is a good choice since it is common in the art of cloning, is found in many expression vectors, and the following FEN-1's contain no internal EcoRI sites. Interestingly, cloning these PCR fragments into the pTRC99a vector yields an ORF containing two amino acids not present in the native sequence. To correct this and obtain a native ORF, mutagenesis reactions were performed with the Transformer™ Site-Directed Mutagenesis Kit (Palo Alto Calif., cat #K1600-1) according to the manufacturer's instructions, using the mutagenic oligonucleotide specified for each FEN-1 endonuclease. After the mutagenesis reaction, selection was achieved by cutting the products with EcoRI. Since the mutant constructs have no EcoRI site, they will not be cut. Any constructs that were not properly mutagenized would still contain and EcoRI restriction site and would be cut during the digest reaction. Bacterial cells were then transformed and grown on selective medium (ampicillin) according to the Transformer™ Site-Directed Mutagenesis Kit instructions. Mutangenic plasmid was isolated according to the manufacturer's instructions, the resultant DNA was again cut with EcoRI, and the products of this reaction were used to transform competent *E. coli* JM 109 cells (Promega) using standard techniques.

9. Cloning of a FEN-1 Endonuclease from *Archaeaglobus veneficus*

[1264] The cloning of a FEN-1 from *Archaeaglobus veneficus* (Ave) was performed as described above except the DSM # 11195, the PCR primers used are Ave 5'-5' TAACGAATTCGGTGCAGACATAGGCGAACTAC (SEQ ID NO:366) and Ave 3'-5'CGGTGTCGACTCAGGAAAACCACCTCTCAAGCG (SEQ ID NO:367), and the mutagenic oligonucleotide used was Ave ΔR1-5' CACAGGAAACAGACCATGGGTGCAGACATAGGCGAAC (SEQ ID NO:368). The open reading frame (ORF) encoding the Ave FEN-1 endonuclease is provided in SEQ ID NO:369; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:370.

10. Cloning of a FEN-1 Endonuclease from *Desulfurococcus amylolyticus*

[1265] The cloning of a FEN-1 from *Desulfurococcus amylolyticus* (Dam) was performed as described above except the DSM #3822, the PCR primers used are Dam 5'-5'CTAAGAATTCGGAGTAGACTTAAAAGACATTATACC (SEQ ID NO:371) and Dam 3'-5' AGTTGTCGACTACTTCGGCTTACTGAACC (SEQ ID NO:372), and the mutagenic oligonucleotide used was Dam ΔR1-5' CAGGAAACAGACCATGGGAGTAGACTTAAAAGAC (SEQ ID NO:373). The open reading frame (ORF) encoding the Dam FEN-1 endonuclease is provided in SEQ ID NO:374; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:375.

11. Cloning of a FEN-1 Endonuclease from *Pyrobaculum aerophilum*

[1266] The cloning of a FEN-1 from *Pyrobaculum aerophilum* (Pae) was performed as described above except the DSM #7523, the PCR primers used were Cloned using EcoR I and Sal I Pae 5'-5' CGTTGAATTCGGAGTTACTGAGTTGGGTAAG (SEQ ID NO:376) and Pae 3'-5' TACTGTCGACAGAAAAAGGAGTCGAGAGAGGAAG (SEQ ID NO:377). A'G' at position 1 of the Pae ORF sequence (SEQ ID NO: 378) was mutated to an 'A' in the 5' primer to create an ATP start codon. The mutagenesis reaction for this enzyme has not yet been done. There are two, non-native amino acids at the 5' end of this protein. The open reading frame (ORF) encoding the Pae FEN-1 endonuclease is provided in SEQ ID NO378; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:379.

12. Cloning of a FEN-1 Endonuclease from *Thermococcus litoralis*

[1267] The cloning of a FEN-1 from *Thermococcus litoralis* (Tli) was performed as described above except the DSM# is 5473, the PCR primers used were Tli 5'-5' TCATGAATTCGGAGTCCAGATTGGTGAGCTT (SEQ ID NO:380) and Tli 3'-5' GATTGTCGACTCACTTTTTAAACCAGCTGTCC (SEQ ID NO:381), and the mutagenic primer was Tli ΔR1-5'AAGCTCACCAATCTGGACTCCCATGGTCTGTTTCCTGTG (SEQ ID NO:382). The open reading frame (ORF) encoding the Tli FEN-1 endonuclease is provided in SEQ ID NO:383; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:384.

13. Cloning of a FEN-1 Endonuclease from *Desulfurococcus mobilis*

[1268] The cloning of a FEN-1 from *Desulfurococcus mobilis* (Dmo) was performed as described above except the

DSM # 2161, the PCR primers used were Dmo 5'-5' CTTGGAATTCGGCGTCGACCTAAGGGAACTC (SEQ ID NO:385) and Dmo 3'-5' AGGTCTGCAGTTAACCCTGCTTACCGGGCTTAGC (SEQ ID NO:386), and the mutagenic primer used was Dmo ΔR1-5' CAGGAAACAGACCATGGGCGTCGACCTAAGG (SEQ ID NO:387). The open reading frame (ORF) encoding the Dmo FEN-1 endonuclease is provided in SEQ ID NO:388; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:389.

14. Cloning of a FEN-1 Endonuclease from *Pyrodictium brockii*

[1269] The cloning of a FEN-1 from *Pyrodictium brockii* (Pbr) was performed as described above, except the DSM # 2708, the PCR primers used were Pbr 5'-5' TAGCGAATTCGGCGTCAACCTCCGCGAG (SEQ ID NO:390) and Pbr 3'-5' CATTCTGCAGCTAGCGGCGCAGCCACGC (SEQ ID NO:391), and the mutagenic primer was Pbr ΔR1-5' CAGGAAACAGACCATGGGCGTCAACCTCCGC (SEQ ID NO:392). A 'G' at position 1 of the Pbr ORF sequence (SEQ ID NO: 393) was mutated to an 'A' in the 5' primer to create an ATP start codon. The open reading frame (ORF) encoding the Pbr FEN-1 endonuclease is provided in SEQ ID NO:393; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:394.

III. Cloning of FEN-1 Endonucleases with Other Enzymes

[1270] The following FEN-1 endonucleases were cloned using restriction endonucleases other than those already described. These particular FEN-1 sequences contain either internal EcoRI sites or internal SalI sites and therefore require different restriction enzymes in the cloning step. None of the PCR primers used in this section yield cloned products containing an ORF with aberrant (non-natural) nucleotides, therefore there is no need for an additional mutagenesis step. All reactions described in this section were performed as in section I, with any exceptions noted below.

15. Cloning of a FEN-1 Endonuclease from *Methanopyrus kandleri*

[1271] The cloning of a FEN-1 from *Methanopyrus kandleri* (Mka) was performed as described above, except the DSM # 6324 and the PCR primers used were Mka 5'-5' CATACCATGGGACTAGCTGAACTCCGAG (SEQ ID NO:395) and Mka 3'-5' TGGATCTAGATCAGAAGAACGCGTCCAGGG (SEQ ID NO:396). A 'T' at position 1 of the Mka ORF sequence (SEQ ID NO: 397) was mutated to an 'A' in the 5' primer to create an ATP start codon. The restriction enzymes used in the cloning reaction were NcoI and XbaI. The open reading frame (ORF) encoding the Mka FEN-1 endonuclease is provided in SEQ ID NO:397; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:398.

16. Cloning of a FEN-1 Endonuclease from *Thermococcus zilligii*

[1272] The cloning of a FEN-1 from *Thermococcus zilligii* (Tzi) was performed as described above, except genomic DNA obtained was obtained from the American Type Culture Collection (ATCC # 700529D) and the PCR primers used were Tzi 5'-5' CGATCCATGGGAGTTCAGATCGGTGAGC (SEQ ID NO:399) and Tzi 3'-5' CAGGCTGCAGTCACCTTCCGAACCAGCTCTC (SEQ ID NO:400). The restriction enzyme used in the cloning reaction were NcoI and PstI. The open reading frame (ORF) encoding the Tzi FEN-1 endonuclease is provided in SEQ ID NO:401; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:402.

Example 66

Activity Assay for Cloned FEN1 Nucleases

[1273] The INVADER assay test was done using a combination target and upstream (INVADER) oligonucleotide and a large molar excess of labeled probe oligonucleotide (as diagrammed FIG. **141**A). Ten μl reactions contained 10 mM MOPS (pH 7.5), 0.05% NP-40, 0.05% Tween 20, 20 ng/μl tRNA (Sigma), 4 mM MgCl2, 100 ng enzyme, 2 μM labeled probe 203-91-01 (5'-(Tet)TTTTCAACTGCCGTGA; SEQ ID NO:403) and 0.2 nM target-Invader 203-91-04 (5'-TCACGGCAGTTGGTGCGCCTCGGAACGAGGCGCACA; SEQ ID NO:404). Reactions were set up by adding all components to individual wells of a 96-well plate in an ice water bath. The reactions were started by placing the 96-well plate on a prewarmed gradient thermal cycler (Eppendorf Mastercycler) and incubated at the set temperature for 20 minutes. The 96-well plate was then put back in the ice water bath to stop the reactions and 10 μl of stop mix (95% formamide, 20 mM EDTA, 0.05% methyl violet) was added. 1 μl of each reaction was loaded onto a denaturing 20% acrylamide gel. After electrophoresis, the gels were visualized using an FMBIO fluoroimager (Hitachi) and quantitated with FMBIO Analysis software. Results are shown graphically in FIG. **142**.

[1274] Cleavage of an 'X-structure' as diagrammed in FIG. **141**B can provide one source of background signal in the sequential invasive cleavage reactions of the present invention, thus it is desirable to determine the level of activity that enzymes have in cleaving such a structure. Ten-μl reactions on the X-structure substrate contained 10 mM MOPS (pH 7.5), 0.05% NP-40, 0.05% Tween 20, 20 ng/μl tRNA (Sigma), 4 mM MgCl2, 100 ng enzyme, and 2 μM labeled 203-81-02 (5'-(Tet)TTTTCAACTGCTTAGAGAATCTAAGCAGTTGGTGCGCCTCGTTAA-NH2; SEQ ID NO:405) and 2 μM target 594-09-01 (5'-AACGAGGCGCACATTTTTTTT; SEQ ID NO:406). Reactions were done as described above except incubation at the reaction temperature was carried out for 60 minutes. Samples were electrophoresed and analyzed as described above. Results are shown graphically in FIG. **143**.

[1275] Together these test allow characterization of the cleavage activities of FEN enzymes and other 5' nucleases, and of any new enzyme suspected of being able to cleave an invasive cleavage structure.

Example 67

Detection of the Human Cytomegalovirus pol Gene

[1276] Example 48 demonstrated the use of the invasive cleavage assay to detect human cytomegalovirus sequences in a background of human genomic DNA. In this example, another embodiment of the multiple invasive cleavage reaction will be demonstrated for the detection of human cytomegalovirus sequence. Example 48 utilized an INVADER and a labeled, primary probe oligonucleotide

targeting the region 3104-3061 of hCMV. In this example bases 2302-2248 of the hCMV genome were targeted. As in previous examples, a FRET cassette was used to generate signal in the presence of the target DNA.

[1277] INVADER and probe oligonucleotides were designed as described above to detect the polymerase gene of HCMV (SEQ ID NO:407 and 408, respectively); the FRET cassette is SEQ ID NO:409. Oligonucleotides are diagrammed in FIG. **144**. The HCMV target sequence detected by this probe set is SEQ ID NO:410.

[1278] Genomic viral DNA was purchased from Advanced Biotechnologies, Inc. (Columbia Md.). The DNA was estimated (but not certified) by personnel at Advanced Biotechnologies to be at a concentration of 170 amol (1×10^8 copies) per microliter. The viral stock was diluted in 10 ng/μl human genomic DNA to final concentrations of 45.7, 137.2, 411.5 and 1234.6 viral copies per microliter. Reactions were performed in MJ 96 well MULTIPLATE (MJ Research MLP-9601) plates, in triplicate in a final volume of μl. Each reaction comprised 12 mM MOPS (pH 7.5), 12 mM $MgCl_2$, 0.5 pmol INVADER oligonucleotide, 10 pmol unlabeled, primary probe, 5 pmol One-Piece FRET cassette, 0, 457, 1372, 4115 or 12346 copies of CMV Viral DNA, 100 ng human genomic DNA and 60 ng AveFEN1, and water to a final volume of 2 μl. The MOPS, INVADER oligonucleotide, water, CMV viral DNA and human genomic DNA were combined, overlaid with CHILLOUT liquid wax, and denatured for 5 minutes at 95° C. Reactions were then cooled to 20° C. and $MgCl_2$, unlabeled primary probe, FRET cassette, and AveFEN1 enzyme were added below the Chill-out layer. The reaction were mixed by pipetting up and down 5-10 times, with care being taken to remain clear of the CHILLOUT layer. Reactions were then incubated for 4 hours at 65° C., and plates were read directly on a Cytoflour plate reader using the following settings: Excitation=485/20, Emission=530/25, Gain=40 at 10 reads/well.

[1279] Results are shown graphically in FIG. **145**, with number of copies of the target DNA indicated on the horizontal axis and the fluorescence units indicated on the vertical axis. These results indicate sensitive detection of HCMV using the sequential invasive cleavage FRET format.

[1280] Selection of oligonucleotides for target nucleic acids other than the analytes shown here, (e.g., oligonucleotide composition and length), and the optimization of cleavage reaction conditions in accord with the models provided here follow routine methods and common practice well known to those skilled in the methods of molecular biology.

[1281] All publications and patents mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described methods and systems of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in the relevant fields are intended to be within the scope of the following claims.

SEQUENCE LISTING

<160> NUMBER OF SEQ ID NOS: 410

<210> SEQ ID NO 1
<211> LENGTH: 2506
<212> TYPE: DNA
<213> ORGANISM: Thermus aquaticus

<400> SEQUENCE: 1

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cacctggcct accgcacctt ccacgccctg aagggcctca ccaccagccg gggggagccg 120

gtgcaggcgg tctacggctt cgccaagagc ctcctcaagg ccctcaagga ggacggggac 180

gcggtgatcg tggtctttga cgccaaggcc ccctccttcc gccacgaggc ctacgggggg 240

tacaaggcgg gccgggcccc cacgccggag gactttcccc ggcaactcgc cctcatcaag 300

gagctggtgg acctcctggg gctggcgcgc ctcgaggtcc cgggctacga ggcggacgac 360

gtcctggcca gcctggccaa gaaggcggaa aaggagggct acgaggtccg catcctcacc 420

gccgacaaag acctttacca gctcctttcc gaccgcatcc acgtcctcca ccccgagggg 480

tacctcatca ccccggcctg gctttgggaa aagtacggcc tgaggcccga ccagtgggcc 540

gactaccggg ccctgaccgg ggacgagtcc gacaaccttc ccggggtcaa gggcatcggg 600

gagaagacgg cgaggaagct tctggaggag tgggggagcc tggaagccct cctcaagaac 660

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gcggccaaga ccatcaactt cggggtcctc tacggcatgt cggcccaccg cctctcccag 2040

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cccaaggtgc gggcctggat tgagaagacc ctggaggagg gcaggaggcg ggggtacgtg 2160

gagaccctct tcggccgccg ccgctacgtg ccagacctag aggcccgggt gaagagcgtg 2220

cgggaggcgg ccgagcgcat ggccttcaac atgcccgtcc agggcaccgc cgccgacctc 2280

atgaagctgg ctatggtgaa gctcttcccc aggctggagg aaatgggggc caggatgctc 2340

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<210> SEQ ID NO 2
<211> LENGTH: 2496
<212> TYPE: DNA
<213> ORGANISM: thermus flavus

<400> SEQUENCE: 2

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caggcggtct acggcttcgc caaaagcctc ctcaaggccc tgaaggagga cggggacgtg 180

gtggtggtgg tctttgacgc caaggccccc tccttccgcc acgaggccta cgaggcctac 240

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ctggccaccc tggccaagcg ggcggaaaag gaggggtacg aggtgcgcat cctcactgcc 420

gaccgcgacc tctaccagct cctttcggag cgcatcgcca tcctccaccc tgaggggtac 480

ctgatcaccc cggcgtggct ttacgagaag tacggcctgc gcccggagca gtgggtggac 540

taccgggccc tggcgggggа cccctcggat aacatccccg gggtgaaggg catcggggag 600

aagaccgccc agaggctcat ccgcgagtgg gggagcctgg aaaacctctt ccagcacctg 660

gaccaggtga agccctcctt gcgggagaag ctccaggcgg gcatggaggc cctggccctt 720

tcccggaagc tttcccaggt gcacactgac ctgcccctgg aggtggactt cgggaggcgc 780

cgcacaccca acctggaggg tctgcgggct tttttggagc ggttggagtt tggaagcctc 840

ctccacgagt tcggcctcct ggaggggccg aaggcggcag aggaggcccc ctggcccccт 900

ccggaagggg ctttttttggg cttttccttt tcccgtcccg agcccatgtg ggccgagctt 960

ctggccctgg ctggggcgtg ggaggggcgc ctccatcggg cacaagaccc ccttaggggc 1020

ctgagggacc ttaagggggt gcggggaatc ctggccaagg acctggcggt tttggccctg 1080

cgggagggcc tggacctctt cccagaggac gaccccatgc tcctggccta ccttctggac 1140

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gccatcggca agacggagaa gacggggaaa cgctccacca gcgctgccgt gctggaggcc 1560

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ggcctggggg aggactggct ctccgccaag gagtag 2496

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<210> SEQ ID NO 3
<211> LENGTH: 2504
<212> TYPE: DNA
<213> ORGANISM: Thermus thermophilus

<400> SEQUENCE: 3

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gtgcaggcgg tctacggctt cgccaagagc ctcctcaagg ccctgaagga ggacgggtac 180

aaggccgtct tcgtggtctt tgacgccaag gccccctcct tccgccacga ggcctacgag 240

gcctacaagg cggggagggc cccgaccccc gaggacttcc cccggcagct cgccctcatc 300

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gacgttctcg ccaccctggc caagaaggcg gaaaaggagg ggtacgaggt gcgcatcctc 420

accgccgacc gcgacctcta ccaactcgtc tccgaccgcg tcgccgtcct ccaccccgag 480

ggccacctca tcaccccgga gtggctttgg gagaagtacg gcctcaggcc ggagcagtgg 540

gtggacttcc gcgccctcgt gggggacccc tccgacaacc tccccggggt caagggcatc 600

ggggagaaga ccgccctcaa gctcctcaag gagtggggaa gcctggaaaa cctcctcaag 660

aacctggacc gggtaaagcc agaaaacgtc cgggagaaga tcaaggccca cctggaagac 720

ctcaggctct ccttggagct ctcccgggtg cgcaccgacc tccccctgga ggtggacctc 780

gcccaggggc gggagcccga ccgggagggg cttagggcct tcctggagag gctggagttc 840

ggcagcctcc tccacgagtt cggcctcctg gaggcccccg ccccctgga ggaggccccc 900

tggccccgc cggaaggggc cttcgtgggc ttcgtcctct cccgccccga gcccatgtgg 960

gcggagctta aagccctggc cgcctgcagg gacggccggg tgcaccgggc agcagacccc 1020

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gcgtcaggga ggccgcggag cgcatggcct tcaacatgcc cgtccagggc accgccgccg 2280

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<210> SEQ ID NO 4
<211> LENGTH: 832
<212> TYPE: PRT
<213> ORGANISM: Thermus aquaticus

<400> SEQUENCE: 4

Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
1 5 10 15

Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
20 25 30

Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
35 40 45

Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
50 55 60

Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
65 70 75 80

Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
85 90 95

Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
100 105 110

Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
115 120 125

Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
130 135 140

Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
145 150 155 160

Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
165 170 175

Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
180 185 190

Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
195 200 205

Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
210 215 220

Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
225 230 235 240

Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
245 250 255

Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
260 265 270

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Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
        275                 280                 285

Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
    290                 295                 300

Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
305                 310                 315                 320

Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
                325                 330                 335

Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
            340                 345                 350

Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
        355                 360                 365

Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
    370                 375                 380

Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
385                 390                 395                 400

Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
                405                 410                 415

Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
            420                 425                 430

Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
        435                 440                 445

Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
    450                 455                 460

Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
465                 470                 475                 480

Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
                485                 490                 495

Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
            500                 505                 510

Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
        515                 520                 525

Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
    530                 535                 540

Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
545                 550                 555                 560

His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
                565                 570                 575

Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
            580                 585                 590

Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
        595                 600                 605

Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
    610                 615                 620

Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
625                 630                 635                 640

Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
                645                 650                 655

Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
            660                 665                 670

Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
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        675                 680                 685

Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
    690                 695                 700

Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
705                 710                 715                 720

Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
                725                 730                 735

Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
            740                 745                 750

Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
        755                 760                 765

Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
    770                 775                 780

Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
785                 790                 795                 800

Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
                805                 810                 815

Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
            820                 825                 830


<210> SEQ ID NO 5
<211> LENGTH: 831
<212> TYPE: PRT
<213> ORGANISM: thermus flavus

<400> SEQUENCE: 5

Met Ala Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu Val
  1               5                  10                  15

Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu Lys Gly Leu
             20                  25                  30

Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala Lys
         35                  40                  45

Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Val Val Val Val Val
     50                  55                  60

Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Glu Ala Tyr
 65                  70                  75                  80

Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu Ala
                 85                  90                  95

Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Val Arg Leu Glu Val
            100                 105                 110

Pro Gly Phe Glu Ala Asp Asp Val Leu Ala Thr Leu Ala Lys Arg Ala
        115                 120                 125

Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Arg Asp Leu
    130                 135                 140

Tyr Gln Leu Leu Ser Glu Arg Ile Ala Ile Leu His Pro Glu Gly Tyr
145                 150                 155                 160

Leu Ile Thr Pro Ala Trp Leu Tyr Glu Lys Tyr Gly Leu Arg Pro Glu
                165                 170                 175

Gln Trp Val Asp Tyr Arg Ala Leu Ala Gly Asp Pro Ser Asp Asn Ile
            180                 185                 190

Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Gln Arg Leu Ile Arg
        195                 200                 205
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Glu Trp Gly Ser Leu Glu Asn Leu Phe Gln His Leu Asp Gln Val Lys
    210                 215                 220

Pro Ser Leu Arg Glu Lys Leu Gln Ala Gly Met Glu Ala Leu Ala Leu
225                 230                 235                 240

Ser Arg Lys Leu Ser Gln Val His Thr Asp Leu Pro Leu Glu Val Asp
                245                 250                 255

Phe Gly Arg Arg Arg Thr Pro Asn Leu Glu Gly Leu Arg Ala Phe Leu
            260                 265                 270

Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu Glu
        275                 280                 285

Gly Pro Lys Ala Ala Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala
    290                 295                 300

Phe Leu Gly Phe Ser Phe Ser Arg Pro Glu Pro Met Trp Ala Glu Leu
305                 310                 315                 320

Leu Ala Leu Ala Gly Ala Trp Glu Gly Arg Leu His Arg Ala Gln Asp
                325                 330                 335

Pro Leu Arg Gly Leu Arg Asp Leu Lys Gly Val Arg Gly Ile Leu Ala
            340                 345                 350

Lys Asp Leu Ala Val Leu Ala Leu Arg Glu Gly Leu Asp Leu Phe Pro
        355                 360                 365

Glu Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr
    370                 375                 380

Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Asp
385                 390                 395                 400

Ala Gly Glu Arg Ala Leu Leu Ala Glu Arg Leu Phe Gln Thr Leu Lys
                405                 410                 415

Glu Arg Leu Lys Gly Glu Glu Arg Leu Leu Trp Leu Tyr Glu Glu Val
            420                 425                 430

Glu Lys Pro Leu Ser Arg Val Leu Ala Arg Met Glu Ala Thr Gly Val
        435                 440                 445

Arg Leu Asp Val Ala Tyr Leu Gln Ala Leu Ser Leu Glu Val Glu Ala
    450                 455                 460

Glu Val Arg Gln Leu Glu Glu Glu Val Phe Arg Leu Ala Gly His Pro
465                 470                 475                 480

Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu
                485                 490                 495

Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser
            500                 505                 510

Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val
        515                 520                 525

Asp Arg Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Asn Thr Tyr
    530                 535                 540

Ile Asp Pro Leu Pro Ala Leu Val His Pro Lys Thr Gly Arg Leu His
545                 550                 555                 560

Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser
                565                 570                 575

Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg
            580                 585                 590

Ile Arg Arg Ala Phe Val Ala Glu Glu Gly Trp Val Leu Val Val Leu
        595                 600                 605

Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp
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    610                 615                 620

Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr Gln
625                 630                 635                 640

Thr Ala Ser Trp Met Phe Gly Val Ser Pro Glu Gly Val Asp Pro Leu
                645                 650                 655

Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met
            660                 665                 670

Ser Ala His Arg Leu Ser Gly Glu Leu Ser Ile Pro Tyr Glu Glu Ala
        675                 680                 685

Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Tyr Pro Lys Val Arg Ala
    690                 695                 700

Trp Ile Glu Gly Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu
705                 710                 715                 720

Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Asn Ala Arg Val
                725                 730                 735

Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val
            740                 745                 750

Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Arg Leu Phe
        755                 760                 765

Pro Arg Leu Gln Glu Leu Gly Ala Arg Met Leu Leu Gln Val His Asp
    770                 775                 780

Glu Leu Val Leu Glu Ala Pro Lys Asp Arg Ala Glu Arg Val Ala Ala
785                 790                 795                 800

Leu Ala Lys Glu Val Met Glu Gly Val Trp Pro Leu Gln Val Pro Leu
                805                 810                 815

Glu Val Glu Val Gly Leu Gly Glu Asp Trp Leu Ser Ala Lys Glu
            820                 825                 830


<210> SEQ ID NO 6
<211> LENGTH: 834
<212> TYPE: PRT
<213> ORGANISM: Thermus thermophilus

<400> SEQUENCE: 6

Met Glu Ala Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
  1               5                  10                  15

Val Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu Lys Gly
             20                  25                  30

Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
         35                  40                  45

Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Tyr Lys Ala Val Phe
     50                  55                  60

Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Glu
 65                  70                  75                  80

Ala Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
                 85                  90                  95

Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Phe Thr Arg Leu
            100                 105                 110

Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Thr Leu Ala Lys
        115                 120                 125

Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Arg
    130                 135                 140
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Asp Leu Tyr Gln Leu Val Ser Asp Arg Val Ala Val Leu His Pro Glu
145                 150                 155                 160

Gly His Leu Ile Thr Pro Glu Trp Leu Trp Glu Lys Tyr Gly Leu Arg
                165                 170                 175

Pro Glu Gln Trp Val Asp Phe Arg Ala Leu Val Gly Asp Pro Ser Asp
            180                 185                 190

Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Leu Lys Leu
        195                 200                 205

Leu Lys Glu Trp Gly Ser Leu Glu Asn Leu Leu Lys Asn Leu Asp Arg
    210                 215                 220

Val Lys Pro Glu Asn Val Arg Glu Lys Ile Lys Ala His Leu Glu Asp
225                 230                 235                 240

Leu Arg Leu Ser Leu Glu Leu Ser Arg Val Arg Thr Asp Leu Pro Leu
                245                 250                 255

Glu Val Asp Leu Ala Gln Gly Arg Glu Pro Asp Arg Glu Gly Leu Arg
            260                 265                 270

Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly
        275                 280                 285

Leu Leu Glu Ala Pro Ala Pro Leu Glu Glu Ala Pro Trp Pro Pro Pro
    290                 295                 300

Glu Gly Ala Phe Val Gly Phe Val Leu Ser Arg Pro Glu Pro Met Trp
305                 310                 315                 320

Ala Glu Leu Lys Ala Leu Ala Ala Cys Arg Asp Gly Arg Val His Arg
                325                 330                 335

Ala Ala Asp Pro Leu Ala Gly Leu Lys Asp Leu Lys Glu Val Arg Gly
            340                 345                 350

Leu Leu Ala Lys Asp Leu Ala Val Leu Ala Ser Arg Glu Gly Leu Asp
        355                 360                 365

Leu Val Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro
    370                 375                 380

Ser Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp
385                 390                 395                 400

Thr Glu Asp Ala Ala His Arg Ala Leu Leu Ser Glu Arg Leu His Arg
                405                 410                 415

Asn Leu Leu Lys Arg Leu Glu Gly Glu Glu Lys Leu Leu Trp Leu Tyr
            420                 425                 430

His Glu Val Glu Lys Pro Leu Ser Arg Val Leu Ala His Met Glu Ala
        435                 440                 445

Thr Gly Val Arg Leu Asp Val Ala Tyr Leu Gln Ala Leu Ser Leu Glu
    450                 455                 460

Leu Ala Glu Glu Ile Arg Arg Leu Glu Glu Glu Val Phe Arg Leu Ala
465                 470                 475                 480

Gly His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu
                485                 490                 495

Phe Asp Glu Leu Arg Leu Pro Ala Leu Gly Lys Thr Gln Lys Thr Gly
            500                 505                 510

Lys Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His
        515                 520                 525

Pro Ile Val Glu Lys Ile Leu Gln His Arg Glu Leu Thr Lys Leu Lys
    530                 535                 540

Asn Thr Tyr Val Asp Pro Leu Pro Ser Leu Val His Pro Arg Thr Gly
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545                 550                 555                 560

Arg Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu
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Ser Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu
            580                 585                 590

Gly Gln Arg Ile Arg Arg Ala Phe Val Ala Glu Ala Gly Trp Ala Leu
        595                 600                 605

Val Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu
    610                 615                 620

Ser Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Lys Asp Ile
625                 630                 635                 640

His Thr Gln Thr Ala Ser Trp Met Phe Gly Val Pro Pro Glu Ala Val
                645                 650                 655

Asp Pro Leu Met Arg Arg Ala Ala Lys Thr Val Asn Phe Gly Val Leu
            660                 665                 670

Tyr Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr
        675                 680                 685

Glu Glu Ala Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys
    690                 695                 700

Val Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Lys Arg Gly
705                 710                 715                 720

Tyr Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Asn
                725                 730                 735

Ala Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn
            740                 745                 750

Met Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val
        755                 760                 765

Lys Leu Phe Pro Arg Leu Arg Glu Met Gly Ala Arg Met Leu Leu Gln
    770                 775                 780

Val His Asp Glu Leu Leu Leu Glu Ala Pro Gln Ala Arg Ala Glu Glu
785                 790                 795                 800

Val Ala Ala Leu Ala Lys Glu Ala Met Glu Lys Ala Tyr Pro Leu Ala
                805                 810                 815

Val Pro Leu Glu Val Glu Val Gly Met Gly Glu Asp Trp Leu Ser Ala
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Lys Gly
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gtgcaggcgg tctacggctt cgccaagagc ctcctcaagg ccctgaagga ggacggggac 180

nnggcggtgn tcgtggtctt tgacgccaag gccccctcct tccgccacga ggcctacgag 240

gcctacaagg cgggccgggc ccccaccccg gaggactttc cccggcagct cgccctcatc 300

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gtggagaccc tcttcggccg ccggcgctac gtgcccgacc tcaacgcccg ggtgaagagc 2220

gtgcgggagg cggcggagcg catggccttc aacatgcccg tccagggcac cgccgccgac 2280

ctcatgaagc tggccatggt gaagctcttc ccccggctnc aggaaatggg ggccaggatg 2340

ctcctncagg tccacgacga gctggtcctc gaggccccca aagagcgggc ggaggnggtg 2460

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<212> TYPE: PRT
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Val Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu Lys Gly
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Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
         35                  40                  45

Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Xaa Val
     50                  55                  60

Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Glu Ala
 65                  70                  75                  80

Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
                 85                  90                  95

Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Xaa Arg Leu Glu
            100                 105                 110

Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Thr Leu Ala Lys Lys
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        115                 120                 125

Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Arg Asp
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Leu Tyr Gln Leu Leu Ser Asp Arg Ile Ala Val Leu His Pro Glu Gly
145                 150                 155                 160

Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
                165                 170                 175

Glu Gln Trp Val Asp Tyr Arg Ala Leu Xaa Gly Asp Pro Ser Asp Asn
            180                 185                 190

Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Xaa Lys Leu Leu
        195                 200                 205

Xaa Glu Trp Gly Ser Leu Glu Asn Leu Leu Lys Asn Leu Asp Arg Val
    210                 215                 220

Lys Pro Xaa Xaa Arg Glu Lys Ile Xaa Ala His Met Glu Asp Leu Xaa
225                 230                 235                 240

Leu Ser Xaa Xaa Leu Ser Xaa Val Arg Thr Asp Leu Pro Leu Glu Val
                245                 250                 255

Asp Phe Ala Xaa Arg Arg Glu Pro Asp Arg Glu Gly Leu Arg Ala Phe
            260                 265                 270

Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
        275                 280                 285

Glu Xaa Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
    290                 295                 300

Ala Phe Val Gly Phe Val Leu Ser Arg Pro Glu Pro Met Trp Ala Glu
305                 310                 315                 320

Leu Leu Ala Leu Ala Ala Ala Arg Xaa Gly Arg Val His Arg Ala Xaa
                325                 330                 335

Asp Pro Leu Xaa Gly Leu Arg Asp Leu Lys Glu Val Arg Gly Leu Leu
            340                 345                 350

Ala Lys Asp Leu Ala Val Leu Ala Leu Arg Glu Gly Leu Asp Leu Xaa
        355                 360                 365

Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
    370                 375                 380

Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
385                 390                 395                 400

Asp Ala Gly Glu Arg Ala Leu Leu Ser Glu Arg Leu Phe Xaa Asn Leu
                405                 410                 415

Xaa Xaa Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Xaa Glu
            420                 425                 430

Val Glu Lys Pro Leu Ser Arg Val Leu Ala His Met Glu Ala Thr Gly
        435                 440                 445

Val Arg Leu Asp Val Ala Tyr Leu Gln Ala Leu Ser Leu Glu Val Ala
    450                 455                 460

Glu Glu Ile Arg Arg Leu Glu Glu Glu Val Phe Arg Leu Ala Gly His
465                 470                 475                 480

Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
                485                 490                 495

Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
            500                 505                 510

Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
        515                 520                 525
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Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Asn Thr
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Tyr Ile Asp Pro Leu Pro Xaa Leu Val His Pro Arg Thr Gly Arg Leu
545                 550                 555                 560

His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
                565                 570                 575

Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
            580                 585                 590

Arg Ile Arg Arg Ala Phe Val Ala Glu Glu Gly Trp Xaa Leu Val Ala
        595                 600                 605

Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
    610                 615                 620

Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
625                 630                 635                 640

Gln Thr Ala Ser Trp Met Phe Gly Val Pro Pro Glu Ala Val Asp Pro
                645                 650                 655

Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
            660                 665                 670

Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
        675                 680                 685

Ala Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
    690                 695                 700

Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
705                 710                 715                 720

Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Asn Ala Arg
                725                 730                 735

Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
            740                 745                 750

Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
        755                 760                 765

Phe Pro Arg Leu Xaa Glu Met Gly Ala Arg Met Leu Leu Gln Val His
    770                 775                 780

Asp Glu Leu Val Leu Glu Ala Pro Lys Xaa Arg Ala Glu Xaa Val Ala
785                 790                 795                 800

Ala Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
                805                 810                 815

Leu Glu Val Glu Val Gly Xaa Gly Glu Asp Trp Leu Ser Ala Lys Glu
            820                 825                 830

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<210> SEQ ID NO 9
<211> LENGTH: 1647
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

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ccggtgcagg cggtctacgg cttcgccaag agcctcctca aggccctcaa ggaggacggg    180
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aaggagctgg tggacctcct ggggctggcg cgcctcgagg tcccgggcta cgaggcggac 360

gacgtcctgg ccagcctggc caagaaggcg gaaaaggagg gctacgaggt ccgcatcctc 420

accgccgaca aagaccttta ccagctcctt tccgaccgca tccacgtcct ccaccccgag 480

gggtacctca tcaccccggc ctggctttgg gaaaagtacg gcctgaggcc cgaccagtgg 540

gccgactacc gggccctgac cggggacgag tccgacaacc ttcccggggt caagggcatc 600

ggggagaaga cggcgaggaa gcttctggag gagtgggga gcctggaagc cctcctcaag 660

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aagctctcct gggacctggc caaggtgcgc accgacctgc ccctggaggt ggacttcgcc 780

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agcctcctcc acgagttcgg ccttctggaa agccccaagg ccctggagga ggccccctgg 900

cccccgccgg aaggggcctt cgtgggcttt gtgctttccc gcaaggagcc catgtgggcc 960

gatcttctgg ccctggccgc cgccaggggg ggccgggtcc accgggcccc cgagccttat 1020

aaagccctca gggacctgaa ggaggcgcgg gggcttctcg ccaaagacct gagcgttctg 1080

gccctgaggg aaggccttgg cctcccgccc ggcgacgacc ccatgctcct cgcctacctc 1140

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actggccgtc gttttacaac gtcgtga 1647

<210> SEQ ID NO 10
<211> LENGTH: 2088
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 10

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ccggtgcagg cggtctacgg cttcgccaag agcctcctca aggccctcaa ggaggacggg 180

gacgcggtga tcgtggtctt tgacgccaag gccccctcct tccgccacga ggcctacggg 240

gggtacaagg cgggccgggc ccccacgccg gaggactttc cccggcaact cgccctcatc 300

aaggagctgg tggacctcct ggggctggcg cgcctcgagg tcccgggcta cgaggcggac 360

gacgtcctgg ccagcctggc caagaaggcg gaaaaggagg gctacgaggt ccgcatcctc 420

accgccgaca aagaccttta ccagctcctt tccgaccgca tccacgtcct ccaccccgag 480

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gggtacctca tcaccccggc ctggctttgg gaaaagtacg gcctgaggcc cgaccagtgg 540

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ggggagaaga cggcgaggaa gcttctggag gagtggggga gcctggaagc cctcctcaag 660

aacctggacc ggctgaagcc cgccatccgg gagaagatcc tggcccacat ggacgatctg 720

aagctctcct gggacctggc caaggtgcgc accgacctgc ccctggaggt ggacttcgcc 780

aaaaggcggg agcccgaccg ggagaggctt agggcctttc tggagaggct tgagtttggc 840

agcctcctcc acgagttcgg ccttctggaa agccccaagg ccctggagga ggccccctgg 900

cccccgccgg aaggggcctt cgtgggcttt gtgctttccc gcaaggagcc catgtgggcc 960

gatcttctgg ccctggccgc cgccaggggg ggccgggtcc accgggcccc cgagccttat 1020

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gccctgaggg aaggccttgg cctcccgccc ggcgacgacc ccatgctcct cgcctacctc 1140

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cgggcggcca agaccatcaa cttcggggtc ctctacggca tgtcggccca ccgcctctcc 2040

caggagctag ctagccatcc cttacgagga ggcccaggcc ttcattga 2088

<210> SEQ ID NO 11
<211> LENGTH: 962
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 11

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ccggtgcagg cggtctacgg cttcgccaag agcctcctca aggccctcaa ggaggacggg 180

gacgcggtga tcgtggtctt tgacgccaag gccccctcct tccgccacga ggcctacggg 240

gggtacaagg cgggccgggc ccccacgccg gaggactttc cccggcaact cgccctcatc 300

aaggagctgg tggacctcct ggggctggcg cgcctcgagg tcccgggcta cgaggcggac 360

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gacgtcctgg ccagcctggc caagaaggcg gaaaaggagg gctacgaggt ccgcatcctc 420

accgccgaca aagaccttta ccagcttctt tccgaccgca tccacgtcct ccaccccgag 480

gggtacctca tcaccccggc ctggctttgg gaaaagtacg gcctgaggcc cgaccagtgg 540

gccgactacc gggccctgac cggggacgag tccgacaacc ttcccggggt caagggcatc 600

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aacctggacc ggctgaagcc cgccatccgg gagaagatcc tggcccacat ggacgatctg 720

aagctctcct gggacctggc caaggtgcgc accgacctgc ccctggaggt ggacttcgcc 780

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tggccgtgcc cctggaggtg gaggtgggga taggggagga ctggctctcc gccaaggagt 960

ga 962

<210> SEQ ID NO 12
<211> LENGTH: 1600
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 12

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ccaccacctg gcctaccgca ccttccacgc cctgaagggc ctcaccacca gccgggggga 120

gccggtgcag gcggtctacg gcttcgccaa gagcctcctc aaggccctca aggaggacgg 180

ggacgcggtg atcgtggtct ttgacgccaa ggccccctcc ttccgccacg aggcctacgg 240

ggggtacaag gcgggccggg cccccacgcc ggaggacttt ccccggcaac tcgccctcat 300

caaggagctg gtggacctcc tggggctggc gcgcctcgag gtcccgggct acgaggcgga 360

cgacgtcctg gccagcctgg ccaagaaggc ggaaaaggag ggctacgagg tccgcatcct 420

caccgccgac aaagaccttt accagctcct ttccgaccgc atccacgtcc tccaccccga 480

ggggtacctc atcaccccgg cctggctttg ggaaaagtac ggcctgaggc ccgaccagtg 540

ggccgactac cgggccctga ccggggacga gtccgacaac cttcccgggg tcaagggcat 600

cggggagaag acggcgagga agcttctgga ggagtggggg agcctggaag ccctcctcaa 660

gaacctggac cggctgaagc ccgccatccg ggagaagatc ctggcccaca tggacgatct 720

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caaaaggcgg gagcccgacc gggagaggct tagggccttt ctggagaggc ttgagtttgg 840

cagcctcctc cacgagttcg gccttctgga aagccccaag atccgccggg ccttcatcgc 900

cgaggagggg tggctattgg tggccctgga ctatagccag atagagctca gggtgctggc 960

ccacctctcc ggcgacgaga acctgatccg ggtcttccag gaggggcggg acatccacac 1020

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gcgggaggcg gccgagcgca tggccttcaa catgcccgtc cggggcaccg ccgccgacct 1380

catgaagctg gctatggtga agctcttccc caggctggag gaaatggggg ccaggatgct 1440

ccttcaggtc cacgacgagc tggtcctcga ggccccaaaa gagagggcgg aggccgtggc 1500

ccggctggcc aaggaggtca tggagggggt gtatcccctg gccgtgcccc tggaggtgga 1560

ggtggggata ggggaggact ggctctccgc caaggagtga 1600

<210> SEQ ID NO 13
<211> LENGTH: 36
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 13

cacgaattcg gggatgctgc ccctctttga gcccaa 36

<210> SEQ ID NO 14
<211> LENGTH: 34
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 14

gtgagatcta tcactccttg gcggagagcc agtc 34

<210> SEQ ID NO 15
<211> LENGTH: 91
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 15

taatacgact cactataggg agaccggaat tcgagctcgc ccgggcgagc tcgaattccg 60

tgtattctat agtgtcacct aaatcgaatt c 91

<210> SEQ ID NO 16
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 16

taatacgact cactataggg 20

<210> SEQ ID NO 17
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 17

gaattcgatt taggtgacac tatagaa 27

<210> SEQ ID NO 18
<211> LENGTH: 31
<212> TYPE: DNA

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<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 18

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<210> SEQ ID NO 19
<211> LENGTH: 42
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 19

ggatcctcta gagtcgacct gcaggcatgc ctaccttggt ag 42

<210> SEQ ID NO 20
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 20

ggatcctcta gagtcgacct gcaggcatgc 30

<210> SEQ ID NO 21
<211> LENGTH: 2502
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 21

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ccggtgcagg cggtctacgg cttcgccaag agcctcctca aggccctcaa ggaggacggg 180

gacgcggtga tcgtggtctt tgacgccaag gccccctcct tccgccacga ggcctacggg 240

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gacgtcctgg ccagcctggc caagaaggcg gaaaaggagg gctacgaggt ccgcatcctc 420

accgccgaca aagacctta ccagctcctt tccgaccgca tccacgtcct ccaccccgag 480

gggtacctca tcaccccggc ctggctttgg gaaaagtacg gcctgaggcc cgaccagtgg 540

gccgactacc gggccctgac cggggacgag tccgacaacc ttcccggggt caagggcatc 600

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cccccgccgg aaggggcctt cgtgggcttt gtgctttccc gcaaggagcc catgtgggcc 960

gatcttctgg ccctggccgc cgccaggggg ggccgggtcc accgggcccc cgagccttat 1020

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aaagccctca gggacctgaa ggaggcgcgg gggcttctcg ccaaagacct gagcgttctg 1080

gccctgaggg aaggccttgg cctcccgccc ggcgacgacc ccatgctcct cgcctacctc 1140

ctggaccctt ccaacaccac ccccgagggg gtggcccggc gctacggcgg ggagtggacg 1200

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gtgcgggagg cggccgagcg catggccttc aacatgcccg tccggggcac cgccgccgac 2280

ctcatgaagc tggctatggt gaagctcttc cccaggctgg aggaaatggg ggccaggatg 2340

ctccttcagg tccacgacga gctggtcctc gaggccccaa aagagagggc ggaggccgtg 2400

gcccggctgg ccaaggaggt catggagggg gtgtatcccc tggccgtgcc cctggaggtg 2460

gaggtgggga taggggagga ctggctctcc gccaaggagt ga 2502

<210> SEQ ID NO 22
<211> LENGTH: 19
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 22

gatttaggtg acactatag 19

<210> SEQ ID NO 23
<211> LENGTH: 50
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 23

acacaggtac cacatggtac aagaggcaag agagacgaca cagcagaaac 50

<210> SEQ ID NO 24

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<211> LENGTH: 15
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 24

Met Ala Ser Met Thr Gly Gly Gln Gln Met Gly Arg Ile Asn Ser
1 5 10 15

<210> SEQ ID NO 25
<211> LENGTH: 969
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 25

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tttgagccca agggccgggt cctcctggtg gacggccacc acctggccta ccgcaccttc 120

cacgccctga agggcctcac caccagccgg ggggagccgg tgcaggcggt ctacggcttc 180

gccaagagcc tcctcaaggc cctcaaggag gacggggacg cggtgatcgt ggtctttgac 240

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gacgagtccg acaaccttcc cggggtcaag ggcatcgggg agaagacggc gaggaagctt 660

ctggaggagt gggggagcct ggaagccctc ctcaagaacc tggaccggct gaagcccgcc 720

atccgggaga agatcctggc ccacatggac gatctgaagc tctcctggga cctggccaag 780

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ctggaaagcc ccaagtcatg gaggggtgt atcccctggc cgtgcccctg gaggtggagg 960

tggggatag 969

<210> SEQ ID NO 26
<211> LENGTH: 948
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 26

atggctagca tgactggtgg acagcaaatg ggtcggatca attcggggat gctgcccctc 60

tttgagccca agggccgggt cctcctggtg gacggccacc acctggccta ccgcaccttc 120

cacgccctga agggcctcac caccagccgg ggggagccgg tgcaggcggt ctacggcttc 180

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ctggaaagcc ccaaggccgc actcgagcac caccaccacc accactga 948

<210> SEQ ID NO 27
<211> LENGTH: 206
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 27

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cactataggg cgaattcgag ctcggtaccc ggggatcctc tagagtcgac ctgcaggcat 120

gcaagcttga gtattctata gtgtcaccta aatagcttgg cgtaatcatg gtcatagctg 180

tttcctgtgt gaaattgtta tccgct 206

<210> SEQ ID NO 28
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 28

aacagctatg accatgatta c 21

<210> SEQ ID NO 29
<211> LENGTH: 60
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 29

gttctctgct ctctggtcgc tgtctcgctt gtgaaacaag cgagacagcg tggtctctcg 60

<210> SEQ ID NO 30
<211> LENGTH: 15
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 30

cgagagacca cgctg 15

-continued

<210> SEQ ID NO 31
<211> LENGTH: 52
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 31

cctttcgctt tcttcccttc ctttctcgcc acgttcgccg gctttccccg tc 52

<210> SEQ ID NO 32
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 32

agaaaggaag ggaagaaagc gaaagg 26

<210> SEQ ID NO 33
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 33

gacggggaaa gccggcgaac g 21

<210> SEQ ID NO 34
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 34

gaaagccggc gaacgtggcg 20

<210> SEQ ID NO 35
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 35

ggcgaacgtg gcgagaaagg a 21

<210> SEQ ID NO 36
<211> LENGTH: 42
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 36

cctttcgctt tcttcccttc ctttctcgcc acgttcgccg gc 42

<210> SEQ ID NO 37
<211> LENGTH: 42
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence

-continued

<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 37

cctttcgctc tcttcccttc ctttctcgcc acgttcgccg gc 42

<210> SEQ ID NO 38
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: modified_base
<222> LOCATION: (8)
<223> OTHER INFORMATION: The residue at this position is
2'-O-methyladenosine.

<400> SEQUENCE: 38

agaaaggaag ggaagaaagc gaaaggt 27

<210> SEQ ID NO 39
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 39

gccggcgaac gtggcgagaa agga 24

<210> SEQ ID NO 40
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 40

ggtttttctt tgaggtttag 20

<210> SEQ ID NO 41
<211> LENGTH: 19
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 41

gcgacactcc accatagat 19

<210> SEQ ID NO 42
<211> LENGTH: 19
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 42

ctgtcttcac gcagaaagc 19

<210> SEQ ID NO 43
<211> LENGTH: 19
<212> TYPE: DNA

-continued

<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 43

gcacggtcta cgagacctc 19

<210> SEQ ID NO 44
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 44

taatacgact cactataggg 20

<210> SEQ ID NO 45
<211> LENGTH: 337
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 45

gggaaagcuu gcaugccugc aggucgacuc uagaggaucu acuagucaua uggauucugu 60

cuucacgcag aaagcgucug gccauggcgu uaguaugagu gucgugcagc cuccaggacc 120

cccccucccg ggagaggcau aguggucugc ggaaccggug aguacaccgg aauugccagg 180

acgaccgggu ccuuucuugg auaaacccgc ucaaugccug gagauuuggg cgugcccccg 240

caagacugcu agccgaguag uguugggucg cgaaaggccu ugugguacug ccugauaggg 300

ugccugcgag ugccccggga ggucucguag accgugc 337

<210> SEQ ID NO 46
<211> LENGTH: 19
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (17)
<223> OTHER INFORMATION: The residue at this position is linked to a fluorescein dye on an abasic linker.

<400> SEQUENCE: 46

ccggtcgtcc tggcaatcc 19

<210> SEQ ID NO 47
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 47

gtttatccaa gaaaggaccc ggtc 24

<210> SEQ ID NO 48
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence

-continued

<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 48

cagggtgaag ggaagaagaa agcgaaaggt 30

<210> SEQ ID NO 49
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 49

caggggaag ggaagaagaa agcgaaaggt 30

<210> SEQ ID NO 50
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: modified_base
<222> LOCATION: (1)..(2)
<223> OTHER INFORMATION: The residues at these positions are amino modified T residues.

<400> SEQUENCE: 50

ttcttttcac cagcgagacg gg 22

<210> SEQ ID NO 51
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 51

attgggcgcc agggtggttt tt 22

<210> SEQ ID NO 52
<211> LENGTH: 53
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 52

cccgtctcgc tggtgaaaag aaaaaccacc ctggcgccca atacgcaaac cgc 53

<210> SEQ ID NO 53
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 53

gaattcgatt taggtgacac tatagaatac a 31

<210> SEQ ID NO 54
<211> LENGTH: 42
<212> TYPE: DNA

-continued

<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 54

cctttcgctt tcttcccttc ctttctcgcc acgttcgccg gc 42

<210> SEQ ID NO 55
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 55

gccggcgaac gtggcgagaa agga 24

<210> SEQ ID NO 56
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 56

cagaaggaag ggaagaaagc gaaagg 26

<210> SEQ ID NO 57
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 57

caggggaag ggaagaaagc gaaagg 26

<210> SEQ ID NO 58
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 58

cagggtacag ggaagaaagc gaaagg 26

<210> SEQ ID NO 59
<211> LENGTH: 42
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 59

gggaaagtcc tcggagccgc gcgggacgag cgtgggggcc cg 42

<210> SEQ ID NO 60
<211> LENGTH: 963
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(960)

-continued

<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 60

```
atg gct agc atg act ggt gga cag caa atg ggt cgg atc aat tcg ggg       48
Met Ala Ser Met Thr Gly Gly Gln Gln Met Gly Arg Ile Asn Ser Gly
  1               5                  10                  15

atg ctg ccc ctc ttt gag ccc aag ggc cgg gtc ctc ctg gtg gac ggc       96
Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu Val Asp Gly
             20                  25                  30

cac cac ctg gcc tac cgc acc ttc cac gcc ctg aag ggc ctc acc acc      144
His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly Leu Thr Thr
         35                  40                  45

agc cgg ggg gag ccg gtg cag gcg gtc tac ggc ttc gcc aag agc ctc      192
Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala Lys Ser Leu
     50                  55                  60

ctc aag gcc ctc aag gag gac ggg gac gcg gtg atc gtg gtc ttt gac      240
Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val Val Phe Asp
 65                  70                  75                  80

gcc aag gcc ccc tcc ttc cgc cac gag gcc tac ggg ggg tac aag gcg      288
Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly Tyr Lys Ala
                 85                  90                  95

ggc cgg gcc ccc acg ctc gtc ccg cgc ggc tcc gag gac ttt ccc cgg      336
Gly Arg Ala Pro Thr Leu Val Pro Arg Gly Ser Glu Asp Phe Pro Arg
            100                 105                 110

caa ctc gcc ctc atc aag gag ctg gtg gac ctc ctg ggg ctg gcg cgc      384
Gln Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg
        115                 120                 125

ctc gag gtc ccg ggc tac gag gcg gac gac gtc ctg gcc agc ctg gcc      432
Leu Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala
    130                 135                 140

aag aag gcg gaa aag gag ggc tac gag gtc cgc atc ctc acc gcc gac      480
Lys Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp
145                 150                 155                 160

aaa gac ctt tac cag ctc ctt tcc gac cgc atc cac gtc ctc cac ccc      528
Lys Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro
                165                 170                 175

gag ggg tac ctc atc acc ccg gcc tgg ctt tgg gaa aag tac ggc ctg      576
Glu Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu
            180                 185                 190

agg ccc gac cag tgg gcc gac tac cgg gcc ctg acc ggg gac gag tcc      624
Arg Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser
        195                 200                 205

gac aac ctt ccc ggg gtc aag ggc atc ggg gag aag acg gcg agg aag      672
Asp Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys
    210                 215                 220

ctt ctg gag gag tgg ggg agc ctg gaa gcc ctc ctc aag aac ctg gac      720
Leu Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp
225                 230                 235                 240

cgg ctg aag ccc gcc atc cgg gag aag atc ctg gcc cac atg gac gat      768
Arg Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp
                245                 250                 255

ctg aag ctc tcc tgg gac ctg gcc aag gtg cgc acc gac ctg ccc ctg      816
Leu Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu
            260                 265                 270

gag gtg gac ttc gcc aaa agg cgg gag ccc gac cgg gag agg ctt agg      864
Glu Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg
        275                 280                 285
```

-continued

```
gcc ttt ctg gag agg ctt gag ttt ggc agc ctc ctc cac gag ttc ggc      912
Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly
    290                 295                 300

ctt ctg gaa agc ccc aag gcc gca ctc gag cac cac cac cac cac cac      960
Leu Leu Glu Ser Pro Lys Ala Ala Leu Glu His His His His His His
305                 310                 315                 320

tga                                                                  963


<210> SEQ ID NO 61
<211> LENGTH: 320
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 61

Met Ala Ser Met Thr Gly Gly Gln Gln Met Gly Arg Ile Asn Ser Gly
  1               5                  10                  15

Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu Val Asp Gly
             20                  25                  30

His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly Leu Thr Thr
         35                  40                  45

Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala Lys Ser Leu
     50                  55                  60

Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val Val Phe Asp
 65                  70                  75                  80

Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly Tyr Lys Ala
                 85                  90                  95

Gly Arg Ala Pro Thr Leu Val Pro Arg Gly Ser Glu Asp Phe Pro Arg
            100                 105                 110

Gln Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg
        115                 120                 125

Leu Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala
    130                 135                 140

Lys Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp
145                 150                 155                 160

Lys Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro
                165                 170                 175

Glu Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu
            180                 185                 190

Arg Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser
        195                 200                 205

Asp Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys
    210                 215                 220

Leu Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp
225                 230                 235                 240

Arg Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp
                245                 250                 255

Leu Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu
            260                 265                 270

Glu Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg
        275                 280                 285

Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly
```

-continued

```
    290                 295                 300

Leu Leu Glu Ser Pro Lys Ala Ala Leu Glu His His His His His His
305                 310                 315                 320


<210> SEQ ID NO 62
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 62

cgatctcctc ggccacctcc                                                  20


<210> SEQ ID NO 63
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 63

ggcggtgccc tggacgggca                                                  20


<210> SEQ ID NO 64
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 64

ccagctcgtt gtggacctga                                                  20


<210> SEQ ID NO 65
<211> LENGTH: 2505
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(2499)

<400> SEQUENCE: 65

atg aat tcg ggg atg ctg ccc ctc ttt gag ccc aag ggc cgg gtc ctc       48
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
  1               5                  10                  15

ctg gtg gac ggc cac cac ctg gcc tac cgc acc ttc cac gcc ctg aag       96
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
             20                  25                  30

ggc ctc acc acc agc cgg ggg gag ccg gtg cag gcg gtc tac ggc ttc      144
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
         35                  40                  45

gcc aag agc ctc ctc aag gcc ctc aag gag gac ggg gac gcg gtg atc      192
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
     50                  55                  60

gtg gtc ttt gac gcc aag gcc ccc tcc ttc cgc cac gag gcc tac ggg      240
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
 65                  70                  75                  80

ggg tac aag gcg ggc cgg gcc ccc acg ccg gag gac ttt ccc cgg caa      288
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
```

-continued

```
                85                  90                  95

ctc gcc ctc atc aag gag ctg gtg gac ctc ctg ggg ctg gcg cgc ctc      336
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
            100                 105                 110

gag gtc ccg ggc tac gag gcg gac gac gtc ctg gcc agc ctg gcc aag      384
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
        115                 120                 125

aag gcg gaa aag gag ggc tac gag gtc cgc atc ctc acc gcc gac aaa      432
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
    130                 135                 140

gac ctt tac cag ctc ctt tcc gac cgc atc cac gtc ctc cac ccc gag      480
Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
145                 150                 155                 160

ggg tac ctc atc acc ccg gcc tgg ctt tgg gaa aag tac ggc ctg agg      528
Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
                165                 170                 175

ccc gac cag tgg gcc gac tac cgg gcc ctg acc ggg gac gag tcc gac      576
Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
            180                 185                 190

aac ctt ccc ggg gtc aag ggc atc ggg gag aag acg gcg agg aag ctt      624
Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
        195                 200                 205

ctg gag gag tgg ggg agc ctg gaa gcc ctc ctc aag aac ctg gac cgg      672
Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
    210                 215                 220

ctg aag ccc gcc atc cgg gag aag atc ctg gcc cac atg gac gat ctg      720
Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
225                 230                 235                 240

aag ctc tcc tgg gac ctg gcc aag gtg cgc acc gac ctg ccc ctg gag      768
Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
                245                 250                 255

gtg gac ttc gcc aaa agg cgg gag ccc gac cgg gag agg ctt agg gcc      816
Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
            260                 265                 270

ttt ctg gag agg ctt gag ttt ggc agc ctc ctc cac gag ttc ggc ctt      864
Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
        275                 280                 285

ctg gaa agc ccc aag gcc ctg gag gag gcc ccc tgg ccc ccg ccg gaa      912
Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
    290                 295                 300

ggg gcc ttc gtg ggc ttt gtg ctt tcc cgc aag gag ccc atg tgg gcc      960
Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
305                 310                 315                 320

gat ctt ctg gcc ctg gcc gcc gcc agg ggg ggc cgg gtc cac cgg gcc     1008
Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
                325                 330                 335

ccc gag cct tat aaa gcc ctc agg gac ctg aag gag gcg cgg ggg ctt     1056
Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
            340                 345                 350

ctc gcc aaa gac ctg agc gtt ctg gcc ctg agg gaa ggc ctt ggc ctc     1104
Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
        355                 360                 365

ccg ccc ggc gac gac ccc atg ctc ctc gcc tac ctc ctg gac cct tcc     1152
Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
    370                 375                 380

aac acc acc ccc gag ggg gtg gcc cgg cgc tac ggc ggg gag tgg acg     1200
Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
```

-continued

```
385                 390                 395                 400

gag gag gcg ggg gag cgg gcc gcc ctt tcc gag agg ctc ttc gcc aac     1248
Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
                405                 410                 415

ctg tgg ggg agg ctt gag ggg gag gag agg ctc ctt tgg ctt tac cgg     1296
Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
            420                 425                 430

gag gtg gag agg ccc ctt tcc gct gtc ctg gcc cac atg gag gcc acg     1344
Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
        435                 440                 445

ggg gtg cgc ctg gac gtg gcc tat ctc agg gcc ttg tcc ctg gag gtg     1392
Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
    450                 455                 460

gcc gag gag atc gcc cgc ctc gag gcc gag gtc ttc cgc ctg gcc ggc     1440
Ala Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
465                 470                 475                 480

cac ccc ttc aac ctc aac tcc cgg gac cag ctg gaa agg gtc ctc ttt     1488
His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
                485                 490                 495

gac gag cta ggg ctt ccc gcc atc ggc aag acg gag aag acc ggc aag     1536
Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
            500                 505                 510

cgc tcc acc agc gcc gcc gtc ctg gag gcc ctc cgc gag gcc cac ccc     1584
Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
        515                 520                 525

atc gtg gag aag atc ctg cag tac cgg gag ctc acc aag ctg aag agc     1632
Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
    530                 535                 540

acc tac att gac ccc ttg ccg gac ctc atc cac ccc agg acg ggc cgc     1680
Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
545                 550                 555                 560

ctc cac acc cgc ttc aac cag acg gcc acg gcc acg ggc agg cta agt     1728
Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
                565                 570                 575

agc tcc gat ccc aac ctc cag aac atc ccc gtc cgc acc ccg ctt ggg     1776
Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
            580                 585                 590

cag agg atc cgc cgg gcc ttc atc gcc gag gag ggg tgg cta ttg gtg     1824
Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
        595                 600                 605

gcc ctg gac tat agc cag ata gag ctc agg gtg ctg gcc cac ctc tcc     1872
Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
    610                 615                 620

ggc gac gag aac ctg atc cgg gtc ttc cag gag ggg cgg gac atc cac     1920
Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
625                 630                 635                 640

acg gag acc gcc agc tgg atg ttc ggc gtc ccc cgg gag gcc gtg gac     1968
Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
                645                 650                 655

ccc ctg atg cgc cgg gcg gcc aag acc atc aac ttc ggg gtc ctc tac     2016
Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
            660                 665                 670

ggc atg tcg gcc cac cgc ctc tcc cag gag cta gcc atc cct tac gag     2064
Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
        675                 680                 685

gag gcc cag gcc ttc att gag cgc tac ttt cag agc ttc ccc aag gtg     2112
Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
```

-continued

```
    690                 695                 700

cgg gcc tgg att gag aag acc ctg gag gag ggc agg agg cgg ggg tac     2160
Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
705                 710                 715                 720

gtg gag acc ctc ttc ggc cgc cgc cgc tac gtg cca gac cta gag gcc     2208
Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
                725                 730                 735

cgg gtg aag agc gtg cgg gag gcg gcc gag cgc atg gcc ttc aac atg     2256
Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
            740                 745                 750

ccc gtc cag ggc acc gcc gcc gac ctc atg aag ctg gct atg gtg aag     2304
Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
        755                 760                 765

ctc ttc ccc agg ctg gag gaa atg ggg gcc agg atg ctc ctt cag gtc     2352
Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
    770                 775                 780

cac aac gag ctg gtc ctc gag gcc cca aaa gag agg gcg gag gcc gtg     2400
His Asn Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
785                 790                 795                 800

gcc cgg ctg gcc aag gag gtc atg gag ggg gtg tat ccc ctg gcc gtg     2448
Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
                805                 810                 815

ccc ctg gag gtg gag gtg ggg ata ggg gag gac tgg ctc tcc gcc aag     2496
Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
            820                 825                 830

gag tgatag                                                          2505
Glu
```

<210> SEQ ID NO 66
<211> LENGTH: 833
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 66

```
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
  1               5                  10                  15

Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
            20                  25                  30

Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
        35                  40                  45

Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
    50                  55                  60

Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
65                  70                  75                  80

Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
                85                  90                  95

Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
            100                 105                 110

Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
        115                 120                 125

Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
    130                 135                 140

Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
145                 150                 155                 160
```

-continued

```
Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
                165                 170                 175

Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
            180                 185                 190

Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
        195                 200                 205

Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
    210                 215                 220

Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
225                 230                 235                 240

Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
                245                 250                 255

Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
            260                 265                 270

Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
        275                 280                 285

Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
    290                 295                 300

Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
305                 310                 315                 320

Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
                325                 330                 335

Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
            340                 345                 350

Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
        355                 360                 365

Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
    370                 375                 380

Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
385                 390                 395                 400

Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
                405                 410                 415

Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
            420                 425                 430

Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
        435                 440                 445

Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
    450                 455                 460

Ala Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
465                 470                 475                 480

His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
                485                 490                 495

Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
            500                 505                 510

Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
        515                 520                 525

Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
    530                 535                 540

Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
545                 550                 555                 560
```

-continued

```
Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
                565                 570                 575

Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
            580                 585                 590

Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
        595                 600                 605

Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
    610                 615                 620

Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
625                 630                 635                 640

Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
                645                 650                 655

Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
            660                 665                 670

Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
        675                 680                 685

Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
    690                 695                 700

Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
705                 710                 715                 720

Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
                725                 730                 735

Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
            740                 745                 750

Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
        755                 760                 765

Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
    770                 775                 780

His Asn Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
785                 790                 795                 800

Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
                805                 810                 815

Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
            820                 825                 830

Glu
```

<210> SEQ ID NO 67
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 67

tggctatagr ccagggccac 20

<210> SEQ ID NO 68
<211> LENGTH: 2505
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(2499)

-continued

<400> SEQUENCE: 68

```
atg aat tcg ggg atg ctg ccc ctc ttt gag ccc aag ggc cgg gtc ctc       48
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
  1               5                  10                  15

ctg gtg gac ggc cac cac ctg gcc tac cgc acc ttc cac gcc ctg aag       96
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
             20                  25                  30

ggc ctc acc acc agc cgg ggg gag ccg gtg cag gcg gtc tac ggc ttc      144
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
         35                  40                  45

gcc aag agc ctc ctc aag gcc ctc aag gag gac ggg gac gcg gtg atc      192
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
     50                  55                  60

gtg gtc ttt gac gcc aag gcc ccc tcc ttc cgc cac gag gcc tac ggg      240
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
 65                  70                  75                  80

ggg tac aag gcg ggc cgg gcc ccc acg ccg gag gac ttt ccc cgg caa      288
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
                 85                  90                  95

ctc gcc ctc atc aag gag ctg gtg gac ctc ctg ggg ctg gcg cgc ctc      336
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
            100                 105                 110

gag gtc ccg ggc tac gag gcg gac gac gtc ctg gcc agc ctg gcc aag      384
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
        115                 120                 125

aag gcg gaa aag gag ggc tac gag gtc cgc atc ctc acc gcc gac aaa      432
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
    130                 135                 140

gac ctt tac cag ctc ctt tcc gac cgc atc cac gtc ctc cac ccc gag      480
Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
145                 150                 155                 160

ggg tac ctc atc acc ccg gcc tgg ctt tgg gaa aag tac ggc ctg agg      528
Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
                165                 170                 175

ccc gac cag tgg gcc gac tac cgg gcc ctg acc ggg gac gag tcc gac      576
Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
            180                 185                 190

aac ctt ccc ggg gtc aag ggc atc ggg gag aag acg gcg agg aag ctt      624
Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
        195                 200                 205

ctg gag gag tgg ggg agc ctg gaa gcc ctc ctc aag aac ctg gac cgg      672
Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
    210                 215                 220

ctg aag ccc gcc atc cgg gag aag atc ctg gcc cac atg gac gat ctg      720
Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
225                 230                 235                 240

aag ctc tcc tgg gac ctg gcc aag gtg cgc acc gac ctg ccc ctg gag      768
Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
                245                 250                 255

gtg gac ttc gcc aaa agg cgg gag ccc gac cgg gag agg ctt agg gcc      816
Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
            260                 265                 270

ttt ctg gag agg ctt gag ttt ggc agc ctc ctc cac gag ttc ggc ctt      864
Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
        275                 280                 285

ctg gaa agc ccc aag gcc ctg gag gag gcc ccc tgg ccc ccg ccg gaa      912
Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
```

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```
    290                 295                 300

ggg gcc ttc gtg ggc ttt gtg ctt tcc cgc aag gag ccc atg tgg gcc      960
Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
305                 310                 315                 320

gat ctt ctg gcc ctg gcc gcc gcc agg ggg ggc cgg gtc cac cgg gcc     1008
Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
                325                 330                 335

ccc gag cct tat aaa gcc ctc agg gac ctg aag gag gcg cgg ggg ctt     1056
Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
            340                 345                 350

ctc gcc aaa gac ctg agc gtt ctg gcc ctg agg gaa ggc ctt ggc ctc     1104
Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
        355                 360                 365

ccg ccc ggc gac gac ccc atg ctc ctc gcc tac ctc ctg gac cct tcc     1152
Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
    370                 375                 380

aac acc acc ccc gag ggg gtg gcc cgg cgc tac ggc ggg gag tgg acg     1200
Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
385                 390                 395                 400

gag gag gcg ggg gag cgg gcc gcc ctt tcc gag agg ctc ttc gcc aac     1248
Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
                405                 410                 415

ctg tgg ggg agg ctt gag ggg gag gag agg ctc ctt tgg ctt tac cgg     1296
Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
            420                 425                 430

gag gtg gag agg ccc ctt tcc gct gtc ctg gcc cac atg gag gcc acg     1344
Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
        435                 440                 445

ggg gtg cgc ctg gac gtg gcc tat ctc agg gcc ttg tcc ctg gag gtg     1392
Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
    450                 455                 460

gcc ggg gag atc gcc cgc ctc gag gcc gag gtc ttc cgc ctg gcc ggc     1440
Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
465                 470                 475                 480

cac ccc ttc aac ctc aac tcc cgg gac cag ctg gaa agg gtc ctc ttt     1488
His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
                485                 490                 495

gac gag cta ggg ctt ccc gcc atc ggc aag acg gag aag acc ggc aag     1536
Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
            500                 505                 510

cgc tcc acc agc gcc gcc gtc ctg gag gcc ctc cgc gag gcc cac ccc     1584
Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
        515                 520                 525

atc gtg gag aag atc ctg cag tac cgg gag ctc acc aag ctg aag agc     1632
Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
    530                 535                 540

acc tac att gac ccc ttg ccg gac ctc atc cac ccc agg acg ggc cgc     1680
Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
545                 550                 555                 560

ctc cac acc cgc ttc aac cag acg gcc acg gcc acg ggc agg cta agt     1728
Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
                565                 570                 575

agc tcc gat ccc aac ctc cag aac atc ccc gtc cgc acc ccg ctt ggg     1776
Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
            580                 585                 590

cag agg atc cgc cgg gcc ttc atc gcc gag gag ggg tgg cta ttg gtg     1824
Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
```

-continued

```
        595                 600                 605

gcc ctg gcc tat agc cag ata gag ctc agg gtg ctg gcc cac ctc tcc     1872
Ala Leu Ala Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
    610                 615                 620

ggc gac gag aac ctg atc cgg gtc ttc cag gag ggg cgg gac atc cac     1920
Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
625                 630                 635                 640

acg gag acc gcc agc tgg atg ttc ggc gtc ccc cgg gag gcc gtg gac     1968
Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
                645                 650                 655

ccc ctg atg cgc cgg gcg gcc aag acc atc aac ttc ggg gtc ctc tac     2016
Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
            660                 665                 670

ggc atg tcg gcc cac cgc ctc tcc cag gag cta gcc atc cct tac gag     2064
Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
        675                 680                 685

gag gcc cag gcc ttc att gag cgc tac ttt cag agc ttc ccc aag gtg     2112
Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
    690                 695                 700

cgg gcc tgg att gag aag acc ctg gag gag ggc agg agg cgg ggg tac     2160
Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
705                 710                 715                 720

gtg gag acc ctc ttc ggc cgc cgc cgc tac gtg cca gac cta gag gcc     2208
Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
                725                 730                 735

cgg gtg aag agc gtg cgg gag gcg gcc gag cgc atg gcc ttc aac atg     2256
Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
            740                 745                 750

ccc gtc cag ggc acc gcc gcc gac ctc atg aag ctg gct atg gtg aag     2304
Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
        755                 760                 765

ctc ttc ccc agg ctg gag gaa atg ggg gcc agg atg ctc ctt cag gtc     2352
Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
    770                 775                 780

cac gac gag ctg gtc ctc gag gcc cca aaa gag agg gcg gag gcc gtg     2400
His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
785                 790                 795                 800

gcc cgg ctg gcc aag gag gtc atg gag ggg gtg tat ccc ctg gcc gtg     2448
Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
                805                 810                 815

ccc ctg gag gtg gag gtg ggg ata ggg gag gac tgg ctc tcc gcc aag     2496
Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
            820                 825                 830

gag tgatag                                                          2505
Glu


<210> SEQ ID NO 69
<211> LENGTH: 833
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 69

Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
  1               5                  10                  15

Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
             20                  25                  30
```

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```
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
         35                  40                  45

Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
     50                  55                  60

Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
 65                  70                  75                  80

Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
                 85                  90                  95

Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
            100                 105                 110

Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
        115                 120                 125

Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
    130                 135                 140

Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
145                 150                 155                 160

Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
                165                 170                 175

Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
            180                 185                 190

Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
        195                 200                 205

Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
    210                 215                 220

Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
225                 230                 235                 240

Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
                245                 250                 255

Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
            260                 265                 270

Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
        275                 280                 285

Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
    290                 295                 300

Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
305                 310                 315                 320

Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
                325                 330                 335

Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
            340                 345                 350

Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
        355                 360                 365

Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
    370                 375                 380

Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
385                 390                 395                 400

Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
                405                 410                 415

Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
            420                 425                 430
```

-continued

```
Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
        435                 440                 445

Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
    450                 455                 460

Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
465                 470                 475                 480

His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
                485                 490                 495

Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
            500                 505                 510

Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
        515                 520                 525

Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
    530                 535                 540

Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
545                 550                 555                 560

Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
                565                 570                 575

Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
            580                 585                 590

Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
        595                 600                 605

Ala Leu Ala Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
    610                 615                 620

Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
625                 630                 635                 640

Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
                645                 650                 655

Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
            660                 665                 670

Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
        675                 680                 685

Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
    690                 695                 700

Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
705                 710                 715                 720

Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
                725                 730                 735

Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
            740                 745                 750

Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
        755                 760                 765

Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
    770                 775                 780

His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
785                 790                 795                 800

Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
                805                 810                 815

Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
            820                 825                 830

Glu
```

-continued

<210> SEQ ID NO 70
<211> LENGTH: 2505
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(2499)

<400> SEQUENCE: 70

```
atg aat tcg ggg atg ctg ccc ctc ttt gag ccc aag ggc cgg gtc ctc       48
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
  1               5                  10                  15

ctg gtg gac ggc cac cac ctg gcc tac cgc acc ttc cac gcc ctg aag       96
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
             20                  25                  30

ggc ctc acc acc agc cgg ggg gag ccg gtg cag gcg gtc tac ggc ttc      144
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
         35                  40                  45

gcc aag agc ctc ctc aag gcc ctc aag gag gac ggg gac gcg gtg atc      192
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
     50                  55                  60

gtg gtc ttt gac gcc aag gcc ccc tcc ttc cgc cac gag gcc tac ggg      240
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
 65                  70                  75                  80

ggg tac aag gcg ggc cgg gcc ccc acg ccg gag gac ttt ccc cgg caa      288
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
                 85                  90                  95

ctc gcc ctc atc aag gag ctg gtg gac ctc ctg ggg ctg gcg cgc ctc      336
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
            100                 105                 110

gag gtc ccg ggc tac gag gcg gac gac gtc ctg gcc agc ctg gcc aag      384
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
        115                 120                 125

aag gcg gaa aag gag ggc tac gag gtc cgc atc ctc acc gcc gac aaa      432
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
    130                 135                 140

gac ctt tac cag ctc ctt tcc gac cgc atc cac gtc ctc cac ccc gag      480
Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
145                 150                 155                 160

ggg tac ctc atc acc ccg gcc tgg ctt tgg gaa aag tac ggc ctg agg      528
Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
                165                 170                 175

ccc gac cag tgg gcc gac tac cgg gcc ctg acc ggg gac gag tcc gac      576
Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
            180                 185                 190

aac ctt ccc ggg gtc aag ggc atc ggg gag aag acg gcg agg aag ctt      624
Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
        195                 200                 205

ctg gag gag tgg ggg agc ctg gaa gcc ctc ctc aag aac ctg gac cgg      672
Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
    210                 215                 220

ctg aag ccc gcc atc cgg gag aag atc ctg gcc cac atg gac gat ctg      720
Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
225                 230                 235                 240

aag ctc tcc tgg gac ctg gcc aag gtg cgc acc gac ctg ccc ctg gag      768
Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
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                245                 250                 255

gtg gac ttc gcc aaa agg cgg gag ccc gac cgg gag agg ctt agg gcc      816
Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
            260                 265                 270

ttt ctg gag agg ctt gag ttt ggc agc ctc ctc cac gag ttc ggc ctt      864
Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
        275                 280                 285

ctg gaa agc ccc aag gcc ctg gag gag gcc ccc tgg ccc ccg ccg gaa      912
Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
    290                 295                 300

ggg gcc ttc gtg ggc ttt gtg ctt tcc cgc aag gag ccc atg tgg gcc      960
Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
305                 310                 315                 320

gat ctt ctg gcc ctg gcc gcc gcc agg ggg ggc cgg gtc cac cgg gcc     1008
Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
                325                 330                 335

ccc gag cct tat aaa gcc ctc agg gac ctg aag gag gcg cgg ggg ctt     1056
Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
            340                 345                 350

ctc gcc aaa gac ctg agc gtt ctg gcc ctg agg gaa ggc ctt ggc ctc     1104
Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
        355                 360                 365

ccg ccc ggc gac gac ccc atg ctc ctc gcc tac ctc ctg gac cct tcc     1152
Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
    370                 375                 380

aac acc acc ccc gag ggg gtg gcc cgg cgc tac ggc ggg gag tgg acg     1200
Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
385                 390                 395                 400

gag gag gcg ggg gag cgg gcc gcc ctt tcc gag agg ctc ttc gcc aac     1248
Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
                405                 410                 415

ctg tgg ggg agg ctt gag ggg gag gag agg ctc ctt tgg ctt tac cgg     1296
Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
            420                 425                 430

gag gtg gag agg ccc ctt tcc gct gtc ctg gcc cac atg gag gcc acg     1344
Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
        435                 440                 445

ggg gtg cgc ctg gac gtg gcc tat ctc agg gcc ttg tcc ctg gag gtg     1392
Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
    450                 455                 460

gcc ggg gag atc gcc cgc ctc gag gcc gag gtc ttc cgc ctg gcc ggc     1440
Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
465                 470                 475                 480

cac ccc ttc aac ctc aac tcc cgg gac cag ctg gaa agg gtc ctc ttt     1488
His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
                485                 490                 495

gac gag cta ggg ctt ccc gcc atc ggc aag acg gag aag acc ggc aag     1536
Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
            500                 505                 510

cgc tcc acc agc gcc gcc gtc ctg gag gcc ctc cgc gag gcc cac ccc     1584
Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
        515                 520                 525

atc gtg gag aag atc ctg cag tac cgg gag ctc acc aag ctg aag agc     1632
Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
    530                 535                 540

acc tac att gac ccc ttg ccg gac ctc atc cac ccc agg acg ggc cgc     1680
Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
```

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545                 550                 555                 560

ctc cac acc cgc ttc aac cag acg gcc acg gcc acg ggc agg cta agt     1728
Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
                565                 570                 575

agc tcc gat ccc aac ctc cag aac atc ccc gtc cgc acc ccg ctt ggg     1776
Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
            580                 585                 590

cag agg atc cgc cgg gcc ttc atc gcc gag gag ggg tgg cta ttg gtg     1824
Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
        595                 600                 605

gcc ctg gtc tat agc cag ata gag ctc agg gtg ctg gcc cac ctc tcc     1872
Ala Leu Val Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
    610                 615                 620

ggc gac gag aac ctg atc cgg gtc ttc cag gag ggg cgg gac atc cac     1920
Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
625                 630                 635                 640

acg gag acc gcc agc tgg atg ttc ggc gtc ccc cgg gag gcc gtg gac     1968
Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
                645                 650                 655

ccc ctg atg cgc cgg gcg gcc aag acc atc aac ttc ggg gtc ctc tac     2016
Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
            660                 665                 670

ggc atg tcg gcc cac cgc ctc tcc cag gag cta gcc atc cct tac gag     2064
Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
        675                 680                 685

gag gcc cag gcc ttc att gag cgc tac ttt cag agc ttc ccc aag gtg     2112
Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
    690                 695                 700

cgg gcc tgg att gag aag acc ctg gag gag ggc agg agg cgg ggg tac     2160
Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
705                 710                 715                 720

gtg gag acc ctc ttc ggc cgc cgc cgc tac gtg cca gac cta gag gcc     2208
Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
                725                 730                 735

cgg gtg aag agc gtg cgg gag gcg gcc gag cgc atg gcc ttc aac atg     2256
Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
            740                 745                 750

ccc gtc cag ggc acc gcc gcc gac ctc atg aag ctg gct atg gtg aag     2304
Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
        755                 760                 765

ctc ttc ccc agg ctg gag gaa atg ggg gcc agg atg ctc ctt cag gtc     2352
Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
    770                 775                 780

cac gac gag ctg gtc ctc gag gcc cca aaa gag agg gcg gag gcc gtg     2400
His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
785                 790                 795                 800

gcc cgg ctg gcc aag gag gtc atg gag ggg gtg tat ccc ctg gcc gtg     2448
Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
                805                 810                 815

ccc ctg gag gtg gag gtg ggg ata ggg gag gac tgg ctc tcc gcc aag     2496
Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
            820                 825                 830

gag tgatag                                                         2505
Glu
```

<210> SEQ ID NO 71
<211> LENGTH: 833

-continued

<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 71

Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
1 5 10 15

Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
20 25 30

Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
35 40 45

Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
50 55 60

Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
65 70 75 80

Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
85 90 95

Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
100 105 110

Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
115 120 125

Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
130 135 140

Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
145 150 155 160

Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
165 170 175

Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
180 185 190

Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
195 200 205

Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
210 215 220

Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
225 230 235 240

Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
245 250 255

Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
260 265 270

Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
275 280 285

Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
290 295 300

Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
305 310 315 320

Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
325 330 335

Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
340 345 350

Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
355 360 365

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Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
    370                 375                 380

Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
385                 390                 395                 400

Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
                405                 410                 415

Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
            420                 425                 430

Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
        435                 440                 445

Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
    450                 455                 460

Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
465                 470                 475                 480

His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
                485                 490                 495

Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
            500                 505                 510

Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
        515                 520                 525

Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
    530                 535                 540

Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
545                 550                 555                 560

Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
                565                 570                 575

Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
            580                 585                 590

Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
        595                 600                 605

Ala Leu Val Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
    610                 615                 620

Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
625                 630                 635                 640

Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
                645                 650                 655

Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
            660                 665                 670

Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
        675                 680                 685

Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
    690                 695                 700

Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
705                 710                 715                 720

Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
                725                 730                 735

Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
            740                 745                 750

Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
        755                 760                 765

Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
```

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    770                 775                 780

His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
785                 790                 795                 800

Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
                805                 810                 815

Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
            820                 825                 830

Glu
```

<210> SEQ ID NO 72
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 72

gggataccat gggagtgcag tttgg 25

<210> SEQ ID NO 73
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 73

ggtaaatttt tctcgtcgac atcccac 27

<210> SEQ ID NO 74
<211> LENGTH: 981
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(978)

<400> SEQUENCE: 74

```
atg gga gtg cag ttt ggt gat ttt att cca aaa aat att atc tcc ttt       48
Met Gly Val Gln Phe Gly Asp Phe Ile Pro Lys Asn Ile Ile Ser Phe
  1               5                  10                  15

gaa gat tta aaa ggg aaa aaa gta gct att gat gga atg aat gca tta       96
Glu Asp Leu Lys Gly Lys Lys Val Ala Ile Asp Gly Met Asn Ala Leu
             20                  25                  30

tat cag ttt tta aca tct ata cgt ttg aga gat ggt tct cca ttg aga      144
Tyr Gln Phe Leu Thr Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
         35                  40                  45

aat aga aaa gga gag ata acc tca gca tat aac gga gtt ttt tat aaa      192
Asn Arg Lys Gly Glu Ile Thr Ser Ala Tyr Asn Gly Val Phe Tyr Lys
     50                  55                  60

acc ata cat ttg tta gag aat gat ata act cca atc tgg gtt ttt gat      240
Thr Ile His Leu Leu Glu Asn Asp Ile Thr Pro Ile Trp Val Phe Asp
 65                  70                  75                  80

ggt gag cca cca aag tta aag gag aaa aca agg aaa gtt agg aga gag      288
Gly Glu Pro Pro Lys Leu Lys Glu Lys Thr Arg Lys Val Arg Arg Glu
                 85                  90                  95

atg aaa gag aaa gct gaa ctt aag atg aaa gag gca att aaa aag gag      336
Met Lys Glu Lys Ala Glu Leu Lys Met Lys Glu Ala Ile Lys Lys Glu
```

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            100                 105                 110

gat ttt gaa gaa gct gct aag tat gca aag agg gtt agc tat cta act      384
Asp Phe Glu Glu Ala Ala Lys Tyr Ala Lys Arg Val Ser Tyr Leu Thr
        115                 120                 125

ccg aaa atg gtt gaa aac tgc aaa tat ttg tta agt ttg atg ggc att      432
Pro Lys Met Val Glu Asn Cys Lys Tyr Leu Leu Ser Leu Met Gly Ile
    130                 135                 140

ccg tat gtt gaa gct ccc tct gag gga gag gca caa gca agc tat atg      480
Pro Tyr Val Glu Ala Pro Ser Glu Gly Glu Ala Gln Ala Ser Tyr Met
145                 150                 155                 160

gca aag aag gga gat gtt tgg gca gtt gta agt caa gat tat gat gcc      528
Ala Lys Lys Gly Asp Val Trp Ala Val Val Ser Gln Asp Tyr Asp Ala
                165                 170                 175

ttg tta tat gga gct ccg aga gtt gtt aga aat tta aca act aca aag      576
Leu Leu Tyr Gly Ala Pro Arg Val Val Arg Asn Leu Thr Thr Thr Lys
            180                 185                 190

gag atg cca gaa ctt att gaa tta aat gag gtt tta gag gat tta aga      624
Glu Met Pro Glu Leu Ile Glu Leu Asn Glu Val Leu Glu Asp Leu Arg
        195                 200                 205

att tct ttg gat gat ttg ata gat ata gcc ata ttt atg gga act gac      672
Ile Ser Leu Asp Asp Leu Ile Asp Ile Ala Ile Phe Met Gly Thr Asp
    210                 215                 220

tat aat cca gga gga gtt aaa gga ata gga ttt aaa agg gct tat gaa      720
Tyr Asn Pro Gly Gly Val Lys Gly Ile Gly Phe Lys Arg Ala Tyr Glu
225                 230                 235                 240

ttg gtt aga agt ggt gta gct aag gat gtt ttg aaa aaa gag gtt gaa      768
Leu Val Arg Ser Gly Val Ala Lys Asp Val Leu Lys Lys Glu Val Glu
                245                 250                 255

tac tac gat gag att aag agg ata ttt aaa gag cca aag gtt acc gat      816
Tyr Tyr Asp Glu Ile Lys Arg Ile Phe Lys Glu Pro Lys Val Thr Asp
            260                 265                 270

aac tat tca tta agc cta aaa ttg cca gat aaa gag gga att ata aaa      864
Asn Tyr Ser Leu Ser Leu Lys Leu Pro Asp Lys Glu Gly Ile Ile Lys
        275                 280                 285

ttc tta gtt gat gaa aat gac ttt aat tat gat agg gtt aaa aag cat      912
Phe Leu Val Asp Glu Asn Asp Phe Asn Tyr Asp Arg Val Lys Lys His
    290                 295                 300

gtt gat aaa ctc tat aac tta att gca aac aaa act aag caa aaa aca      960
Val Asp Lys Leu Tyr Asn Leu Ile Ala Asn Lys Thr Lys Gln Lys Thr
305                 310                 315                 320

tta gat gca tgg ttt aaa taa                                         981
Leu Asp Ala Trp Phe Lys
                325


<210> SEQ ID NO 75
<211> LENGTH: 326
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 75

Met Gly Val Gln Phe Gly Asp Phe Ile Pro Lys Asn Ile Ile Ser Phe
  1               5                  10                  15

Glu Asp Leu Lys Gly Lys Lys Val Ala Ile Asp Gly Met Asn Ala Leu
             20                  25                  30

Tyr Gln Phe Leu Thr Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
         35                  40                  45
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Asn Arg Lys Gly Glu Ile Thr Ser Ala Tyr Asn Gly Val Phe Tyr Lys
     50                  55                  60

Thr Ile His Leu Leu Glu Asn Asp Ile Thr Pro Ile Trp Val Phe Asp
 65                  70                  75                  80

Gly Glu Pro Pro Lys Leu Lys Glu Lys Thr Arg Lys Val Arg Arg Glu
                85                  90                  95

Met Lys Glu Lys Ala Glu Leu Lys Met Lys Glu Ala Ile Lys Lys Glu
            100                 105                 110

Asp Phe Glu Glu Ala Ala Lys Tyr Ala Lys Arg Val Ser Tyr Leu Thr
        115                 120                 125

Pro Lys Met Val Glu Asn Cys Lys Tyr Leu Leu Ser Leu Met Gly Ile
    130                 135                 140

Pro Tyr Val Glu Ala Pro Ser Glu Gly Glu Ala Gln Ala Ser Tyr Met
145                 150                 155                 160

Ala Lys Lys Gly Asp Val Trp Ala Val Val Ser Gln Asp Tyr Asp Ala
                165                 170                 175

Leu Leu Tyr Gly Ala Pro Arg Val Val Arg Asn Leu Thr Thr Thr Lys
            180                 185                 190

Glu Met Pro Glu Leu Ile Glu Leu Asn Glu Val Leu Glu Asp Leu Arg
        195                 200                 205

Ile Ser Leu Asp Asp Leu Ile Asp Ile Ala Ile Phe Met Gly Thr Asp
    210                 215                 220

Tyr Asn Pro Gly Gly Val Lys Gly Ile Gly Phe Lys Arg Ala Tyr Glu
225                 230                 235                 240

Leu Val Arg Ser Gly Val Ala Lys Asp Val Leu Lys Lys Glu Val Glu
                245                 250                 255

Tyr Tyr Asp Glu Ile Lys Arg Ile Phe Lys Glu Pro Lys Val Thr Asp
            260                 265                 270

Asn Tyr Ser Leu Ser Leu Lys Leu Pro Asp Lys Glu Gly Ile Ile Lys
        275                 280                 285

Phe Leu Val Asp Glu Asn Asp Phe Asn Tyr Asp Arg Val Lys Lys His
    290                 295                 300

Val Asp Lys Leu Tyr Asn Leu Ile Ala Asn Lys Thr Lys Gln Lys Thr
305                 310                 315                 320

Leu Asp Ala Trp Phe Lys
                325
```

<210> SEQ ID NO 76
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 76

gaggtgatac catgggtgtc c 21

<210> SEQ ID NO 77
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 77

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```
gaaactctgc agcgcgtcag                                                  20


<210> SEQ ID NO 78
<211> LENGTH: 1023
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus furiosus
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(1020)

<400> SEQUENCE: 78

atg ggt gtc cca att ggt gag att ata cca aga aaa gaa att gag tta       48
Met Gly Val Pro Ile Gly Glu Ile Ile Pro Arg Lys Glu Ile Glu Leu
  1               5                  10                  15

gaa aac cta tac ggg aaa aaa atc gca atc gac gct ctt aat gca atc       96
Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
             20                  25                  30

tac caa ttt ttg tcc aca ata aga cag aaa gat gga act cca ctt atg      144
Tyr Gln Phe Leu Ser Thr Ile Arg Gln Lys Asp Gly Thr Pro Leu Met
         35                  40                  45

gat tca aag ggt aga ata acc tcc cac cta agc ggg ctc ttt tac agg      192
Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
     50                  55                  60

aca ata aac cta atg gag gct gga ata aaa cct gtg tat gtt ttt gat      240
Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Val Tyr Val Phe Asp
 65                  70                  75                  80

gga gaa cct cca gaa ttc aaa aag aaa gag ctc gaa aaa aga aga gaa      288
Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Arg Glu
                 85                  90                  95

gcg aga gag gaa gct gaa gaa aag tgg aga gaa gca ctt gaa aaa gga      336
Ala Arg Glu Glu Ala Glu Glu Lys Trp Arg Glu Ala Leu Glu Lys Gly
            100                 105                 110

gag ata gag gaa gca aga aaa tat gcc caa aga gca acc agg gta aat      384
Glu Ile Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Arg Val Asn
        115                 120                 125

gaa atg ctc atc gag gat gca aaa aaa ctc tta gag ctt atg gga att      432
Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
    130                 135                 140

cct ata gtt caa gca cct agc gag gga gag gcc caa gct gca tat atg      480
Pro Ile Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
145                 150                 155                 160

gcc gca aag ggg agc gtg tat gca tcg gct agt caa gat tac gat tcc      528
Ala Ala Lys Gly Ser Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
                165                 170                 175

cta ctt ttt gga gct cca aga ctt gtt aga aac tta aca ata aca gga      576
Leu Leu Phe Gly Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
            180                 185                 190

aaa aga aag ttg cct ggg aaa aat gtc tac gtc gag ata aag ccc gag      624
Lys Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Ile Lys Pro Glu
        195                 200                 205

ttg ata att ttg gag gaa gta ctc aag gaa tta aag cta aca aga gaa      672
Leu Ile Ile Leu Glu Glu Val Leu Lys Glu Leu Lys Leu Thr Arg Glu
    210                 215                 220

aag ctc att gaa cta gca atc ctc gtt gga aca gac tac aac cca gga      720
Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225                 230                 235                 240

gga ata aag ggc ata ggc ctt aaa aaa gct tta gag att gtt aga cac      768
Gly Ile Lys Gly Ile Gly Leu Lys Lys Ala Leu Glu Ile Val Arg His
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               245                 250                 255

tca aaa gat ccg cta gca aag ttc caa aag caa agc gat gtg gat tta      816
Ser Lys Asp Pro Leu Ala Lys Phe Gln Lys Gln Ser Asp Val Asp Leu
            260                 265                 270

tat gca ata aaa gag ttc ttc cta aac cca cca gtc aca gat aac tac      864
Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asn Tyr
        275                 280                 285

aat tta gtg tgg aga gat ccc gac gaa gag gga ata cta aag ttc tta      912
Asn Leu Val Trp Arg Asp Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
    290                 295                 300

tgt gac gag cat gac ttt agt gag gaa aga gta aag aat gga tta gag      960
Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu
305                 310                 315                 320

agg ctt aag aag gca atc aaa agt gga aaa caa tca acc ctt gaa agt     1008
Arg Leu Lys Lys Ala Ile Lys Ser Gly Lys Gln Ser Thr Leu Glu Ser
                325                 330                 335

tgg ttc aag aga taa                                             1023
Trp Phe Lys Arg
            340


<210> SEQ ID NO 79
<211> LENGTH: 340
<212> TYPE: PRT
<213> ORGANISM: Pyrococcus furiosus

<400> SEQUENCE: 79

Met Gly Val Pro Ile Gly Glu Ile Ile Pro Arg Lys Glu Ile Glu Leu
  1               5                  10                  15

Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
             20                  25                  30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Lys Asp Gly Thr Pro Leu Met
         35                  40                  45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
     50                  55                  60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Val Tyr Val Phe Asp
 65                  70                  75                  80

Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Arg Glu
                 85                  90                  95

Ala Arg Glu Glu Ala Glu Glu Lys Trp Arg Glu Ala Leu Glu Lys Gly
            100                 105                 110

Glu Ile Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Arg Val Asn
        115                 120                 125

Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
    130                 135                 140

Pro Ile Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
145                 150                 155                 160

Ala Ala Lys Gly Ser Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
                165                 170                 175

Leu Leu Phe Gly Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
            180                 185                 190

Lys Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Ile Lys Pro Glu
        195                 200                 205

Leu Ile Ile Leu Glu Glu Val Leu Lys Glu Leu Lys Leu Thr Arg Glu
    210                 215                 220
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Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225                 230                 235                 240

Gly Ile Lys Gly Ile Gly Leu Lys Lys Ala Leu Glu Ile Val Arg His
                245                 250                 255

Ser Lys Asp Pro Leu Ala Lys Phe Gln Lys Gln Ser Asp Val Asp Leu
            260                 265                 270

Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asn Tyr
        275                 280                 285

Asn Leu Val Trp Arg Asp Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
    290                 295                 300

Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu
305                 310                 315                 320

Arg Leu Lys Lys Ala Ile Lys Ser Gly Lys Gln Ser Thr Leu Glu Ser
                325                 330                 335

Trp Phe Lys Arg
            340
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<210> SEQ ID NO 80
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus wosei

<400> SEQUENCE: 80

gataccatgg gtgtcccaat tggtg 25

<210> SEQ ID NO 81
<211> LENGTH: 37
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus wosei

<400> SEQUENCE: 81

tcgacgtcga cttatctctt gaaccaactt tcaaggg 37

<210> SEQ ID NO 82
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus wosei

<400> SEQUENCE: 82

agcgagggag aggcccaagc 20

<210> SEQ ID NO 83
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus wosei

<400> SEQUENCE: 83

gcctatgccc tttattcctc c 21

<210> SEQ ID NO 84
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 84

tggtcgctgt ctcgctgaaa gcgagacagc gtg 33

-continued

<210> SEQ ID NO 85
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 85

tgctctctgg tcgctgtctg aaagacagcg 30

<210> SEQ ID NO 86
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 86

agaaaggaag ggaagaaagc gaaagg 26

<210> SEQ ID NO 87
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (26)
<223> OTHER INFORMATION: The residue at this position is linked to a spacer bearing a Cy3 dye.
<220> FEATURE:
<221> NAME/KEY: modified_base
<222> LOCATION: (27)
<223> OTHER INFORMATION: The residue at this position is a dideoxycytidine.

<400> SEQUENCE: 87

agaaaggaag ggaagaaagc gaaaggc 27

<210> SEQ ID NO 88
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: modified_base
<222> LOCATION: (24)
<223> OTHER INFORMATION: The residue at this position is a dideoxycytidine.

<400> SEQUENCE: 88

gccggcgaac gtggcgagaa aggc 24

<210> SEQ ID NO 89
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (26)
<223> OTHER INFORMATION: The residue at this position is linked to spacer bearing a Cy3 dye.
<220> FEATURE:

-continued

<221> NAME/KEY: modified_base
<222> LOCATION: (27)
<223> OTHER INFORMATION: The residue at this position is a dideoxycytidine.

<400> SEQUENCE: 89

agaaaggaag ggaagaaagc gaaaggc 27

<210> SEQ ID NO 90
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 90

aaaattcctt tctctttgcc ctttgcttcc 30

<210> SEQ ID NO 91
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 91

ggaaagccgg cgaacgtggc gagaaa 26

<210> SEQ ID NO 92
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 92

ggaaagccgg cgaacgtggc gaga 24

<210> SEQ ID NO 93
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 93

agaaaggaag ggaagaaagc gaaaggt 27

<210> SEQ ID NO 94
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(2)
<223> OTHER INFORMATION: The residues at these positions have an amino group added.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (22)
<223> OTHER INFORMATION: The residue at this position is linked to a spacer containing a fluorescein label.

<400> SEQUENCE: 94

-continued

ttccagagcc taatttgcca gta 23

<210> SEQ ID NO 95
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (22)
<223> OTHER INFORMATION: The residue at this position is linked to a spacer containing a fluorescein label.

<400> SEQUENCE: 95

ttccagagcc taatttgcca gta 23

<210> SEQ ID NO 96
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 96

cttaccaacg ctaacgagcg tcttg 25

<210> SEQ ID NO 97
<211> LENGTH: 43
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 97

cccgtctcgc tggtgaaaag aaaaaccacc ctggcgccca ata 43

<210> SEQ ID NO 98
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 98

tattgggcgc catggtggtt ttt 23

<210> SEQ ID NO 99
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)
<223> OTHER INFORMATION: The residue at this position is attached to an abasic linker (5' nitroindole).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (14)
<223> OTHER INFORMATION: The residue at this position is attached to an abasic linker (5' nitroindole).

<400> SEQUENCE: 99

-continued

tattgggcgc agggggtttt t 21

<210> SEQ ID NO 100
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)
<223> OTHER INFORMATION: The residue at this position is attached to an abasic linker (5' nitroindole).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (14)
<223> OTHER INFORMATION: The residue at this position is attached to an abasic linker (5' nitroindole).

<400> SEQUENCE: 100

tattgggcgc atggggtttt t 21

<210> SEQ ID NO 101
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (15)
<223> OTHER INFORMATION: The residue at this position is attached to an abasic linker (3-nitropyrrole).

<400> SEQUENCE: 101

tattgggcgc caggggttt tt 22

<210> SEQ ID NO 102
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (15)
<223> OTHER INFORMATION: g at this position is attached to an abasic linker (3-nitropyrrole).

<400> SEQUENCE: 102

tattgggcgc catggggttt tt 22

<210> SEQ ID NO 103
<211> LENGTH: 56
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (2)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (3)

-continued

<223> OTHER INFORMATION: The residue at this position is a
2'deoxyguanosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (4)..(5)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (6)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (7)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (8)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)..(10)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 103

ctgaatataa acttgtggta gttggagctg gtgccgtagg caagagtgcc ttgacg 56

<210> SEQ ID NO 104
<211> LENGTH: 56
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (2)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (3)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxyguanosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (4)..(5)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (6)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (7)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxyadenosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference

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<222> LOCATION: (8)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)..(10)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 104

ctgaatataa acttgtggta gttggagctg gtgacgtagg caagagtgcc ttgacg 56

<210> SEQ ID NO 105
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxyguanosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (2)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (3)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (5)..(6)
<223> OTHER INFORMATION: The residues at these positions are
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (7)..(8)
<223> OTHER INFORMATION: The residues at these positions are
2'deoxyguanosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 105

gctcaaggca ctcttgccta cga 23

<210> SEQ ID NO 106
<211> LENGTH: 8
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:

-continued

<221> NAME/KEY: misc_feature
<222> LOCATION: (1)..(2)
<223> OTHER INFORMATION: The residues at these positions have an amino group added.

<400> SEQUENCE: 106

ttcaccag 8

<210> SEQ ID NO 107
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (2)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (3)..(4)
<223> OTHER INFORMATION: The residues at these positions are a 2'deoxycytosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (5)..(6)
<223> OTHER INFORMATION: The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (7)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (8)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 107

ctccaactac cacaagttta tattcag 27

<210> SEQ ID NO 108
<211> LENGTH: 14
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 108

cgagagacca cgct 14

<210> SEQ ID NO 109
<211> LENGTH: 14

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<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (14)
<223> OTHER INFORMATION: The residue at this position contains an abasic ribose.

<400> SEQUENCE: 109

cgagagacca cgct 14

<210> SEQ ID NO 110
<211> LENGTH: 14
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (14)
<223> OTHER INFORMATION: The residue at this position contains an abasic ribose with a 3' phosphate group.
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 110

cgagagacca cgct 14

<210> SEQ ID NO 111
<211> LENGTH: 15
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (15)
<223> OTHER INFORMATION: The residue at this position contains a 3' phosphate group.
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 111

cgagagacca cgctg 15

<210> SEQ ID NO 112
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxyguanosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (2)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (3)..(4)
<223> OTHER INFORMATION: The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (5)
<223> OTHER INFORMATION: The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate).

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<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (6)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (7)..(8)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxyadenosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (10)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 112

gtaatcttac caacgctaac gagcgtcttg 30

<210> SEQ ID NO 113
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(2)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxycytosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (3)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxythymidine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (4)..(5)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxyadenosine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (6)..(8)
<223> OTHER INFORMATION: The residues at these positions are a
2'deoxythymidine 5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (9)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxyguanosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (10)
<223> OTHER INFORMATION: The residue at this position is a
2'deoxycytosine
5'-O-(1-Thiomonophosphate).
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 113

cctaatttgc cagttacaaa ataaacagcc c 31

-continued

<210> SEQ ID NO 114
<211> LENGTH: 8
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (1)..(2)
<223> OTHER INFORMATION: The residues at these positions have an amino group added.

<400> SEQUENCE: 114

ttccagag 8

<210> SEQ ID NO 115
<211> LENGTH: 44
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 115

ttttccagag cctaatgaaa ttaggctctg gaaagacgct cgtg 44

<210> SEQ ID NO 116
<211> LENGTH: 14
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 116

aacgagcgtc tttg 14

<210> SEQ ID NO 117
<211> LENGTH: 14
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 117

aacgagcgtc attg 14

<210> SEQ ID NO 118
<211> LENGTH: 50
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 118

ttttttttta attaggctct ggaaagacgc tcgtgaaacg agcgtctttg 50

<210> SEQ ID NO 119
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 119

ttttccagag cctaatg 17

-continued

<210> SEQ ID NO 120
<211> LENGTH: 13
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 120

ccggtcgtcc tgg 13

<210> SEQ ID NO 121
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 121

caattccggt gtactcaccg gttcc 25

<210> SEQ ID NO 122
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 122

ccggtcgtcc tggcaa 16

<210> SEQ ID NO 123
<211> LENGTH: 47
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 123

tgttttgacc tccatagaag accctatagt gagtcgtatt aatttcg 47

<210> SEQ ID NO 124
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 124

cgaaattaat acgactcact ata 23

<210> SEQ ID NO 125
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 125

cgaaattaat acgactcact atacccagaa 30

<210> SEQ ID NO 126
<211> LENGTH: 16
<212> TYPE: DNA

-continued

<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 126

cgaaattaat acgact 16

<210> SEQ ID NO 127
<211> LENGTH: 13
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 127

cgaaattaat acg 13

<210> SEQ ID NO 128
<211> LENGTH: 12
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 128

cgaaattaat ac 12

<210> SEQ ID NO 129
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 129

cactataggg tcttctatgg aggtc 25

<210> SEQ ID NO 130
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 130

actcactata gggtcttcta tggaggtc 28

<210> SEQ ID NO 131
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 131

gactcactat agggtcttct atggaggtc 29

<210> SEQ ID NO 132
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

-continued

<400> SEQUENCE: 132

cgaaattaat acgcagtatg ttagcaaacg 30

<210> SEQ ID NO 133
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 133

gaactggcat gattaagact ccttattacc 30

<210> SEQ ID NO 134
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 134

gaactggcat gattaagact ccttattaa 29

<210> SEQ ID NO 135
<211> LENGTH: 326
<212> TYPE: PRT
<213> ORGANISM: Methanococcus jannaschii

<400> SEQUENCE: 135

Met Gly Val Gln Phe Gly Asp Phe Ile Pro Lys Asn Ile Ile Ser Phe
1 5 10 15

Glu Asp Leu Lys Gly Lys Lys Val Ala Ile Asp Gly Met Asn Ala Leu
20 25 30

Tyr Gln Phe Leu Thr Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
35 40 45

Asn Arg Lys Gly Glu Ile Thr Ser Ala Tyr Asn Gly Val Phe Tyr Lys
50 55 60

Thr Ile His Leu Leu Glu Asn Asp Ile Thr Pro Ile Trp Val Phe Asp
65 70 75 80

Gly Glu Pro Pro Lys Leu Lys Glu Lys Thr Arg Lys Val Arg Arg Glu
85 90 95

Met Lys Glu Lys Ala Glu Leu Lys Met Lys Glu Ala Ile Lys Lys Glu
100 105 110

Asp Phe Glu Glu Ala Ala Lys Tyr Ala Lys Arg Val Ser Tyr Leu Thr
115 120 125

Pro Lys Met Val Glu Asn Cys Lys Tyr Leu Leu Ser Leu Met Gly Ile
130 135 140

Pro Tyr Val Glu Ala Pro Ser Glu Gly Glu Ala Gln Ala Ser Tyr Met
145 150 155 160

Ala Lys Lys Gly Asp Val Trp Ala Val Val Ser Gln Asp Tyr Asp Ala
165 170 175

Leu Leu Tyr Gly Ala Pro Arg Val Val Arg Asn Leu Thr Thr Thr Lys
180 185 190

Glu Met Pro Glu Leu Ile Glu Leu Asn Glu Val Leu Glu Asp Leu Arg
195 200 205

Ile Ser Leu Asp Asp Leu Ile Asp Ile Ala Ile Phe Met Gly Thr Asp

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    210                 215                 220

Tyr Asn Pro Gly Gly Val Lys Gly Ile Gly Phe Lys Arg Ala Tyr Glu
225                 230                 235                 240

Leu Val Arg Ser Gly Val Ala Lys Asp Val Leu Lys Lys Glu Val Glu
                245                 250                 255

Tyr Tyr Asp Glu Ile Lys Arg Ile Phe Lys Glu Pro Lys Val Thr Asp
            260                 265                 270

Asn Tyr Ser Leu Ser Leu Lys Leu Pro Asp Lys Glu Gly Ile Ile Lys
        275                 280                 285

Phe Leu Val Asp Glu Asn Asp Phe Asn Tyr Asp Arg Val Lys Lys His
    290                 295                 300

Val Asp Lys Leu Tyr Asn Leu Ile Ala Asn Lys Thr Lys Gln Lys Thr
305                 310                 315                 320

Leu Asp Ala Trp Phe Lys
                325


<210> SEQ ID NO 136
<211> LENGTH: 340
<212> TYPE: PRT
<213> ORGANISM: Pyrococcus furiosus

<400> SEQUENCE: 136

Met Gly Val Pro Ile Gly Glu Ile Ile Pro Arg Lys Glu Ile Glu Leu
  1               5                  10                  15

Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
             20                  25                  30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Lys Asp Gly Thr Pro Leu Met
         35                  40                  45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
     50                  55                  60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Val Tyr Val Phe Asp
 65                  70                  75                  80

Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Arg Glu
                 85                  90                  95

Ala Arg Glu Glu Ala Glu Glu Lys Trp Arg Glu Ala Leu Glu Lys Gly
            100                 105                 110

Glu Ile Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Arg Val Asn
        115                 120                 125

Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
    130                 135                 140

Pro Ile Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
145                 150                 155                 160

Ala Ala Lys Gly Ser Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
                165                 170                 175

Leu Leu Phe Gly Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
            180                 185                 190

Lys Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Ile Lys Pro Glu
        195                 200                 205

Leu Ile Ile Leu Glu Glu Val Leu Lys Glu Leu Lys Leu Thr Arg Glu
    210                 215                 220

Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225                 230                 235                 240
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```
Gly Ile Lys Gly Ile Gly Leu Lys Lys Ala Leu Glu Ile Val Arg His
               245                 250                 255

Ser Lys Asp Pro Leu Ala Lys Phe Gln Lys Gln Ser Asp Val Asp Leu
            260                 265                 270

Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asn Tyr
        275                 280                 285

Asn Leu Val Trp Arg Asp Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
    290                 295                 300

Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu
305                 310                 315                 320

Arg Leu Lys Lys Ala Ile Lys Ser Gly Lys Gln Ser Thr Leu Glu Ser
               325                 330                 335

Trp Phe Lys Arg
            340


<210> SEQ ID NO 137
<211> LENGTH: 380
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 137

Met Gly Ile Gln Gly Leu Ala Lys Leu Ile Ala Asp Val Ala Pro Ser
  1               5                  10                  15

Ala Ile Arg Glu Asn Asp Ile Lys Ser Tyr Phe Gly Arg Lys Val Ala
             20                  25                  30

Ile Asp Ala Ser Met Ser Ile Tyr Gln Phe Leu Ile Ala Val Arg Gln
         35                  40                  45

Gly Gly Asp Val Leu Gln Asn Glu Glu Gly Glu Thr Thr Ser His Leu
     50                  55                  60

Met Gly Met Phe Tyr Arg Thr Ile Arg Met Met Glu Asn Gly Ile Lys
 65                  70                  75                  80

Pro Val Tyr Val Phe Asp Gly Lys Pro Pro Gln Leu Lys Ser Gly Glu
                 85                  90                  95

Leu Ala Lys Arg Ser Glu Arg Arg Ala Glu Ala Glu Lys Gln Leu Gln
            100                 105                 110

Gln Ala Gln Ala Ala Gly Ala Glu Gln Glu Val Glu Lys Phe Thr Lys
        115                 120                 125

Arg Leu Val Lys Val Thr Lys Gln His Asn Asp Glu Cys Lys His Leu
    130                 135                 140

Leu Ser Leu Met Gly Ile Pro Tyr Leu Asp Ala Pro Ser Glu Ala Glu
145                 150                 155                 160

Ala Ser Cys Ala Ala Leu Val Lys Ala Gly Lys Val Tyr Ala Ala Ala
               165                 170                 175

Thr Glu Asp Met Asp Cys Leu Thr Phe Gly Ser Pro Val Leu Met Arg
            180                 185                 190

His Leu Thr Ala Ser Glu Ala Lys Lys Leu Pro Ile Gln Glu Phe His
        195                 200                 205

Leu Ser Arg Ile Leu Gln Glu Leu Gly Leu Asn Gln Glu Gln Phe Val
    210                 215                 220

Asp Leu Cys Ile Leu Leu Gly Ser Asp Tyr Cys Glu Ser Ile Arg Gly
225                 230                 235                 240

Ile Gly Pro Lys Arg Ala Val Asp Leu Ile Gln Lys His Lys Ser Ile
               245                 250                 255
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```
Glu Glu Ile Val Arg Arg Leu Asp Pro Asn Lys Tyr Pro Val Pro Glu
            260                 265                 270

Asn Trp Leu His Lys Glu Ala His Gln Leu Phe Leu Glu Pro Glu Val
        275                 280                 285

Leu Asp Pro Glu Ser Val Glu Leu Lys Trp Ser Glu Pro Asn Glu Glu
    290                 295                 300

Glu Leu Ile Lys Phe Met Cys Gly Glu Lys Gln Phe Ser Glu Glu Arg
305                 310                 315                 320

Ile Arg Ser Gly Val Lys Arg Leu Ser Lys Ser Arg Gln Gly Ser Thr
                325                 330                 335

Gln Gly Arg Leu Asp Asp Phe Phe Lys Val Thr Gly Ser Leu Ser Ser
            340                 345                 350

Ala Lys Arg Lys Glu Pro Glu Pro Lys Gly Ser Thr Lys Lys Lys Ala
        355                 360                 365

Lys Thr Gly Ala Ala Gly Lys Phe Lys Arg Gly Lys
    370                 375                 380


<210> SEQ ID NO 138
<211> LENGTH: 378
<212> TYPE: PRT
<213> ORGANISM: Mus musculus

<400> SEQUENCE: 138

Met Gly Ile His Gly Leu Ala Lys Leu Ile Ala Asp Val Ala Pro Ser
  1               5                  10                  15

Ala Ile Arg Glu Asn Asp Ile Lys Ser Tyr Phe Gly Arg Lys Val Ala
             20                  25                  30

Ile Asp Ala Ser Met Ser Ile Tyr Gln Phe Leu Ile Ala Val Arg Gln
         35                  40                  45

Gly Gly Asp Val Leu Gln Asn Glu Glu Gly Glu Thr Thr Ser Leu Met
     50                  55                  60

Gly Met Phe Tyr Arg Thr Ile Arg Met Glu Asn Gly Ile Lys Pro Val
 65                  70                  75                  80

Tyr Val Phe Asp Gly Lys Pro Pro Gln Leu Lys Ser Gly Glu Leu Ala
                 85                  90                  95

Lys Arg Ser Glu Arg Arg Ala Glu Ala Glu Lys Gln Leu Gln Gln Ala
            100                 105                 110

Gln Glu Ala Gly Met Glu Glu Glu Val Glu Lys Phe Thr Lys Arg Leu
        115                 120                 125

Val Lys Val Thr Lys Gln His Asn Asp Glu Cys Lys His Leu Leu Ser
    130                 135                 140

Leu Met Gly Ile Pro Tyr Leu Asp Ala Pro Ser Glu Ala Glu Ala Ser
145                 150                 155                 160

Cys Ala Ala Leu Ala Lys Ala Gly Lys Val Tyr Ala Ala Ala Thr Glu
                165                 170                 175

Asp Met Asp Cys Leu Thr Phe Gly Ser Pro Val Leu Met Arg His Leu
            180                 185                 190

Thr Ala Ser Glu Ala Lys Lys Leu Pro Ile Gln Glu Phe His Leu Ser
        195                 200                 205

Arg Val Leu Gln Glu Leu Gly Leu Asn Gln Glu Gln Phe Val Asp Leu
    210                 215                 220

Cys Ile Leu Leu Gly Ser Asp Tyr Cys Glu Ser Ile Arg Gly Ile Gly
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```
225                 230                 235                 240

Ala Lys Arg Ala Val Asp Leu Ile Gln Lys His Lys Ser Ile Glu Glu
                245                 250                 255

Ile Val Arg Arg Leu Asp Pro Ser Lys Tyr Pro Val Pro Glu Asn Trp
            260                 265                 270

Leu His Lys Glu Ala Gln Gln Leu Phe Leu Glu Pro Glu Val Val Asp
        275                 280                 285

Pro Glu Ser Val Glu Leu Lys Trp Ser Glu Pro Asn Glu Glu Glu Leu
    290                 295                 300

Val Lys Phe Met Cys Gly Glu Lys Gln Phe Ser Glu Glu Arg Ile Arg
305                 310                 315                 320

Ser Gly Val Lys Arg Leu Ser Lys Ser Arg Gln Gly Ser Thr Gln Gly
                325                 330                 335

Arg Leu Asp Asp Phe Phe Lys Val Thr Gly Ser Leu Ser Ser Ala Lys
            340                 345                 350

Arg Lys Glu Pro Glu Pro Lys Gly Pro Ala Lys Lys Lys Ala Lys Thr
        355                 360                 365

Gly Gly Ala Gly Lys Phe Arg Arg Gly Lys
    370                 375


<210> SEQ ID NO 139
<211> LENGTH: 382
<212> TYPE: PRT
<213> ORGANISM: Saccharomyces cerevisiae

<400> SEQUENCE: 139

Met Gly Ile Lys Gly Leu Asn Ala Ile Ile Ser Glu His Val Pro Ser
  1               5                  10                  15

Ala Ile Arg Lys Ser Asp Ile Lys Ser Phe Phe Gly Arg Lys Val Ala
             20                  25                  30

Ile Asp Ala Ser Met Ser Leu Tyr Gln Phe Leu Ile Ala Val Arg Gln
         35                  40                  45

Gln Asp Gly Gly Gln Leu Thr Asn Glu Ala Gly Glu Thr Thr Ser His
     50                  55                  60

Leu Met Gly Met Phe Tyr Arg Thr Leu Arg Met Ile Asp Asn Gly Ile
 65                  70                  75                  80

Lys Pro Cys Tyr Val Phe Asp Gly Lys Pro Pro Asp Leu Lys Ser His
                 85                  90                  95

Glu Leu Thr Lys Arg Ser Ser Arg Arg Val Glu Thr Glu Lys Lys Leu
            100                 105                 110

Ala Glu Ala Thr Thr Glu Leu Glu Lys Met Lys Gln Glu Arg Arg Leu
        115                 120                 125

Val Lys Val Ser Lys Glu His Asn Glu Glu Ala Gln Lys Leu Leu Gly
    130                 135                 140

Leu Met Gly Ile Pro Tyr Ile Ile Ala Pro Thr Glu Ala Glu Ala Gln
145                 150                 155                 160

Cys Ala Glu Leu Ala Lys Lys Gly Lys Val Tyr Ala Ala Ala Ser Glu
                165                 170                 175

Asp Met Asp Thr Leu Cys Tyr Arg Thr Pro Phe Leu Leu Arg His Leu
            180                 185                 190

Thr Phe Ser Glu Ala Lys Lys Glu Pro Ile His Glu Ile Asp Thr Glu
        195                 200                 205
```

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```
Leu Val Leu Arg Gly Leu Asp Leu Thr Ile Glu Gln Phe Val Asp Leu
    210                 215                 220

Cys Ile Met Leu Gly Cys Asp Tyr Cys Glu Ser Ile Arg Gly Val Gly
225                 230                 235                 240

Pro Val Thr Ala Leu Lys Leu Ile Lys Thr His Gly Ser Ile Glu Lys
                245                 250                 255

Ile Val Glu Phe Ile Glu Ser Gly Glu Ser Asn Asn Thr Lys Trp Lys
            260                 265                 270

Ile Pro Glu Asp Trp Pro Tyr Lys Gln Ala Arg Met Leu Phe Leu Asp
        275                 280                 285

Pro Glu Val Ile Asp Gly Asn Glu Ile Asn Leu Lys Trp Ser Pro Pro
    290                 295                 300

Lys Glu Lys Glu Leu Ile Glu Tyr Leu Cys Asp Asp Lys Lys Phe Ser
305                 310                 315                 320

Glu Glu Arg Val Lys Ser Gly Ile Ser Arg Leu Lys Lys Gly Leu Lys
                325                 330                 335

Ser Gly Ile Gln Gly Arg Leu Asp Gly Phe Phe Gln Val Val Pro Lys
            340                 345                 350

Thr Lys Glu Gln Leu Ala Ala Ala Ala Lys Arg Ala Gln Glu Asn Lys
        355                 360                 365

Lys Leu Asn Lys Asn Lys Asn Lys Val Thr Lys Gly Arg Arg
    370                 375                 380


<210> SEQ ID NO 140
<211> LENGTH: 387
<212> TYPE: PRT
<213> ORGANISM: Saccharomyces cerevisiae

<400> SEQUENCE: 140

Met Gly Val His Ser Phe Trp Asp Ile Ala Gly Pro Thr Ala Arg Pro
  1               5                  10                  15

Val Arg Leu Glu Ser Leu Glu Asp Lys Arg Met Ala Val Asp Ala Ser
             20                  25                  30

Ile Trp Ile Tyr Gln Phe Leu Lys Ala Val Arg Asp Gln Glu Gly Asn
         35                  40                  45

Ala Val Lys Asn Ser His Ile Thr Gly Phe Phe Arg Arg Ile Cys Lys
     50                  55                  60

Leu Leu Tyr Phe Gly Ile Arg Pro Val Phe Val Phe Asp Gly Gly Val
 65                  70                  75                  80

Pro Val Leu Lys Arg Glu Thr Ile Arg Gln Arg Lys Glu Arg Arg Gln
                 85                  90                  95

Gly Lys Arg Glu Ser Ala Lys Ser Thr Ala Arg Lys Leu Leu Ala Leu
            100                 105                 110

Gln Leu Gln Asn Gly Ser Asn Asp Asn Glu Val Thr Met Asp Met Ile
        115                 120                 125

Lys Glu Val Gln Glu Leu Leu Ser Arg Phe Gly Ile Pro Tyr Ile Thr
    130                 135                 140

Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Glu Leu Leu Gln Leu Asn
145                 150                 155                 160

Leu Val Asp Gly Ile Ile Thr Asp Asp Ser Asp Val Phe Leu Phe Gly
                165                 170                 175

Gly Thr Lys Ile Tyr Lys Asn Met Phe His Glu Lys Asn Tyr Val Glu
            180                 185                 190
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```
Phe Tyr Asp Ala Glu Ser Ile Leu Lys Leu Leu Gly Leu Asp Arg Lys
        195                 200                 205

Asn Met Ile Glu Leu Ala Gln Leu Leu Gly Ser Asp Tyr Thr Asn Gly
    210                 215                 220

Leu Lys Gly Met Gly Pro Val Ser Ser Ile Glu Val Ile Ala Glu Phe
225                 230                 235                 240

Gly Asn Leu Lys Asn Phe Lys Asp Trp Tyr Asn Asn Gly Gln Phe Asp
                245                 250                 255

Lys Arg Lys Gln Glu Thr Glu Asn Lys Phe Glu Lys Asp Leu Arg Lys
            260                 265                 270

Lys Leu Val Asn Asn Glu Ile Ile Leu Asp Asp Asp Phe Pro Ser Val
        275                 280                 285

Met Val Tyr Asp Ala Tyr Met Arg Pro Glu Val Asp His Asp Thr Thr
    290                 295                 300

Pro Phe Val Trp Gly Val Pro Asp Leu Asp Met Leu Arg Ser Phe Met
305                 310                 315                 320

Lys Thr Gln Leu Gly Trp Pro His Glu Lys Ser Asp Glu Ile Leu Ile
                325                 330                 335

Pro Leu Ile Arg Asp Val Asn Lys Arg Lys Lys Lys Gly Lys Gln Lys
            340                 345                 350

Arg Ile Asn Glu Phe Phe Pro Arg Glu Tyr Ile Ser Gly Asp Lys Lys
        355                 360                 365

Leu Asn Thr Ser Lys Arg Ile Ser Thr Ala Thr Gly Lys Leu Lys Lys
    370                 375                 380

Arg Lys Met
385


<210> SEQ ID NO 141
<211> LENGTH: 488
<212> TYPE: PRT
<213> ORGANISM: Shizosaccharomyces pombe

<400> SEQUENCE: 141

Met Gly Val Ser Gly Leu Trp Asn Ile Leu Glu Pro Val Lys Arg Pro
  1               5                  10                  15

Val Lys Leu Glu Thr Leu Val Asn Lys Arg Leu Ala Ile Asp Ala Ser
             20                  25                  30

Ile Trp Ile Tyr Gln Phe Leu Lys Ala Val Arg Asp Lys Glu Gly Asn
         35                  40                  45

Gln Leu Lys Ser Ser His Val Val Gly Phe Phe Arg Arg Ile Cys Lys
     50                  55                  60

Leu Leu Phe Phe Gly Ile Lys Pro Val Phe Val Phe Asp Gly Gly Ala
 65                  70                  75                  80

Pro Ser Leu Lys Arg Gln Thr Ile Gln Lys Arg Gln Ala Arg Arg Leu
                 85                  90                  95

Asp Arg Glu Glu Asn Ala Thr Val Thr Ala Asn Lys Leu Leu Ala Leu
            100                 105                 110

Gln Met Arg His Gln Ala Met Leu Leu Lys Arg Asp Ala Asp Glu Val
        115                 120                 125

Thr Gln Val Met Ile Lys Glu Cys Gln Glu Leu Leu Arg Leu Phe Gly
    130                 135                 140

Leu Pro Tyr Ile Val Ala Pro Gln Glu Ala Glu Ala Gln Cys Ser Lys
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```
145                 150                 155                 160

Leu Leu Glu Leu Lys Leu Val Asp Gly Ile Val Thr Asp Asp Ser Asp
                165                 170                 175

Val Phe Leu Phe Gly Gly Thr Arg Val Tyr Arg Asn Met Phe Asn Gln
            180                 185                 190

Asn Lys Phe Val Glu Leu Tyr Leu Met Asp Asp Met Lys Arg Glu Phe
        195                 200                 205

Asn Val Asn Gln Met Asp Leu Ile Lys Leu Ala His Leu Leu Gly Ser
    210                 215                 220

Asp Tyr Thr Met Gly Leu Ser Arg Val Gly Pro Val Leu Ala Leu Glu
225                 230                 235                 240

Ile Leu His Glu Phe Pro Gly Asp Thr Gly Leu Phe Glu Phe Lys Lys
                245                 250                 255

Trp Phe Gln Arg Leu Ser Thr Gly His Ala Ser Lys Asn Asp Val Asn
            260                 265                 270

Thr Pro Val Lys Lys Arg Ile Asn Lys Leu Val Gly Lys Ile Ile Leu
        275                 280                 285

Pro Ser Glu Phe Pro Asn Pro Leu Val Asp Glu Ala Tyr Leu His Pro
    290                 295                 300

Ala Val Asp Asp Ser Lys Gln Ser Phe Gln Trp Gly Ile Pro Asp Leu
305                 310                 315                 320

Asp Glu Leu Arg Gln Phe Leu Met Ala Thr Val Gly Trp Ser Lys Gln
                325                 330                 335

Arg Thr Asn Glu Val Leu Leu Pro Val Ile Gln Asp Met His Lys Lys
            340                 345                 350

Gln Phe Val Gly Thr Gln Ser Asn Leu Thr Gln Phe Phe Glu Gly Gly
        355                 360                 365

Asn Thr Asn Val Tyr Ala Pro Arg Val Ala Tyr His Phe Lys Ser Lys
    370                 375                 380

Arg Leu Glu Asn Ala Leu Ser Ser Phe Lys Asn Gln Ile Ser Asn Gln
385                 390                 395                 400

Ser Pro Met Ser Glu Glu Ile Gln Ala Asp Ala Asp Ala Phe Gly Glu
                405                 410                 415

Ser Lys Gly Ser Asp Glu Leu Gln Ser Arg Ile Leu Arg Arg Lys Lys
            420                 425                 430

Met Met Ala Ser Lys Asn Ser Ser Asp Ser Asp Ser Asp Ser Glu Asp
        435                 440                 445

Asn Phe Leu Ala Ser Leu Thr Pro Lys Thr Asn Ser Ser Ser Ile Ser
    450                 455                 460

Ile Glu Asn Leu Pro Arg Lys Thr Lys Leu Ser Thr Ser Leu Leu Lys
465                 470                 475                 480

Lys Pro Ser Lys Arg Arg Arg Lys
                485


<210> SEQ ID NO 142
<211> LENGTH: 550
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 142

Met Gly Val Gln Gly Leu Trp Lys Leu Leu Glu Cys Ser Gly Arg Gln
  1               5                  10                  15
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```
Val Ser Pro Glu Ala Leu Glu Gly Lys Ile Leu Ala Val Asp Ile Ser
            20                  25                  30

Ile Trp Leu Asn Gln Ala Leu Lys Gly Val Arg Asp Arg His Gly Asn
        35                  40                  45

Ser Ile Glu Asn Pro His Leu Leu Thr Leu Phe His Arg Leu Cys Lys
    50                  55                  60

Leu Leu Phe Phe Arg Ile Arg Pro Ile Phe Val Phe Asp Gly Asp Ala
65                  70                  75                  80

Pro Leu Leu Lys Lys Gln Thr Leu Val Lys Arg Arg Gln Arg Lys Asp
                85                  90                  95

Leu Ala Ser Ser Asp Ser Arg Lys Thr Thr Glu Lys Leu Leu Lys Thr
            100                 105                 110

Phe Leu Lys Arg Gln Ala Ile Lys Thr Glu Arg Ile Ala Ala Thr Val
        115                 120                 125

Thr Gly Gln Met Phe Leu Glu Ser Gln Glu Leu Leu Arg Leu Phe Gly
    130                 135                 140

Ile Pro Tyr Ile Gln Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Ile
145                 150                 155                 160

Leu Asp Leu Thr Asp Gln Thr Ser Gly Thr Ile Thr Asp Asp Ser Asp
                165                 170                 175

Ile Trp Leu Phe Gly Ala Arg His Val Tyr Arg Asn Phe Phe Asn Lys
            180                 185                 190

Asn Lys Phe Val Glu Tyr Tyr Gln Tyr Val Asp Phe His Asn Gln Leu
        195                 200                 205

Gly Leu Asp Arg Asn Lys Leu Ile Asn Leu Ala Tyr Leu Leu Gly Ser
    210                 215                 220

Asp Tyr Thr Glu Gly Ile Pro Thr Val Gly Cys Val Thr Ala Met Glu
225                 230                 235                 240

Ile Leu Asn Glu Phe Pro Gly His Gly Leu Glu Pro Leu Leu Lys Phe
                245                 250                 255

Ser Glu Trp Trp His Glu Ala Gln Lys Asn Pro Lys Ile Arg Pro Asn
            260                 265                 270

Pro His Asp Thr Lys Val Lys Lys Lys Leu Arg Thr Leu Gln Leu Thr
        275                 280                 285

Pro Gly Phe Pro Asn Pro Ala Val Ala Glu Ala Tyr Leu Lys Pro Val
    290                 295                 300

Val Asp Asp Ser Lys Gly Ser Phe Leu Trp Gly Lys Pro Asp Leu Asp
305                 310                 315                 320

Lys Ile Arg Glu Phe Cys Gln Arg Tyr Phe Gly Trp Asn Arg Thr Lys
                325                 330                 335

Thr Asp Glu Ser Leu Phe Pro Val Leu Lys Gln Leu Asp Ala Gln Gln
            340                 345                 350

Thr Gln Leu Arg Ile Asp Ser Phe Phe Arg Leu Ala Gln Gln Glu Lys
        355                 360                 365

Glu Asp Ala Lys Arg Ile Lys Ser Gln Arg Leu Asn Arg Ala Val Thr
    370                 375                 380

Cys Met Leu Arg Lys Glu Lys Glu Ala Ala Ala Ser Glu Ile Glu Ala
385                 390                 395                 400

Val Ser Val Ala Met Glu Lys Glu Phe Glu Leu Leu Asp Lys Ala Lys
                405                 410                 415

Arg Lys Thr Gln Lys Arg Gly Ile Thr Asn Thr Leu Glu Glu Ser Ser
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            420                 425                 430

Ser Leu Lys Arg Lys Arg Leu Ser Asp Ser Lys Arg Lys Asn Thr Cys
        435                 440                 445

Gly Gly Phe Leu Gly Glu Thr Cys Leu Ser Glu Ser Ser Asp Gly Ser
    450                 455                 460

Ser Ser Glu His Ala Glu Ser Ser Ser Leu Met Asn Val Gln Arg Arg
465                 470                 475                 480

Thr Ala Ala Lys Glu Pro Lys Thr Ser Ala Ser Asp Ser Gln Asn Ser
                485                 490                 495

Val Lys Glu Ala Pro Val Lys Asn Gly Gly Ala Thr Thr Ser Ser Ser
            500                 505                 510

Ser Asp Ser Asp Asp Asp Gly Gly Lys Glu Lys Met Val Leu Val Thr
        515                 520                 525

Ala Arg Ser Val Phe Gly Lys Lys Arg Arg Lys Leu Arg Arg Ala Arg
    530                 535                 540

Gly Arg Lys Arg Lys Thr
545                 550


<210> SEQ ID NO 143
<211> LENGTH: 543
<212> TYPE: PRT
<213> ORGANISM: Mus musculus

<400> SEQUENCE: 143

Met Gly Val Gln Gly Leu Trp Lys Leu Leu Glu Cys Ser Gly His Arg
  1               5                  10                  15

Val Ser Pro Glu Ala Leu Glu Gly Lys Val Leu Ala Val Asp Ile Ser
             20                  25                  30

Ile Trp Leu Asn Gln Ala Leu Lys Gly Val Arg Asp Ser His Gly Asn
         35                  40                  45

Val Ile Glu Asn Ala His Leu Leu Thr Leu Phe His Arg Leu Cys Lys
     50                  55                  60

Leu Leu Phe Phe Arg Ile Arg Pro Ile Phe Val Phe Asp Gly Asp Ala
 65                  70                  75                  80

Pro Leu Leu Lys Lys Gln Thr Leu Ala Lys Arg Arg Gln Arg Lys Asp
                85                  90                  95

Ser Ala Ser Ile Asp Ser Arg Lys Thr Thr Glu Lys Leu Leu Lys Thr
            100                 105                 110

Phe Leu Lys Arg Gln Ala Leu Lys Thr Asp Arg Ile Ala Ala Ser Val
        115                 120                 125

Thr Gly Gln Met Phe Leu Glu Ser Gln Glu Leu Leu Arg Leu Phe Gly
    130                 135                 140

Val Pro Tyr Ile Gln Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Val
145                 150                 155                 160

Leu Asp Leu Ser Asp Gln Thr Ser Gly Thr Ile Thr Asp Asp Ser Asp
                165                 170                 175

Ile Trp Leu Phe Gly Ala Arg His Val Tyr Lys Asn Phe Phe Asn Lys
            180                 185                 190

Asn Lys Phe Val Glu Tyr Tyr Gln Tyr Val Asp Phe Tyr Ser Gln Leu
        195                 200                 205

Gly Leu Asp Arg Asn Lys Leu Ile Asn Leu Ala Tyr Leu Leu Gly Ser
    210                 215                 220
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Asp Tyr Thr Glu Gly Ile Pro Thr Val Gly Cys Val Thr Ala Met Glu
225                 230                 235                 240

Ile Leu Asn Glu Phe Pro Gly Arg Gly Leu Asp Pro Leu Leu Lys Phe
                245                 250                 255

Ser Glu Trp Trp His Glu Ala Gln Asn Asn Lys Lys Val Ala Glu Asn
            260                 265                 270

Pro Tyr Asp Thr Lys Val Lys Lys Lys Leu Arg Lys Leu Gln Leu Thr
        275                 280                 285

Pro Gly Phe Pro Asn Pro Ala Val Ala Asp Ala Tyr Leu Arg Pro Val
    290                 295                 300

Val Asp Asp Ser Arg Gly Ser Phe Leu Trp Gly Lys Pro Asp Val Asp
305                 310                 315                 320

Lys Ile Arg Glu Phe Cys Gln Arg Tyr Phe Gly Trp Asn Arg Met Lys
                325                 330                 335

Thr Asp Glu Ser Leu Tyr Pro Val Leu Lys His Leu Asn Ala His Gln
            340                 345                 350

Thr Gln Leu Arg Ile Asp Ser Phe Phe Arg Leu Ala Gln Gln Glu Lys
        355                 360                 365

Gln Asp Ala Lys Leu Ile Lys Ser His Arg Leu Ser Arg Ala Val Thr
    370                 375                 380

Cys Met Leu Arg Lys Glu Arg Glu Glu Lys Ala Pro Glu Leu Thr Lys
385                 390                 395                 400

Val Thr Glu Ala Met Glu Lys Glu Phe Glu Leu Leu Asp Asp Ala Lys
                405                 410                 415

Gly Lys Thr Gln Lys Arg Glu Leu Pro Tyr Lys Lys Glu Thr Ser Val
            420                 425                 430

Pro Lys Arg Arg Arg Pro Ser Gly Asn Gly Gly Phe Leu Gly Asp Pro
        435                 440                 445

Tyr Cys Ser Glu Ser Pro Gln Glu Ser Ser Cys Glu Asp Gly Glu Gly
    450                 455                 460

Ser Ser Val Met Ser Ala Arg Gln Arg Ser Ala Ala Glu Ser Ser Lys
465                 470                 475                 480

Ile Gly Cys Ser Asp Val Pro Asp Leu Val Arg Asp Ser Pro His Gly
                485                 490                 495

Arg Gln Gly Cys Val Ser Thr Ser Ser Ser Asp Ser Glu Asp Gly Glu
            500                 505                 510

Asp Lys Ala Lys Thr Val Leu Val Thr Ala Arg Pro Val Phe Gly Lys
        515                 520                 525

Lys Arg Arg Lys Leu Lys Ser Met Lys Arg Arg Lys Lys Lys Thr
    530                 535                 540


<210> SEQ ID NO 144
<211> LENGTH: 527
<212> TYPE: PRT
<213> ORGANISM: Xenopus laevis

<400> SEQUENCE: 144

Met Gly Val Gln Gly Leu Trp Lys Leu Leu Glu Cys Ser Gly Arg Pro
  1               5                  10                  15

Ile Asn Pro Gly Thr Leu Glu Gly Lys Ile Leu Ala Val Asp Ile Ser
             20                  25                  30

Ile Trp Leu Asn Gln Ala Val Lys Gly Ala Arg Asp Arg Gln Gly Asn
         35                  40                  45
```

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```
Ala Ile Gln Asn Ala His Leu Leu Thr Leu Phe His Arg Leu Cys Lys
     50                  55                  60

Leu Leu Phe Phe Arg Ile Arg Pro Ile Phe Val Phe Asp Gly Glu Ala
 65                  70                  75                  80

Pro Leu Leu Lys Arg Gln Thr Leu Ala Lys Arg Arg Gln Arg Thr Asp
                85                  90                  95

Lys Ala Ser Asn Asp Ala Arg Lys Thr Asn Glu Lys Leu Leu Arg Thr
            100                 105                 110

Phe Leu Lys Arg Gln Ala Ile Lys Ala Glu Arg Ile Ala Ala Thr Val
        115                 120                 125

Thr Gly Gln Met Cys Leu Glu Ser Gln Glu Leu Leu Gln Leu Phe Gly
    130                 135                 140

Ile Pro Tyr Ile Val Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Ile
145                 150                 155                 160

Leu Asp Leu Thr Asp Gln Thr Ser Gly Thr Ile Thr Asp Asp Ser Asp
                165                 170                 175

Ile Trp Leu Phe Gly Ala Arg His Val Tyr Lys Asn Phe Phe Ser Gln
            180                 185                 190

Asn Lys His Val Glu Tyr Tyr Gln Tyr Ala Asp Ile His Asn Gln Leu
        195                 200                 205

Gly Leu Asp Arg Ser Lys Leu Ile Asn Leu Ala Tyr Leu Leu Gly Ser
    210                 215                 220

Asp Tyr Thr Glu Gly Ile Pro Thr Val Gly Tyr Val Ser Ala Met Glu
225                 230                 235                 240

Ile Leu Asn Glu Phe Pro Gly Gln Gly Leu Glu Pro Leu Val Lys Phe
                245                 250                 255

Lys Glu Trp Trp Ser Glu Ala Gln Lys Asp Lys Lys Met Arg Pro Asn
            260                 265                 270

Pro Asn Asp Thr Lys Val Lys Lys Lys Leu Arg Leu Leu Asp Leu Gln
        275                 280                 285

Gln Ser Phe Pro Asn Pro Ala Val Ala Ser Ala Tyr Leu Lys Pro Val
    290                 295                 300

Val Asp Glu Ser Lys Ser Ala Phe Ser Trp Gly Arg Pro Asp Leu Glu
305                 310                 315                 320

Gln Ile Arg Glu Phe Cys Glu Ser Arg Phe Gly Trp Tyr Arg Leu Lys
                325                 330                 335

Thr Asp Glu Val Leu Leu Pro Val Leu Lys Gln Leu Asn Ala Gln Gln
            340                 345                 350

Thr Gln Leu Arg Ile Asp Ser Phe Phe Arg Leu Glu Gln His Glu Ala
        355                 360                 365

Ala Gly Leu Lys Ser Gln Arg Leu Arg Arg Ala Val Thr Cys Met Lys
    370                 375                 380

Arg Lys Glu Arg Asp Val Glu Ala Glu Glu Val Glu Ala Ala Val Ala
385                 390                 395                 400

Val Met Glu Arg Glu Cys Thr Asn Gln Arg Lys Gly Gln Lys Thr Asn
                405                 410                 415

Thr Lys Ser Gln Gly Thr Lys Arg Arg Lys Pro Thr Glu Cys Ser Gln
            420                 425                 430

Glu Asp Gln Asp Pro Gly Gly Gly Phe Ile Gly Ile Glu Leu Lys Thr
        435                 440                 445
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```
Leu Ser Ser Lys Ala Tyr Ser Ser Asp Gly Ser Ser Ser Asp Ala Glu
    450                 455                 460

Asp Leu Pro Ser Gly Leu Ile Asp Lys Gln Ser Gln Ser Gly Ile Val
465                 470                 475                 480

Gly Arg Gln Lys Ala Ser Asn Lys Val Glu Ser Ser Ser Ser Ser Asp
                485                 490                 495

Asp Glu Asp Arg Thr Val Met Val Thr Ala Lys Pro Val Phe Gln Gly
            500                 505                 510

Lys Lys Thr Lys Ser Lys Thr Met Lys Glu Thr Val Lys Arg Lys
        515                 520                 525


<210> SEQ ID NO 145
<211> LENGTH: 434
<212> TYPE: PRT
<213> ORGANISM: Cunninghamella elegans

<400> SEQUENCE: 145

Met Thr Ile Asn Gly Ile Trp Glu Trp Ala Asn His Val Val Arg Lys
  1               5                  10                  15

Val Pro Asn Glu Thr Met Arg Asp Lys Thr Leu Ser Ile Asp Gly His
             20                  25                  30

Ile Trp Leu Tyr Glu Ser Leu Lys Gly Cys Glu Ala His His Gln Gln
         35                  40                  45

Thr Pro Asn Ser Tyr Leu Val Thr Phe Phe Thr Arg Ile Gln Arg Leu
     50                  55                  60

Leu Glu Leu Lys Ile Ile Pro Ile Val Val Phe Asp Asn Ile Asn Ala
 65                  70                  75                  80

Ser Ser Ser Ala His Glu Ser Lys Asp Gln Asn Glu Phe Val Pro Arg
                 85                  90                  95

Lys Arg Arg Ser Phe Gly Asp Ser Pro Phe Thr Asn Leu Val Asp His
            100                 105                 110

Val Tyr Lys Thr Asn Ala Leu Leu Thr Glu Leu Gly Ile Lys Val Ile
        115                 120                 125

Ile Ala Pro Gly Asp Gly Glu Ala Gln Cys Ala Arg Leu Glu Asp Leu
    130                 135                 140

Gly Val Thr Ser Gly Cys Ile Thr Thr Asp Phe Asp Tyr Phe Leu Phe
145                 150                 155                 160

Gly Gly Lys Asn Leu Tyr Arg Phe Asp Phe Thr Ala Gly Thr Ser Ser
                165                 170                 175

Thr Ala Cys Leu His Asp Ile Met His Leu Ser Leu Gly Arg Met Phe
            180                 185                 190

Met Glu Lys Lys Val Ser Arg Pro His Leu Ile Ser Thr Ala Ile Leu
        195                 200                 205

Leu Gly Cys Asp Tyr Phe Gln Arg Gly Val Gln Asn Ile Gly Ile Val
    210                 215                 220

Ser Val Phe Asp Ile Leu Gly Glu Phe Gly Asp Asp Gly Asn Glu Glu
225                 230                 235                 240

Ile Asp Pro His Val Ile Leu Asp Arg Phe Ala Ser Tyr Val Arg Glu
                245                 250                 255

Glu Ile Pro Ala Arg Ser Glu Asp Thr Gln Arg Lys Leu Arg Leu Arg
            260                 265                 270

Arg Lys Lys Tyr Asn Phe Pro Val Gly Phe Pro Asn Cys Asp Ala Val
        275                 280                 285
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```
His Asn Ala Ile Thr Met Tyr Leu Arg Pro Pro Val Ser Ser Glu Ile
    290                 295                 300

Pro Lys Ile Ile Pro Arg Ala Ala Asn Phe Gln Gln Val Ala Glu Ile
305                 310                 315                 320

Met Met Lys Glu Cys Gly Trp Pro Ala Thr Arg Thr Gln Lys Glu Leu
                325                 330                 335

Ala Leu Ser Ile Arg Arg Lys Val His Leu Thr Thr Thr Val Ala Gln
            340                 345                 350

Thr Arg Ile Pro Asp Phe Phe Ala Ala Thr Lys Ser Lys Asn Phe Thr
        355                 360                 365

Pro Ile Val Glu Pro Cys Glu Ser Leu Glu Asp Tyr Ile Ser Ala Asn
    370                 375                 380

Asn Thr Trp Met Arg Lys Arg Lys Arg Ser Glu Ser Pro Gln Ile Leu
385                 390                 395                 400

Gln His His Ala Lys Arg Gln Val Pro Asp Arg Lys Arg Ser Val Lys
                405                 410                 415

Ile Arg Ala Phe Lys Pro Tyr Pro Thr Asp Val Ile Glu Leu Gly Asp
            420                 425                 430

Ser Asp
```

<210> SEQ ID NO 146
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 146

tactgactca ctatagggtc ttctatggag gtc 33

<210> SEQ ID NO 147
<211> LENGTH: 42
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 147

ttttttttta attaggctct ggaagacgct gaaagcgtct tg 42

<210> SEQ ID NO 148
<211> LENGTH: 38
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 148

ttttttttta attaggctct ggaagacgga acgtcttg 38

<210> SEQ ID NO 149
<211> LENGTH: 34
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 149

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tttttttttta attaggctct ggaagagaat cttg 34

<210> SEQ ID NO 150
<211> LENGTH: 32
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 150

tttttttttta attaggctct ggaaggaact tg 32

<210> SEQ ID NO 151
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 151

tttttttttta attaggctct ggaag 25

<210> SEQ ID NO 152
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 152

attagaaagg aagggaagaa agcgaa 26

<210> SEQ ID NO 153
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 153

acggggaaag ccggcgaacg tggcgagaaa 30

<210> SEQ ID NO 154
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 154

tgacggggaa agccggcgaa cgtggcgaga 30

<210> SEQ ID NO 155
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 155

cttgacgggg aaagccggcg aacgtggcga 30

<210> SEQ ID NO 156

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<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 156

gcttgacggg gaaagccggc gaacgtggcg 30

<210> SEQ ID NO 157
<211> LENGTH: 18
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 157

agaaaggaag ggaagaaa 18

<210> SEQ ID NO 158
<211> LENGTH: 45
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 158

tggaggtcaa aacatcgata agtcgaagaa aggaagggaa gaaat 45

<210> SEQ ID NO 159
<211> LENGTH: 14
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 159

tgttttgacc tcca 14

<210> SEQ ID NO 160
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 160

acacagtgtc ctcccgctcc tcctgagcaa 30

<210> SEQ ID NO 161
<211> LENGTH: 18
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 161

tttccctcct cctcttcc 18

<210> SEQ ID NO 162
<211> LENGTH: 54
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:

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<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 162

atgaggaaga ggaggagggt gctcaggagg agcgggagga cactgtgtct gtca 54

<210> SEQ ID NO 163
<211> LENGTH: 53
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 163

ttcgctttct tcccttcctt tctcgccacg ttcgccggct ttccccgtca agc 53

<210> SEQ ID NO 164
<211> LENGTH: 1011
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus fulgidus

<400> SEQUENCE: 164

atgggtgcgg atattggtga cctctttgag agggaagagg tcgagcttga gtacttctca 60

ggaaagaaaa ttgccgttga tgctttcaac acgctatacc agttcatctc gataataagg 120

cagcctgacg gtacgccgtt aaaggactca cagggcagaa tcacctctca cctttccgga 180

atcctataca gagtctccaa catggtcgag gtgggaatca ggccggtgtt tgtattcgac 240

ggagagccac cggagttcaa gaaggctgaa attgaggaga ggaaaaagag aagggctgag 300

gcagaggaga tgtggattgc ggctttgcag gcaggagata aggacgcgaa aaagtatgct 360

caggctgcag ggagggttga cgagtacatt gttgactccg caaagacgct tttaagttac 420

atggggattc cctttgtcga tgccccgtct gaaggagagg cgcaggctgc ttacatggca 480

gcaaaaggcg atgtggagta cacaggaagc caggattacg attctctgct cttcggaagc 540

ccgagactcg ccagaaatct cgcaataacg ggaaaaagga agcttcccgg caaaaatgtc 600

tatgtggatg taaagccgga gataataatt ctggaaagca acctcaaaag gctgggtttg 660

acgagggagc agctcatcga catagcgatt ctggtcggga cggactacaa tgagggtgtg 720

aagggtgtcg gcgtcaagaa ggctttgaac tacatcaaga cctacggaga tattttcagg 780

gcactcaagg ctctgaaagt aaatattgac cacgtagagg agataaggaa tttcttcctg 840

aatcctcctg tgactgacga ctacagaata gagttcaggg agcctgactt tgagaaggcc 900

atcgagttcc tgtgcgagga gcacgacttc agcagggaga gggtcgagaa ggccttggag 960

aagctcaaag ctctgaagtc aacccaggcc acgcttgaga ggtggttctg a 1011

<210> SEQ ID NO 165
<211> LENGTH: 336
<212> TYPE: PRT
<213> ORGANISM: Archaeoglobus fulgidus

<400> SEQUENCE: 165

Met Gly Ala Asp Ile Gly Asp Leu Phe Glu Arg Glu Glu Val Glu Leu
1 5 10 15

Glu Tyr Phe Ser Gly Lys Lys Ile Ala Val Asp Ala Phe Asn Thr Leu
20 25 30

Tyr Gln Phe Ile Ser Ile Ile Arg Gln Pro Asp Gly Thr Pro Leu Lys
35 40 45

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Asp Ser Gln Gly Arg Ile Thr Ser His Leu Ser Gly Ile Leu Tyr Arg
     50                  55                  60

Val Ser Asn Met Val Glu Val Gly Ile Arg Pro Val Phe Val Phe Asp
 65                  70                  75                  80

Gly Glu Pro Pro Glu Phe Lys Lys Ala Glu Ile Glu Glu Arg Lys Lys
                85                  90                  95

Arg Arg Ala Glu Ala Glu Glu Met Trp Ile Ala Ala Leu Gln Ala Gly
            100                 105                 110

Asp Lys Asp Ala Lys Lys Tyr Ala Gln Ala Ala Gly Arg Val Asp Glu
        115                 120                 125

Tyr Ile Val Asp Ser Ala Lys Thr Leu Leu Ser Tyr Met Gly Ile Pro
    130                 135                 140

Phe Val Asp Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met Ala
145                 150                 155                 160

Ala Lys Gly Asp Val Glu Tyr Thr Gly Ser Gln Asp Tyr Asp Ser Leu
                165                 170                 175

Leu Phe Gly Ser Pro Arg Leu Ala Arg Asn Leu Ala Ile Thr Gly Lys
            180                 185                 190

Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Asp Val Lys Pro Glu Ile
        195                 200                 205

Ile Ile Leu Glu Ser Asn Leu Lys Arg Leu Gly Leu Thr Arg Glu Gln
    210                 215                 220

Leu Ile Asp Ile Ala Ile Leu Val Gly Thr Asp Tyr Asn Glu Gly Val
225                 230                 235                 240

Lys Gly Val Gly Val Lys Lys Ala Leu Asn Tyr Ile Lys Thr Tyr Gly
                245                 250                 255

Asp Ile Phe Arg Ala Leu Lys Ala Leu Lys Val Asn Ile Asp His Val
            260                 265                 270

Glu Glu Ile Arg Asn Phe Phe Leu Asn Pro Pro Val Thr Asp Asp Tyr
        275                 280                 285

Arg Ile Glu Phe Arg Glu Pro Asp Phe Glu Lys Ala Ile Glu Phe Leu
    290                 295                 300

Cys Glu Glu His Asp Phe Ser Arg Glu Arg Val Glu Lys Ala Leu Glu
305                 310                 315                 320

Lys Leu Lys Ala Leu Lys Ser Thr Gln Ala Thr Leu Glu Arg Trp Phe
                325                 330                 335


<210> SEQ ID NO 166
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 166

ccgtcaacat ttaccatggg tgcgga                                          26


<210> SEQ ID NO 167
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence:  Synthetic

<400> SEQUENCE: 167
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ccgccacctc gtagtcgaca tccttttcgt g 31

<210> SEQ ID NO 168
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 168

ggcgaccaca cccgtcctgt 20

<210> SEQ ID NO 169
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 169

ccacgatgcg tccggcgtag 20

<210> SEQ ID NO 170
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 170

aacgaggcgc acccacccaa ggcacagc 28

<210> SEQ ID NO 171
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 171

acgggtcaat gtccatgccc caaaga 26

<210> SEQ ID NO 172
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (23)..(27)
<223> OTHER INFORMATION: The residue at these positions are 2'
O-methyls.

<400> SEQUENCE: 172

gtctgagatg aaagtgcgcc tcgttaa 27

<210> SEQ ID NO 173
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

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<400> SEQUENCE: 173

tcttcgcaca tttcatctca gacgga 26

<210> SEQ ID NO 174
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(21)
<223> OTHER INFORMATION: The residues at these positions are 2'
O-methyls.

<400> SEQUENCE: 174

gctgtgcctt gggtgggtgc g 21

<210> SEQ ID NO 175
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 175

aacgaggcgc acccacccaa ggcacagc 28

<210> SEQ ID NO 176
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 176

acgggtcaat gtccatgccc caaaga 26

<210> SEQ ID NO 177
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (23)..(27)
<223> OTHER INFORMATION: The residues at these positions are 2' -
O-methyls.

<400> SEQUENCE: 177

gtctgagatg aaagtgcgcc tcgttaa 27

<210> SEQ ID NO 178
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 178

tcttcgcaca tttcatctca gac 23

<210> SEQ ID NO 179

-continued

<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(17)
<223> OTHER INFORMATION: The residues at these positons are 2'
O-methyls.

<400> SEQUENCE: 179

gctgtgcctt gggtggg 17

<210> SEQ ID NO 180
<211> LENGTH: 19
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(19)
<223> OTHER INFORMATION: The residues at these positions are 2'
O-methyls.

<400> SEQUENCE: 180

gctgtgcctt gggtgggtg 19

<210> SEQ ID NO 181
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(21)
<223> OTHER INFORMATION: The residues at these positions are 2'
O-methyls.

<400> SEQUENCE: 181

gctgtgcctt gggtgggtgc g 21

<210> SEQ ID NO 182
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(22)
<223> OTHER INFORMATION: The residues at these positions are 2'
O-methyls.

<400> SEQUENCE: 182

gctgtgcctt gggtgggtgc gc 22

<210> SEQ ID NO 183
<211> LENGTH: 41
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (22)

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<223> OTHER INFORMATION: The residue at this positon indicates 2' O-methyl sugar.

<400> SEQUENCE: 183

gtctgagatg aaagtgctcc cgcacccacc caaggcacag c 41

<210> SEQ ID NO 184
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(17)
<223> OTHER INFORMATION: The residues at these positions are 2' O-methyl sugars.

<400> SEQUENCE: 184

gctgtgcctt gggtggg 17

<210> SEQ ID NO 185
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 185

aacgaggcgc acccacccaa ggcacagc 28

<210> SEQ ID NO 186
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 186

gctgtgcctt gggtgggtgc g 21

<210> SEQ ID NO 187
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 187

gctgtgcctt gggtgggtgc 20

<210> SEQ ID NO 188
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (15)..(20)
<223> OTHER INFORMATION: The residues at these positions are 2' O-methyl sugars.

<400> SEQUENCE: 188

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gctgtgcctt gggtgggtgc 20

<210> SEQ ID NO 189
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_difference
<222> LOCATION: (1)..(20)
<223> OTHER INFORMATION: The residues at these positions are 2' O-methyl sugars.

<400> SEQUENCE: 189

gctgtgcctt gggtgggtgc 20

<210> SEQ ID NO 190
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 190

tcttcgcaca tttcatctca gacgga 26

<210> SEQ ID NO 191
<211> LENGTH: 54
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 191

ctgggcgcgg acatggagga cgtgcgcggc cgcctggtgc agtaccgcgg cgag 54

<210> SEQ ID NO 192
<211> LENGTH: 54
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 192

ctgggcgcgg acatggagga cgtgtgcggc cgcctggtgc agtaccgcgg cgag 54

<210> SEQ ID NO 193
<211> LENGTH: 56
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 193

cgcgatgccg atgacctgca gaagcgcctg gcagtgtacc aggccggggc ccgcga 56

<210> SEQ ID NO 194
<211> LENGTH: 56
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 194

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cgcgatgccg atgacctgca gaagtgcctg gcagtgtacc aggccggggc ccgcga 56

<210> SEQ ID NO 195
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 195

cggtactgca ccaggcggcc gct 23

<210> SEQ ID NO 196
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 196

ccccggcctg gtacactgcc aggct 25

<210> SEQ ID NO 197
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 197

aacgaggcgc acgcacgtcc tccatgt 27

<210> SEQ ID NO 198
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: modified_base
<222> LOCATION: (25)
<223> OTHER INFORMATION: The residue at this position is a 2-amino deoxyadenosine.
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 198

gaacgaggcg cacacacgtc ctccntgt 28

<210> SEQ ID NO 199
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 199

aacgaggcgc acgcttctgc aggtcatc 28

<210> SEQ ID NO 200
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (21)

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<223> OTHER INFORMATION: The residue at this position is a 2-amino deoxyadenosine.
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 200

aacgaggcgc acacttctgc nggtcatc 28

<210> SEQ ID NO 201
<211> LENGTH: 39
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is linked to an abasic linker.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (37)..(39)
<223> OTHER INFORMATION: The residues at these positions are 2'-O'-methyl.

<400> SEQUENCE: 201

cctcgtctcg gttttccgag acgagggtgc gcctcgttc 39

<210> SEQ ID NO 202
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 202

cccctgggga agagcagaga tatacgtc 28

<210> SEQ ID NO 203
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 203

gggctccaca cggcgactct catt 24

<210> SEQ ID NO 204
<211> LENGTH: 39
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 204

ggtgctccac ctggcacgta tatctctgct cttccccag 39

<210> SEQ ID NO 205
<211> LENGTH: 39
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 205

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ggtgctccac ctggtacgta tatctctgct cttccccag 39

<210> SEQ ID NO 206
<211> LENGTH: 46
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 206

agctgttcgt gttctatgat catgagagtc gccgtgtgga gccccg 46

<210> SEQ ID NO 207
<211> LENGTH: 46
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 207

agctgttcgt gttctatgat gatgagagtc gccgtgtgga gccccg 46

<210> SEQ ID NO 208
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 208

aacgaacgcg caggccaggt ggagcattt 29

<210> SEQ ID NO 209
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 209

aacgaacgcg cagaccaggt ggagcac 27

<210> SEQ ID NO 210
<211> LENGTH: 40
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is linked to an abasic linker.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (38)..(40)
<223> OTHER INFORMATION: The residues at these positions are 2'-O'-methyl.

<400> SEQUENCE: 210

ctccgtctcg gttttccgag acggagctgc gcgttcguuu 40

<210> SEQ ID NO 211
<211> LENGTH: 35

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<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 211

aagcacgcag cacgatcata gaacacgaac agttt 35

<210> SEQ ID NO 212
<211> LENGTH: 35
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 212

aagcacgcag caccatcata gaacacgaac agttt 35

<210> SEQ ID NO 213
<211> LENGTH: 40
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is linked to an abasic linker.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (38)..(40)
<223> OTHER INFORMATION: The residues at these positions are 2'-O'-methyl.

<400> SEQUENCE: 213

acgcgtctcg gttttccgag acgcgtgtgc tgcgtgcuuu 40

<210> SEQ ID NO 214
<211> LENGTH: 50
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 214

gaaggtgtct gcgggagccg atttcatcat cacgcagctt ttctttgagg 50

<210> SEQ ID NO 215
<211> LENGTH: 50
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 215

gaaggtgtct gcgggagtcg atttcatcat cacgcagctt ttctttgagg 50

<210> SEQ ID NO 216
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 216

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caaagaaaag ctgcgtgatg atgaaatcgc 30

<210> SEQ ID NO 217
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 217

aacgaggcgc acgctcccgc agacac 26

<210> SEQ ID NO 218
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 218

aacgaggcgc acactcccgc agacacc 27

<210> SEQ ID NO 219
<211> LENGTH: 39
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is linked to an abasic linker (Cy3).

<400> SEQUENCE: 219

cctcgtctcg gttttccgag acgagggtgc gcctcgttt 39

<210> SEQ ID NO 220
<211> LENGTH: 51
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 220

actgggagca ttgaggctcg ctgagagtca cttttattgg gaaccatagt t 51

<210> SEQ ID NO 221
<211> LENGTH: 51
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 221

actgggagca ttgaggcttg ctgagagtca cttttattgg gaaccatagt t 51

<210> SEQ ID NO 222
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

-continued

<400> SEQUENCE: 222

tatggttccc aataaaagtg actctcagct 30

<210> SEQ ID NO 223
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 223

aacgaggcgc acgagcctca atgctccc 28

<210> SEQ ID NO 224
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 224

aacgaggcgc acaagcctca atgctccc 28

<210> SEQ ID NO 225
<211> LENGTH: 39
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is an abasic linker (Cy3).

<400> SEQUENCE: 225

cctcgtctcg gttttccgag acgagggtgc gcctcgttt 39

<210> SEQ ID NO 226
<211> LENGTH: 52
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 226

tgaagtctag agaaagggtt gtacggctga ggtctggaga aatgggcatc tg 52

<210> SEQ ID NO 227
<211> LENGTH: 46
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 227

tttgaaatgt cacagggttc ctaacagcca ctcttccctg gatggg 46

<210> SEQ ID NO 228
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

-continued

<400> SEQUENCE: 228

agatgcccat ttctccagac ctcagccc 28

<210> SEQ ID NO 229
<211> LENGTH: 36
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 229

aagcacgcag cacgtacaac cctttctcta gacaaa 36

<210> SEQ ID NO 230
<211> LENGTH: 40
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is linked to an abasic linker (Cy3).

<400> SEQUENCE: 230

ctccgtctcg gttttccgag acggaggtgc tgcgtgcuuu 40

<210> SEQ ID NO 231
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 231

ccatccaggg aagagtggcc tgttt 25

<210> SEQ ID NO 232
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 232

aagcacgcag cacaggaacc ctgtgacat 29

<210> SEQ ID NO 233
<211> LENGTH: 46
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 233

taggttttga ggggcatggg gacggggttc agcctccagg gtccta 46

<210> SEQ ID NO 234
<211> LENGTH: 46
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:

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<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 234

taggttttga ggggcatgag gacggggttc agcctccagg gtccta 46

<210> SEQ ID NO 235
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 235

gaccctggag gctgaacccc gtcca 25

<210> SEQ ID NO 236
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 236

aacgaggcgc acccatcggg gtcaaaac 28

<210> SEQ ID NO 237
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 237

aacgaggcgc actcatgccc ctcaaaac 28

<210> SEQ ID NO 238
<211> LENGTH: 56
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 238

aaggacaaaa tacctgtatt cctcgcctgt ccagggatct gctcttacag attaga 56

<210> SEQ ID NO 239
<211> LENGTH: 56
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 239

aaggacaaaa tacctgtatt ccttgcctgt ccagggatct gctcttacag attaga 56

<210> SEQ ID NO 240
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 240

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taatctgtaa gagcagatcc ctggacagrc c 31

<210> SEQ ID NO 241
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 241

aacgaggcgc acgaggaata caggtatttt gtc 33

<210> SEQ ID NO 242
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 242

aacgaggcgc acaaggaata caggtatttt gtc 33

<210> SEQ ID NO 243
<211> LENGTH: 24
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 243

ggtaaaggtt ggcaaaaaga taac 24

<210> SEQ ID NO 244
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 244

gcgccgaggt cttggggtgg ttacaag 27

<210> SEQ ID NO 245
<211> LENGTH: 37
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (4)
<223> OTHER INFORMATION: The residue at this position is linked to an abasic linker (Cy3).

<400> SEQUENCE: 245

tctcgtctcg gttttccgag actgagacct cggcgcg 37

<210> SEQ ID NO 246
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 246

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cacttgcttc aggaccatat ttctctctc 29

<210> SEQ ID NO 247
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 247

cgcgccgagg acacctttt tagggtgctt tgt 33

<210> SEQ ID NO 248
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 248

aaaatcgatg gtaaaggttg gc 22

<210> SEQ ID NO 249
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 249

agttctgcag taccggattt gc 22

<210> SEQ ID NO 250
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 250

tcgctactag ttgcttagtg 20

<210> SEQ ID NO 251
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 251

gtaaacataa gcaactttag 20

<210> SEQ ID NO 252
<211> LENGTH: 41
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 252

cttgtaacca ccccaagatt atctttttgc caacctttac c 41

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<210> SEQ ID NO 253
<211> LENGTH: 51
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 253

acaaagcacc ctaaaaaagg tgtagagaga aatatggtcc tgaagcaagt g 51

<210> SEQ ID NO 254
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 254

cacgaattcc gaggcgatgc ttccgctc 28

<210> SEQ ID NO 255
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 255

tcgacgtcga ctaacccttg gcggaaagcc 30

<210> SEQ ID NO 256
<211> LENGTH: 23
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 256

gcatcgcctc ggaattcatg gtc 23

<210> SEQ ID NO 257
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 257

caggaggagc tcgttgtgga cctgga 26

<210> SEQ ID NO 258
<211> LENGTH: 2511
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 258

atgaattccg aggcgatgct tccgctcttt gaacccaaag gccgggtcct cctggtggac 60

ggccaccacc tggcctaccg caccttcttc gccctgaagg gcctcaccac gagccggggc 120

gaaccggtgc aggcggtcta cggcttcgcc aagagcctcc tcaaggccct gaaggaggac 180

gggtacaagg ccgtcttcgt ggtctttgac gccaaggccc cctccttccg ccacgaggcc 240

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tacgaggcct acaaggcggg gagggccccg acccccgagg acttcccccg gcagctcgcc 300

ctcatcaagg agctggtgga cctcctgggg tttacccgcc tcgaggtccc cggctacgag 360

gcggacgacg ttctcgccac cctggccaag aaggcggaaa aggaggggta cgaggtgcgc 420

atcctcaccg ccgaccgcga cctctaccaa ctcgtctccg accgcgtcgc cgtcctccac 480

cccgagggcc acctcatcac cccggagtgg ctttgggaga agtacggcct caggccggag 540

cagtgggtgg acttccgcgc cctcgtgggg gacccctccg acaacctccc cggggtcaag 600

ggcatcgggg agaagaccgc cctcaagctc ctcaaggagt ggggaagcct ggaaaacctc 660

ctcaagaacc tggaccgggt aaagccagaa aacgtccggg agaagatcaa ggcccacctg 720

gaagacctca ggctctcctt ggagctctcc cgggtgcgca ccgacctccc cctggaggtg 780

gacctcgccc aggggcggga gcccgaccgg gaggggctta gggccttcct ggagaggctg 840

gagttcggca gcctcctcca cgagttcggc ctcctggagg cccccgcccc cctggaggag 900

gccccctggc ccccgccgga aggggccttc gtgggcttcg tcctctcccg ccccgagccc 960

atgtgggcgg agcttaaagc cctggccgcc tgcagggacg gccgggtgca ccgggcagca 1020

gaccccttgg cggggctaaa ggacctcaag gaggtccggg gcctcctcgc caaggacctc 1080

gccgtcttgg cctcgaggga ggggctagac ctcgtgcccg gggacgaccc catgctcctc 1140

gcctacctcc tggacccctc caacaccacc cccgaggggg tggcgcggcg ctacgggggg 1200

gagtggacgg aggacgccgc ccaccgggcc ctcctctcgg agaggctcca tcggaacctc 1260

cttaagcgcc tcgaggggga ggagaagctc ctttggctct accacgaggt ggaaaagccc 1320

ctctcccggg tcctggccca catggaggcc accggggtac ggcgggacgt ggcctacctt 1380

caggcccttt ccctggagct tgcggaggag atccgccgcc tcgaggagga ggtcttccgc 1440

ttggcgggcc acccttcaa cctcaactcc cgggaccagc tggaaagggt gctctttgac 1500

gagcttaggc ttcccgcctt ggggaagacg caaaagacag gcaagcgctc caccagcgcc 1560

gcggtgctgg aggccctacg ggaggcccac cccatcgtgg agaagatcct ccagcaccgg 1620

gagctcacca agctcaagaa cacctacgtg gacccctcc caagcctcgt ccacccgagg 1680

acgggccgcc tccacacccg cttcaaccag acggccacgg ccacggggag gcttagtagc 1740

tccgacccca acctgcagaa catccccgtc cgcaccccct tgggccagag gatccgccgg 1800

gccttcgtgg ccgaggcggg ttgggcgttg gtggccctgg actatagcca gatagagctc 1860

cgcgtcctcg cccacctctc cggggacgaa aacctgatca gggtcttcca ggaggggaag 1920

gacatccaca cccagaccgc aagctggatg ttcggcgtcc ccccggaggc cgtggacccc 1980

ctgatgcgcc gggcggccaa gacggtgaac ttcggcgtcc tctacggcat gtccgcccat 2040

aggctctccc aggagcttgc catcccctac gaggaggcgg tggcctttat agagcgctac 2100

ttccaaagct tccccaaggt gcgggcctgg atagaaaaga ccctggagga ggggaggaag 2160

cggggctacg tggaaaccct cttcggaaga aggcgctacg tgcccgacct caacgcccgg 2220

gtgaagagcg tcagggaggc cgcggagcgc atggccttca acatgcccgt ccagggcacc 2280

gccgccgacc tcatgaagct cgccatggtg aagctcttcc cccgcctccg ggagatgggg 2340

gcccgcatgc tcctccaggt ccacaacgag ctcctcctgg aggcccccca agcgcgggcc 2400

gaggaggtgg cggctttggc caaggaggcc atggagaagg cctatcccct cgccgtgccc 2460

ctggaggtgg aggtggggat gggggaggac tggctttccg ccaagggtta g 2511

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<210> SEQ ID NO 259
<211> LENGTH: 836
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 259

```
Met Asn Ser Glu Ala Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val
  1               5                  10                  15

Leu Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu
             20                  25                  30

Lys Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly
         35                  40                  45

Phe Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Tyr Lys Ala
     50                  55                  60

Val Phe Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala
 65                  70                  75                  80

Tyr Glu Ala Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro
                 85                  90                  95

Arg Gln Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Phe Thr
            100                 105                 110

Arg Leu Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Thr Leu
        115                 120                 125

Ala Lys Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala
    130                 135                 140

Asp Arg Asp Leu Tyr Gln Leu Val Ser Asp Arg Val Ala Val Leu His
145                 150                 155                 160

Pro Glu Gly His Leu Ile Thr Pro Glu Trp Leu Trp Glu Lys Tyr Gly
                165                 170                 175

Leu Arg Pro Glu Gln Trp Val Asp Phe Arg Ala Leu Val Gly Asp Pro
            180                 185                 190

Ser Asp Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Leu
        195                 200                 205

Lys Leu Leu Lys Glu Trp Gly Ser Leu Glu Asn Leu Leu Lys Asn Leu
    210                 215                 220

Asp Arg Val Lys Pro Glu Asn Val Arg Glu Lys Ile Lys Ala His Leu
225                 230                 235                 240

Glu Asp Leu Arg Leu Ser Leu Glu Leu Ser Arg Val Arg Thr Asp Leu
                245                 250                 255

Pro Leu Glu Val Asp Leu Ala Gln Gly Arg Glu Pro Asp Arg Glu Gly
            260                 265                 270

Leu Arg Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu
        275                 280                 285

Phe Gly Leu Leu Glu Ala Pro Ala Pro Leu Glu Glu Ala Pro Trp Pro
    290                 295                 300

Pro Pro Glu Gly Ala Phe Val Gly Phe Val Leu Ser Arg Pro Glu Pro
305                 310                 315                 320

Met Trp Ala Glu Leu Lys Ala Leu Ala Ala Cys Arg Asp Gly Arg Val
                325                 330                 335

His Arg Ala Ala Asp Pro Leu Ala Gly Leu Lys Asp Leu Lys Glu Val
            340                 345                 350
```

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```
Arg Gly Leu Leu Ala Lys Asp Leu Ala Val Leu Ala Ser Arg Glu Gly
        355                 360                 365

Leu Asp Leu Val Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu
    370                 375                 380

Asp Pro Ser Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly
385                 390                 395                 400

Glu Trp Thr Glu Asp Ala Ala His Arg Ala Leu Leu Ser Glu Arg Leu
                405                 410                 415

His Arg Asn Leu Leu Lys Arg Leu Glu Gly Glu Glu Lys Leu Leu Trp
            420                 425                 430

Leu Tyr His Glu Val Glu Lys Pro Leu Ser Arg Val Leu Ala His Met
        435                 440                 445

Glu Ala Thr Gly Val Arg Arg Asp Val Ala Tyr Leu Gln Ala Leu Ser
    450                 455                 460

Leu Glu Leu Ala Glu Glu Ile Arg Arg Leu Glu Glu Glu Val Phe Arg
465                 470                 475                 480

Leu Ala Gly His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg
                485                 490                 495

Val Leu Phe Asp Glu Leu Arg Leu Pro Ala Leu Gly Lys Thr Gln Lys
            500                 505                 510

Thr Gly Lys Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu
        515                 520                 525

Ala His Pro Ile Val Glu Lys Ile Leu Gln His Arg Glu Leu Thr Lys
    530                 535                 540

Leu Lys Asn Thr Tyr Val Asp Pro Leu Pro Ser Leu Val His Pro Arg
545                 550                 555                 560

Thr Gly Arg Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly
                565                 570                 575

Arg Leu Ser Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr
            580                 585                 590

Pro Leu Gly Gln Arg Ile Arg Arg Ala Phe Val Ala Glu Ala Gly Trp
        595                 600                 605

Ala Leu Val Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala
    610                 615                 620

His Leu Ser Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Lys
625                 630                 635                 640

Asp Ile His Thr Gln Thr Ala Ser Trp Met Phe Gly Val Pro Pro Glu
                645                 650                 655

Ala Val Asp Pro Leu Met Arg Arg Ala Ala Lys Thr Val Asn Phe Gly
            660                 665                 670

Val Leu Tyr Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile
        675                 680                 685

Pro Tyr Glu Glu Ala Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe
    690                 695                 700

Pro Lys Val Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Lys
705                 710                 715                 720

Arg Gly Tyr Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp
                725                 730                 735

Leu Asn Ala Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala
            740                 745                 750
```

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```
Phe Asn Met Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala
        755                 760                 765

Met Val Lys Leu Phe Pro Arg Leu Arg Glu Met Gly Ala Arg Met Leu
    770                 775                 780

Leu Gln Val His Asn Glu Leu Leu Leu Glu Ala Pro Gln Ala Arg Ala
785                 790                 795                 800

Glu Glu Val Ala Ala Leu Ala Lys Glu Ala Met Glu Lys Ala Tyr Pro
                805                 810                 815

Leu Ala Val Pro Leu Glu Val Glu Val Gly Met Gly Glu Asp Trp Leu
            820                 825                 830

Ser Ala Lys Gly
        835
```

<210> SEQ ID NO 260
<211> LENGTH: 777
<212> TYPE: DNA
<213> ORGANISM: Methanobacterium thermoautotrophicum

<400> SEQUENCE: 260

```
atgggagtta aactcaggga tgttgtatca ccccgcagga tacgccttga ggaccttagg     60

ggaagaacgg tcgcagtcga tgcagccaac acactctacc agttcctatc aagcataagg    120

cagagggatg gaacacccct catggattcc aggggtagag taacatcaca cctcagcggc    180

atactctaca ggacggccgc ggtcatggag agggagataa gggtcatata tgtcttcgat    240

ggaaggtccc accacctcaa gggcgagacc gtgagcagga gggctgatat ccggaagaaa    300

tctgaggttg agtggaagag ggcccttgag gaggggggaca ttgacagggc gaaaaaatat    360

gctgtaaggt cctcaaggat gtcctcagaa atactggaga gttcaaagag gctcctggaa    420

cttctgggaa taccctatgt acaggcaccc ggtgaggggg aggctcaggc atcatacatg    480

gttaagatgg gcgatgcatg ggccgtggca tcccaggact atgactgtct cctctttggc    540

gccccaaggg ttgtaaggaa cctcaccctc agcggaaaac ttgaggaccc cgagatcatt    600

gaactggagt ccaccctcag ggaactctca atcagccaca cacagctcgt ggatatggca    660

ctactcgtcg ggactgactt caatgagggt gtaaagggga taggcgcaag gaggggactc    720

aaactcatca gggagaaggg cgacattttc aaagtcatca gggaccttga agcttga       777
```

<210> SEQ ID NO 261
<211> LENGTH: 258
<212> TYPE: PRT
<213> ORGANISM: Methanobacterium thermoautotrophicum

<400> SEQUENCE: 261

```
Met Gly Val Lys Leu Arg Asp Val Val Ser Pro Arg Arg Ile Arg Leu
  1               5                  10                  15

Glu Asp Leu Arg Gly Arg Thr Val Ala Val Asp Ala Ala Asn Thr Leu
             20                  25                  30

Tyr Gln Phe Leu Ser Ser Ile Arg Gln Arg Asp Gly Thr Pro Leu Met
         35                  40                  45

Asp Ser Arg Gly Arg Val Thr Ser His Leu Ser Gly Ile Leu Tyr Arg
     50                  55                  60

Thr Ala Ala Val Met Glu Arg Glu Ile Arg Val Ile Tyr Val Phe Asp
 65                  70                  75                  80

Gly Arg Ser His His Leu Lys Gly Glu Thr Val Ser Arg Arg Ala Asp
```

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```
                85                  90                  95

Ile Arg Lys Lys Ser Glu Val Glu Trp Lys Arg Ala Leu Glu Glu Gly
            100                 105                 110

Asp Ile Asp Arg Ala Lys Lys Tyr Ala Val Arg Ser Ser Arg Met Ser
        115                 120                 125

Ser Glu Ile Leu Glu Ser Ser Lys Arg Leu Leu Glu Leu Leu Gly Ile
    130                 135                 140

Pro Tyr Val Gln Ala Pro Gly Glu Gly Glu Ala Gln Ala Ser Tyr Met
145                 150                 155                 160

Val Lys Met Gly Asp Ala Trp Ala Val Ala Ser Gln Asp Tyr Asp Cys
                165                 170                 175

Leu Leu Phe Gly Ala Pro Arg Val Val Arg Asn Leu Thr Leu Ser Gly
            180                 185                 190

Lys Leu Glu Asp Pro Glu Ile Ile Glu Leu Glu Ser Thr Leu Arg Glu
        195                 200                 205

Leu Ser Ile Ser His Thr Gln Leu Val Asp Met Ala Leu Leu Val Gly
    210                 215                 220

Thr Asp Phe Asn Glu Gly Val Lys Gly Ile Gly Ala Arg Arg Gly Leu
225                 230                 235                 240

Lys Leu Ile Arg Glu Lys Gly Asp Ile Phe Lys Val Ile Arg Asp Leu
                245                 250                 255

Glu Ala
```

<210> SEQ ID NO 262
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 262

gggtgttccc atgggagtta aactcagg 28

<210> SEQ ID NO 263
<211> LENGTH: 22
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 263

ctgaattctg cagaaaaagg gg 22

<210> SEQ ID NO 264
<211> LENGTH: 987
<212> TYPE: DNA
<213> ORGANISM: Methanobacterium thermoautotrophicum

<400> SEQUENCE: 264

atgggagtta aactcaggga tgttgtatca ccccgcagga tacgccttga ggaccttagg 60

ggaagaacgg tcgcagtcga tgcagccaac acactctacc agttcctatc aagcataagg 120

cagagggatg gaacacccct catggattcc aggggtagag taacatcaca cctcagcggc 180

atactctaca ggacggccgc ggtcatggag agggagataa gggtcatata tgtcttcgat 240

ggaaggtccc accacctcaa gggcgagacc gtgagcagga gggctgatat ccggaagaaa 300

-continued

tctgaggttg agtggaagag ggcccttgag gaggggggaca ttgacagggc gagaaaatat 360

gctgtaaggt cctcaaggat gtcctcagaa atactggaga gttcaaagag gctcctggaa 420

cttctgggaa taccctatgt acaggcaccc ggtgaggggg aggctcaggc atcatacatg 480

gttaagatgg gcgatgcatg ggccgtggca tcccaggact atgactgtct cctctttggc 540

gccccaaggg ttgtaaggaa ggtcaccctc agcggaaaac ttgaggaccc ccacatcatt 600

gaactggagt ccaccctcag ggccctctca atcagccaca cacagctcgt ggatatggca 660

ctactcgtcg ggactgactt caatgagggt gtaaaggggt atggcgcaag gaggggactc 720

aaactcatca gggagaaggg cgacattttc aaagtcatca gggaccttga agctgacata 780

ggtggcgacc cccaggtcct caggaggatc tttctggagc cagaggtttc agaggactat 840

gagatcaggt ggagaaaacc tgacgtggaa ggtgttatcg agttcctgtg cactgaacac 900

ggcttttcag aggaccgtgt gagggatgca cttaaaaaat ttgagggtgc atcctccacc 960

cagaagagcc tggaggactg gttctga 987

<210> SEQ ID NO 265
<211> LENGTH: 328
<212> TYPE: PRT
<213> ORGANISM: Methanobacterium thermoautotrophicum

<400> SEQUENCE: 265

Met Gly Val Lys Leu Arg Asp Val Val Ser Pro Arg Arg Ile Arg Leu
1 5 10 15

Glu Asp Leu Arg Gly Arg Thr Val Ala Val Asp Ala Ala Asn Thr Leu
20 25 30

Tyr Gln Phe Leu Ser Ser Ile Arg Gln Arg Asp Gly Thr Pro Leu Met
35 40 45

Asp Ser Arg Gly Arg Val Thr Ser His Leu Ser Gly Ile Leu Tyr Arg
50 55 60

Thr Ala Ala Val Met Glu Arg Glu Ile Arg Val Ile Tyr Val Phe Asp
65 70 75 80

Gly Arg Ser His His Leu Lys Gly Glu Thr Val Ser Arg Arg Ala Asp
85 90 95

Ile Arg Lys Lys Ser Glu Val Glu Trp Lys Arg Ala Leu Glu Glu Gly
100 105 110

Asp Ile Asp Arg Ala Arg Lys Tyr Ala Val Arg Ser Ser Arg Met Ser
115 120 125

Ser Glu Ile Leu Glu Ser Ser Lys Arg Leu Leu Glu Leu Leu Gly Ile
130 135 140

Pro Tyr Val Gln Ala Pro Gly Glu Gly Glu Ala Gln Ala Ser Tyr Met
145 150 155 160

Val Lys Met Gly Asp Ala Trp Ala Val Ala Ser Gln Asp Tyr Asp Cys
165 170 175

Leu Leu Phe Gly Ala Pro Arg Val Val Arg Lys Val Thr Leu Ser Gly
180 185 190

Lys Leu Glu Asp Pro His Ile Ile Glu Leu Glu Ser Thr Leu Arg Ala
195 200 205

Leu Ser Ile Ser His Thr Gln Leu Val Asp Met Ala Leu Leu Val Gly
210 215 220

Thr Asp Phe Asn Glu Gly Val Lys Gly Tyr Gly Ala Arg Arg Gly Leu
225 230 235 240

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Lys Leu Ile Arg Glu Lys Gly Asp Ile Phe Lys Val Ile Arg Asp Leu
245 250 255

Glu Ala Asp Ile Gly Gly Asp Pro Gln Val Leu Arg Arg Ile Phe Leu
260 265 270

Glu Pro Glu Val Ser Glu Asp Tyr Glu Ile Arg Trp Arg Lys Pro Asp
275 280 285

Val Glu Gly Val Ile Glu Phe Leu Cys Thr Glu His Gly Phe Ser Glu
290 295 300

Asp Arg Val Arg Asp Ala Leu Lys Lys Phe Glu Gly Ala Ser Ser Thr
305 310 315 320

Gln Lys Ser Leu Glu Asp Trp Phe
325

<210> SEQ ID NO 266
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 266

tgtggaattg tgagcgg 17

<210> SEQ ID NO 267
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 267

tggaggctct ccatcaaaaa c 21

<210> SEQ ID NO 268
<211> LENGTH: 296
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 268

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatggga gtgcagtttg 60

gtgattttat tccaaaaaat attatctcct ttgaagattt aaaagggaaa aaagtagcta 120

ttgatggaat gaatgcatta tatcagtttt taacatctat acgtttgaga gatggttctc 180

cattgagaaa tagaaaagga gagataacct cagcatataa cggagttttt tataaaacca 240

tacatttgtt agagaatgat ataactccaa tctgggtttt tgatggagag cctcca 296

<210> SEQ ID NO 269
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 269

taatctgtat caggctg 17

-continued

<210> SEQ ID NO 270
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 270

gtttttgatg gagagcctcc a 21

<210> SEQ ID NO 271
<211> LENGTH: 889
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 271

gtttttgatg gagagcctcc agaattcaaa aagaaagagc tcgaaaaaag aagagaagcg 60

agagaggaag ctgaagaaaa gtggagagaa gcacttgaaa aaggagagat agaggaagca 120

agaaaatatg cccaaagagc aaccagggta aatgaaatgc tcatcgagga tgcaaaaaaa 180

ctcttagagc ttatgggaat tcctatagtt caagcaccta gcgagggaga ggcccaagct 240

gcatatatgg ccgcaaaggg gagcgtgtat gcatcggcta gtcaagatta cgattcccta 300

ctttttggag ctccaagact tgttagaaac ttaacaataa caggaaaaag aaagttgcct 360

gggaaaaatg tctacgtcga gataaagccc gagttgataa ttttggagga agtactcaag 420

gaattaaagc taacaagaga aaagctcatt gaactagcaa tcctcgttgg aacagactac 480

aacccaggag gaataaaggg cataggcctt aaaaaagctt tagagattgt tagacactca 540

aaagatccgc tagcaaagtt ccaaaagcaa agcgatgtgg atttatatgc aataaaagag 600

ttcttcctaa acccaccagt cacagataac tacaatttag tgtggagaga tcccgacgaa 660

gagggaatac taaagttctt atgtgacgag catgacttta gtgaggaaag agtaaagaat 720

ggattagaga ggcttaagaa ggcaatcaaa agtggaaaac aatcaaccct tgaaagttgg 780

ttcaagagat aaccttaaag tctattgcaa tgttatactg acgcgctgca ggcatgcaag 840

cttggctgtt ttggcggatg agagaagatt ttcagcctga tacagatta 889

<210> SEQ ID NO 272
<211> LENGTH: 1164
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 272

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatggga gtgcagtttg 60

gtgattttat tccaaaaaat attatctcct ttgaagattt aaaagggaaa aaagtagcta 120

ttgatggaat gaatgcatta tatcagtttt taacatctat acgtttgaga gatggttctc 180

cattgagaaa tagaaaagga gagataacct cagcatataa cggagttttt tataaaacca 240

tacatttgtt agagaatgat ataactccaa tctgggtttt tgatggagag cctccagaat 300

tcaaaaagaa agagctcgaa aaaagaagag aagcgagaga ggaagctgaa gaaaagtgga 360

gagaagcact tgaaaaagga gagatagagg aagcaagaaa atatgcccaa agagcaacca 420

gggtaaatga aatgctcatc gaggatgcaa aaaaactctt agagcttatg ggaattccta 480

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tagttcaagc acctagcgag ggagaggccc aagctgcata tatggccgca aaggggagcg 540

tgtatgcatc ggctagtcaa gattacgatt ccctactttt tggagctcca agacttgtta 600

gaaacttaac aataacagga aaaagaaagt tgcctgggaa aaatgtctac gtcgagataa 660

agcccgagtt gataattttg gaggaagtac tcaaggaatt aaagctaaca agagaaaagc 720

tcattgaact agcaatcctc gttggaacag actacaaccc aggaggaata aagggcatag 780

gccttaaaaa agctttagag attgttagac actcaaaaga tccgctagca aagttccaaa 840

agcaaagcga tgtggattta tatgcaataa aagagttctt cctaaaccca ccagtcacag 900

ataactacaa tttagtgtgg agagatcccg acgaagaggg aatactaaag ttcttatgtg 960

acgagcatga ctttagtgag gaaagagtaa agaatggatt agagaggctt aagaaggcaa 1020

tcaaaagtgg aaaacaatca acccttgaaa gttggttcaa gagataacct taaagtctat 1080

tgcaatgtta tactgacgcg ctgcaggcat gcaagcttgg ctgttttggc ggatgagaga 1140

agattttcag cctgatacag atta 1164

<210> SEQ ID NO 273
<211> LENGTH: 296
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 273

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatgggt gtcccaattg 60

gtgagattat accaagaaaa gaaattgagt tagaaaacct atacgggaaa aaaatcgcaa 120

tcgacgctct taatgcaatc taccaatttt tgtccacaat aagacagaaa gatggaactc 180

cacttatgga ttcaaagggt agaataacct cccacctaag cgggctcttt tacaggacaa 240

taaacctaat ggaggctgga ataaaacctg tgtatgtttt tgatggagag cctcca 296

<210> SEQ ID NO 274
<211> LENGTH: 840
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 274

gtttttgatg gagagcctcc aaagttaaag gagaaaacaa ggaaagttag gagagagatg 60

aaagagaaag ctgaacttaa gatgaaagag gcaattaaaa aggaggattt tgaagaagct 120

gctaagtatg caaagagggt tagctatcta actccgaaaa tggttgaaaa ctgcaaatat 180

ttgttaagtt tgatgggcat tccgtatgtt gaagctccct ctgagggaga ggcacaagca 240

agctatatgg caaagaaggg agatgtttgg gcagttgtaa gtcaagatta tgatgccttg 300

ttatatggag ctccgagagt tgttagaaat ttaacaacta caaaggagat gccagaactt 360

attgaattaa atgaggtttt agaggattta agaatttctt tggatgattt gatagatata 420

gccatattta tgggaactga ctataatcca ggaggagtta aaggaatagg atttaaaagg 480

gcttatgaat tggttagaag tggtgtagct aaggatgttt tgaaaaaaga ggttgaatac 540

tacgatgaga ttaagaggat atttaaagag ccaaaggtta ccgataacta ttcattaagc 600

ctaaaattgc cagataaaga gggaattata aaattcttag ttgatgaaaa tgactttaat 660

-continued

tatgataggg ttaaaaagca tgttgataaa ctctataact taattgcaaa caaaactaag 720

caaaaaacat tagatgcatg gtttaaataa tttatataat tttgtgggat gtcgacctgc 780

aggcatgcaa gcttggctgt tttggcggat gagagaagat ttcagcctg atacagatta 840

<210> SEQ ID NO 275
<211> LENGTH: 1115
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 275

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatgggt gtcccaattg 60

gtgagattat accaagaaaa gaaattgagt tagaaaacct atacgggaaa aaaatcgcaa 120

tcgacgctct taatgcaatc taccaatttt tgtccacaat aagacagaaa gatggaactc 180

cacttatgga ttcaaagggt agaataacct cccacctaag cgggctcttt tacaggacaa 240

taaacctaat ggaggctgga ataaaacctg tgtatgtttt tgatggagag cctccaaagt 300

taaaggagaa aacaaggaaa gttaggagag agatgaaaga gaaagctgaa cttaagatga 360

aagaggcaat taaaaaggag gattttgaag aagctgctaa gtatgcaaag agggttagct 420

atctaactcc gaaaatggtt gaaaactgca aatatttgtt aagtttgatg ggcattccgt 480

atgttgaagc tccctctgag ggagaggcac aagcaagcta tatggcaaag aagggagatg 540

tttgggcagt tgtaagtcaa gattatgatg ccttgttata tggagctccg agagttgtta 600

gaaatttaac aactacaaag gagatgccag aacttattga attaaatgag gttttagagg 660

atttaagaat ttctttggat gatttgatag atatagccat atttatggga actgactata 720

atccaggagg agttaaagga ataggattta aaagggctta tgaattggtt agaagtggtg 780

tagctaagga tgttttgaaa aaagaggttg aatactacga tgagattaag aggatattta 840

aagagccaaa ggttaccgat aactattcat taagcctaaa attgccagat aaagagggaa 900

ttataaaatt cttagttgat gaaaatgact ttaattatga tagggttaaa aagcatgttg 960

ataaactcta taacttaatt gcaaacaaaa ctaagcaaaa aacattagat gcatggttta 1020

aataatttat ataattttgt gggatgtcga cctgcaggca tgcaagcttg gctgttttgg 1080

cggatgagag aagattttca gcctgataca gatta 1115

<210> SEQ ID NO 276
<211> LENGTH: 386
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 276

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatgggt gtcccaattg 60

gtgagattat accaagaaaa gaaattgagt tagaaaacct atacgggaaa aaaatcgcaa 120

tcgacgctct taatgcaatc taccaatttt tgtccacaat aagacagaaa gatggaactc 180

cacttatgga ttcaaagggt agaataacct cccacctaag cgggctcttt tacaggacaa 240

taaacctaat ggaggctgga ataaaacctg tgtatgtttt tgatggagaa cctccagaat 300

tcaaaaagaa agagctcgaa aaaagaagag aagcgagaga ggaagctgaa gaaaagtgga 360

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gagaagcact tgaaaaagga gagata 386

<210> SEQ ID NO 277
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 277

tacttagcag cttcttctat ctctcctttt tca 33

<210> SEQ ID NO 278
<211> LENGTH: 668
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 278

gaagaagctg ctaagtatgc aaagagggtt agctatctaa ctccgaaaat ggttgaaaac 60

tgcaaatatt tgttaagttt gatgggcatt ccgtatgttg aagctccctc tgagggagag 120

gcacaagcaa gctatatggc aaagaaggga gatgtttggg cagttgtaag tcaagattat 180

gatgccttgt tatatggagc tccgagagtt gttagaaatt taacaactac aaaggagatg 240

ccagaactta ttgaattaaa tgaggtttta gaggatttaa gaatttcttt ggatgatttg 300

atagatatag ccatatttat gggaactgac tataatccag gaggagttaa aggaatagga 360

tttaaaaggg cttatgaatt ggttagaagt ggtgtagcta aggatgtttt gaaaaaagag 420

gttgaatact acgatgagat taagaggata tttaaagagc caaaggttac cgataactat 480

tcattaagcc taaaattgcc agataaagag ggaattataa aattcttagt tgatgaaaat 540

gactttaatt atgatagggt taaaaagcat gttgataaac tctataactt aattgcaaac 600

aaaactaagc aaaaaacatt agatgcatgg tttaaacacc accaccacca ccactaactg 660

cagcggta 668

<210> SEQ ID NO 279
<211> LENGTH: 53
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 279

taccgctgca gttagtggtg gtggtggtgg tgtttaaacc atgcatctaa tgt 53

<210> SEQ ID NO 280
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 280

gaagaagctg ctaagta 17

<210> SEQ ID NO 281
<211> LENGTH: 1054

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<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 281

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatgggt gtcccaattg 60

gtgagattat accaagaaaa gaaattgagt tagaaaacct atacgggaaa aaaatcgcaa 120

tcgacgctct taatgcaatc taccaatttt tgtccacaat aagacagaaa gatggaactc 180

cacttatgga ttcaaagggt agaataacct cccacctaag cgggctcttt tacaggacaa 240

taaacctaat ggaggctgga ataaaacctg tgtatgtttt tgatggagaa cctccagaat 300

tcaaaaagaa agagctcgaa aaaagaagag aagcgagaga ggaagctgaa gaaaagtgga 360

gagaagcact tgaaaaagga gagatagaag aagctgctaa gtatgcaaag agggttagct 420

atctaactcc gaaaatggtt gaaaactgca aatatttgtt aagtttgatg ggcattccgt 480

atgttgaagc tccctctgag ggagaggcac aagcaagcta tatggcaaag aagggagatg 540

tttgggcagt tgtaagtcaa gattatgatg ccttgttata tggagctccg agagttgtta 600

gaaatttaac aactacaaag gagatgccag aacttattga attaaatgag gttttagagg 660

atttaagaat ttctttggat gatttgatag atatagccat atttatggga actgactata 720

atccaggagg agttaaagga ataggattta aaagggctta tgaattggtt agaagtggtg 780

tagctaagga tgttttgaaa aaagaggttg aatactacga tgagattaag aggatattta 840

aagagccaaa ggttaccgat aactattcat taagcctaaa attgccagat aaagagggaa 900

ttataaaatt cttagttgat gaaaatgact ttaattatga tagggttaaa aagcatgttg 960

ataaactcta taacttaatt gcaaacaaaa ctaagcaaaa aacattagat gcatggttta 1020

aacaccacca ccaccaccac taactgcagc ggta 1054

<210> SEQ ID NO 282
<211> LENGTH: 514
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 282

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatggga gtgcagtttg 60

gtgattttat tccaaaaaat attatctcct ttgaagattt aaaagggaaa aaagtagcta 120

ttgatggaat gaatgcatta tatcagtttt taacatctat acgtttgaga gatggttctc 180

cattgagaaa tagaaaagga gagataacct cagcatataa cggagttttt tataaaacca 240

tacatttgtt agagaatgat ataactccaa tctgggtttt tgatggtgag ccaccaaagt 300

taaaggagaa aacaaggaaa gttaggagag agatgaaaga gaaagctgaa cttaagatga 360

aagaggcaat taaaaaggag gattttgaag aagctgctaa gtatgcaaag agggttagct 420

atctaactcc gaaaatggtt gaaaactgca aatatttgtt aagtttgatg ggcattccgt 480

atgttgaagc tccctctgag ggagaggccc aagc 514

<210> SEQ ID NO 283
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence

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<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 283

gcttgggcct ctccctc 17

<210> SEQ ID NO 284
<211> LENGTH: 667
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 284

gagggagagg cccaagctgc atatatggcc gcaaagggga gcgtgtatgc atcggctagt 60

caagattacg attccctact ttttggagct ccaagacttg ttagaaactt aacaataaca 120

ggaaaaagaa agttgcctgg gaaaaatgtc tacgtcgaga taaagcccga gttgataatt 180

ttggaggaag tactcaagga attaaagcta acaagagaaa agctcattga actagcaatc 240

ctcgttggaa cagactacaa cccaggagga ataaagggca taggccttaa aaaagcttta 300

gagattgtta gacactcaaa agatccgcta gcaaagttcc aaaagcaaag cgatgtggat 360

ttatatgcaa taaaagagtt cttcctaaac ccaccagtca cagataacta caatttagtg 420

tggagagatc ccgacgaaga gggaatacta aagttcttat gtgacgagca tgactttagt 480

gaggaaagag taaagaatgg attagagagg cttaagaagg caatcaaaag tggaaaacaa 540

tcaacccttg aaagttggtt caagagataa ccttaaagtc tattgcaatg ttatactgac 600

gcgctgcagg catgcaagct tggctgtttt ggcggatgag agaagatttt cagcctgata 660

cagatta 667

<210> SEQ ID NO 285
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 285

gagggagagg cccaagc 17

<210> SEQ ID NO 286
<211> LENGTH: 1164
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 286

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatggga gtgcagtttg 60

gtgattttat tccaaaaaat attatctcct ttgaagattt aaaagggaaa aaagtagcta 120

ttgatggaat gaatgcatta tatcagtttt taacatctat acgtttgaga gatggttctc 180

cattgagaaa tagaaaagga gagataacct cagcatataa cggagttttt tataaaacca 240

tacatttgtt agagaatgat ataactccaa tctgggtttt tgatggtgag ccaccaaagt 300

taaaggagaa aacaaggaaa gttaggagag agatgaaaga gaaagctgaa cttaagatga 360

aagaggcaat taaaaaggag gattttgaag aagctgctaa gtatgcaaag agggttagct 420

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atctaactcc gaaaatggtt gaaaactgca aatatttgtt aagtttgatg ggcattccgt 480

atgttgaagc tccctctgag ggagaggccc aagctgcata tatggccgca aaggggagcg 540

tgtatgcatc ggctagtcaa gattacgatt ccctactttt tggagctcca agacttgtta 600

gaaacttaac aataacagga aaaagaaagt tgcctgggaa aaatgtctac gtcgagataa 660

agcccgagtt gataattttg gaggaagtac tcaaggaatt aaagctaaca agagaaaagc 720

tcattgaact agcaatcctc gttggaacag actacaaccc aggaggaata aagggcatag 780

gccttaaaaa agctttagag attgttagac actcaaaaga tccgctagca aagttccaaa 840

agcaaagcga tgtggattta tatgcaataa aagagttctt cctaaaccca ccagtcacag 900

ataactacaa tttagtgtgg agagatcccg acgaagaggg aatactaaag ttcttatgtg 960

acgagcatga ctttagtgag gaaagagtaa agaatggatt agagaggctt aagaaggcaa 1020

tcaaaagtgg aaaacaatca acccttgaaa gttggttcaa gagataacct taaagtctat 1080

tgcaatgtta tactgacgcg ctgcaggcat gcaagcttgg ctgttttggc ggatgagaga 1140

agattttcag cctgatacag atta 1164

<210> SEQ ID NO 287
<211> LENGTH: 514
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 287

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatgggt gtcccaattg 60

gtgagattat accaagaaaa gaaattgagt tagaaaacct atacgggaaa aaaatcgcaa 120

tcgacgctct taatgcaatc taccaatttt tgtccacaat aagacagaaa gatggaactc 180

cacttatgga ttcaaagggt agaataacct cccacctaag cgggctcttt tacaggacaa 240

taaacctaat ggaggctgga ataaaacctg tgtatgtttt tgatggagaa cctccagaat 300

tcaaaaagaa agagctcgaa aaaagaagag aagcgagaga ggaagctgaa gaaaagtgga 360

gagaagcact tgaaaaagga gagatagagg aagcaagaaa atatgcccaa agagcaacca 420

gggtaaatga aatgctcatc gaggatgcaa aaaaactctt agagcttatg ggaattccta 480

tagttcaagc acctagcgag ggagaggccc aagc 514

<210> SEQ ID NO 288
<211> LENGTH: 618
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 288

gagggagagg cccaagcaag ctatatggca aagaagggag atgtttgggc agttgtaagt 60

caagattatg atgccttgtt atatggagct ccgagagttg ttagaaattt aacaactaca 120

aaggagatgc cagaacttat tgaattaaat gaggttttag aggatttaag aatttctttg 180

gatgatttga tagatatagc catatttatg ggaactgact ataatccagg aggagttaaa 240

ggaataggat ttaaaagggc ttatgaattg gttagaagtg gtgtagctaa ggatgttttg 300

aaaaaagagg ttgaatacta cgatgagatt aagaggatat ttaaagagcc aaaggttacc 360

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gataactatt cattaagcct aaaattgcca gataaagagg gaattataaa attcttagtt 420

gatgaaaatg actttaatta tgatagggtt aaaaagcatg ttgataaact ctataactta 480

attgcaaaca aaactaagca aaaaacatta gatgcatggt ttaaataatt tatataattt 540

tgtgggatgt cgacctgcag gcatgcaagc ttggctgttt tggcggatga gagaagattt 600

tcagcctgat acagatta 618

<210> SEQ ID NO 289
<211> LENGTH: 1115
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 289

tgtggaattg tgagcggata acaatttcac acaggaaaca gaccatgggt gtcccaattg 60

gtgagattat accaagaaaa gaaattgagt tagaaaacct atacgggaaa aaaatcgcaa 120

tcgacgctct taatgcaatc taccaatttt tgtccacaat aagacagaaa gatggaactc 180

cacttatgga ttcaaagggt agaataacct cccacctaag cgggctcttt tacaggacaa 240

taaacctaat ggaggctgga ataaaacctg tgtatgtttt tgatggagaa cctccagaat 300

tcaaaaagaa agagctcgaa aaaagaagag aagcgagaga ggaagctgaa gaaaagtgga 360

gagaagcact tgaaaaagga gagatagagg aagcaagaaa atatgcccaa agagcaacca 420

gggtaaatga aatgctcatc gaggatgcaa aaaaactctt agagcttatg ggaattccta 480

tagttcaagc acctagcgag ggagaggccc aagcaagcta tatggcaaag aagggagatg 540

tttgggcagt tgtaagtcaa gattatgatg ccttgttata tggagctccg agagttgtta 600

gaaatttaac aactacaaag gagatgccag aacttattga attaaatgag gttttagagg 660

atttaagaat ttctttggat gatttgatag atatagccat atttatggga actgactata 720

atccaggagg agttaaagga ataggattta aaagggctta tgaattggtt agaagtggtg 780

tagctaagga tgttttgaaa aaagaggttg aatactacga tgagattaag aggatattta 840

aagagccaaa ggttaccgat aactattcat taagcctaaa attgccagat aaagagggaa 900

ttataaaatt cttagttgat gaaaatgact ttaattatga tagggttaaa aagcatgttg 960

ataaactcta taacttaatt gcaaacaaaa ctaagcaaaa aacattagat gcatggttta 1020

aataatttat ataattttgt gggatgtcga cctgcaggca tgcaagcttg gctgttttgg 1080

cggatgagag aagattttca gcctgataca gatta 1115

<210> SEQ ID NO 290
<211> LENGTH: 350
<212> TYPE: DNA
<213> ORGANISM: Escherichia coli

<400> SEQUENCE: 290

agagtttgat catggctcag attgaacgct ggcggcaggc ctaacacatg caagtcgaac 60

ggtaacagga agaagcttgc ttctttgctg acgagtggcg gacgggtgag taatgtctgg 120

gaaactgcct gatggagggg gataactact ggaaacggta gctaataccg cataacgtcg 180

caagaccaaa gaggggacc ttcgggcctc ttgccatcgg atgtgcccag atgggattag 240

ctagtaggtg gggtaacggc tcacctaggc gacgatccct agctggtctg agaggatgac 300

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cagccacact ggaactgaga cacggtccag actcctacgg gaggcagcag 350

<210> SEQ ID NO 291
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 291

agagtttgat cctggctcag 20

<210> SEQ ID NO 292
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 292

ctgctgcctc ccgtaggagt 20

<210> SEQ ID NO 293
<211> LENGTH: 34
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 293

ttttcgctgt ctcgctgaaa gcgagacagc gttt 34

<210> SEQ ID NO 294
<211> LENGTH: 59
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 294

ttttcgctgt ctcgctgaaa gcgagacagc gaaagacgct cgtgaaacga gcgtctttg 59

<210> SEQ ID NO 295
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (27)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.
<220> FEATURE:
<223> OTHER INFORMATION: Synthetic

<400> SEQUENCE: 295

atctctagca ctgctgtntt ygayggn 27

<210> SEQ ID NO 296
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature

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<222> LOCATION: (22)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (28)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.

<400> SEQUENCE: 296

gatctctagc actgctgarg gngargcnca r 31

<210> SEQ ID NO 297
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 297

gatctctagc actgctcarg aytaygay 28

<210> SEQ ID NO 298
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (20)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (26)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.

<400> SEQUENCE: 298

cttaaggtag gactacytgn gcytcnccyt c 31

<210> SEQ ID NO 299
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 299

ttaaggtagg actacytcrt aytcytgrct 30

<210> SEQ ID NO 300
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (28)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.

<400> SEQUENCE: 300

ttaaggtagg actacytcrt aytcytgnga 30

<210> SEQ ID NO 301
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence

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<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (25)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (28)
<223> OTHER INFORMATION: n at this position can be a, c, t, or g.

<400> SEQUENCE: 301

ttaaggtagg actacrttrw artcngtncc 30

<210> SEQ ID NO 302
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 302

gatctctagg actgct 16

<210> SEQ ID NO 303
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 303

cttaaggtag gactac 16

<210> SEQ ID NO 304
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Acidianus ambivalens

<400> SEQUENCE: 304

gccatgtcat tagttaacct agttgcc 27

<210> SEQ ID NO 305
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Acidianus ambivalens

<400> SEQUENCE: 305

ggcaatggga attccagtag tgcaagc 27

<210> SEQ ID NO 306
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Acidianus brierleyi

<400> SEQUENCE: 306

gccatctcgt ttgtaagtct ggttgcc 27

<210> SEQ ID NO 307
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Acidianus brierleyi

<400> SEQUENCE: 307

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cttacaaacg agatggcaga cgaagg 26

<210> SEQ ID NO 308
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 308

ttgctgtgca tacttcctcg cttcagc 27

<210> SEQ ID NO 309
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 309

ccgaggtgat agacttagaa tacaacc 27

<210> SEQ ID NO 310
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 310

tatcgcagcg atccacttct cctctgc 27

<210> SEQ ID NO 311
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 311

cttaaacggc aacctgagaa ggcttgg 27

<210> SEQ ID NO 312
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 312

ctatctcctt ctgcttgaaa acaggagg 28

<210> SEQ ID NO 313
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 313

acaagggaac agctcgtcga tatcgcg 27

<210> SEQ ID NO 314
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 314

tgctgcctcc tccttaacgg ctttcc 26

<210> SEQ ID NO 315
<211> LENGTH: 27

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<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 315

ccggagctca tagagctcga caaactc 27

<210> SEQ ID NO 316
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 316

tctcgcagcc tcctccctga caaccc 26

<210> SEQ ID NO 317
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 317

ctcgataaac tgctttcaaa gctgggc 27

<210> SEQ ID NO 318
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Methanococcus igneus

<400> SEQUENCE: 318

cctctttgcg tatttttgca tctcatc 27

<210> SEQ ID NO 319
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Methanococcus igneus

<400> SEQUENCE: 319

cttaacaaag gacatcgtag agaactc 27

<210> SEQ ID NO 320
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 320

cagtttctcc atcgcctcct ccttcc 26

<210> SEQ ID NO 321
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 321

ttggtggaag acgcgaagag gctgttg 27

<210> SEQ ID NO 322
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Pyrobaculum aerophilum

<400> SEQUENCE: 322

catggccttc tcacgcgtct tcctcc 26

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<210> SEQ ID NO 323
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Pyrobaculum aerophilum

<400> SEQUENCE: 323

ctgagctata tgggcgtacc ctgggt 26

<210> SEQ ID NO 324
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 324

cccatggcct ccagcagctt cttagc 26

<210> SEQ ID NO 325
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Pyrodictium brockii

<400> SEQUENCE: 325

aacctcgcta taacgggtaa gaggaag 27

<210> SEQ ID NO 326
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Sulfolobus solfataricus

<400> SEQUENCE: 326

agcttgaact acaggtatac ccatagc 27

<210> SEQ ID NO 327
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Sulfolobus solfataricus

<400> SEQUENCE: 327

gctatgggta tacctgtagt tcaagct 27

<210> SEQ ID NO 328
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 328

ctgcgcttcc tccctagcct cagctc 26

<210> SEQ ID NO 329
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 329

atgggcatcc catgggtgca ggctcc 26

<210> SEQ ID NO 330
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Thermococcus gorgonarius

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<400> SEQUENCE: 330

aggttcctta caagtctcgg cgcgcc 26

<210> SEQ ID NO 331
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Thermococcus gorgonarius

<400> SEQUENCE: 331

agctcggcat agacagggaa aagctg 26

<210> SEQ ID NO 332
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Thermococcus zilligii

<400> SEQUENCE: 332

aggtttctca cgagtttcgg cgcgcc 26

<210> SEQ ID NO 333
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Thermococcus zilligii

<400> SEQUENCE: 333

agcttggcat agaccgggag aaactc 26

<210> SEQ ID NO 334
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Acidianus ambivalens

<400> SEQUENCE: 334

gcaaccatgg gagtagacct tgctgatttg g 31

<210> SEQ ID NO 335
<211> LENGTH: 32
<212> TYPE: DNA
<213> ORGANISM: Acidianus ambivalens

<400> SEQUENCE: 335

ccatgtcgac taaaaccact gatctaaacc gc 32

<210> SEQ ID NO 336
<211> LENGTH: 1056
<212> TYPE: DNA
<213> ORGANISM: Acidianus ambivalens

<400> SEQUENCE: 336

ataggagtag accttgctga tttggtaaaa gaaatcaaaa gagaagttca gctaagtgaa 60

ttaaaaggga agaaagtaag catagatgct tataacgcta tttaccagtt tttgactgca 120

ataagacagc cagatggtac tccactaatg gactcacaag gaagagttac tagtcatctt 180

agtggaatat tttatagaac aataagcctt ttagaagaag gagtaattcc aatttatgta 240

ttcgatggaa aaccaccaga acttaaagct caagaattag aaagaagaag aaaaataaag 300

gaagaagctg agaaaaaatt ggaaaaagcc aaagaagaag gagaaacaaa ggaattaaag 360

aagtattcgc aaatggcaac taggttaact aatgacatgg cagaagaaag taaaaaactt 420

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ttagaggcaa tgggaattcc agtagtgcaa gctccaagtg aaggagaagc tgaggcagcg 480

tatttatgta gtcaagggta tacttgggca gcggctagcc aagattacga ttctttgctt 540

tttggtgcaa ataaattaat tagaaactta acattaactg gaaagaggaa attacctaaa 600

aaagacgtat atgtagaaat taagccagaa cttatagaac ttgaagattt gcttaaaaag 660

ttcggaatta ctagagaaca actagttgat ataggaatat taataggaac tgattatgac 720

cctgacggaa taaagggaat agggccagtt actgctctaa gaataataaa gaaatacgga 780

aatatagaaa aagctgtaga aaaaggagaa ttaccgaaat acattcttga tcttaatatt 840

aatgaaatta gatctatctt tcttaatccg ccagtagtta agcctgaggg ctcgttagat 900

ctaaaagagc ctaatgagga agaaatcaag aaaatcctca tagatgagca taactttagt 960

gaggatagag taactaatgg aatagaaaga ctgattaaag ccggtaagga agctaaagga 1020

gctagtaggc agagcggttt agatcagtgg ttttag 1056

<210> SEQ ID NO 337
<211> LENGTH: 351
<212> TYPE: PRT
<213> ORGANISM: Acidianus ambivalens

<400> SEQUENCE: 337

Ile Gly Val Asp Leu Ala Asp Leu Val Lys Glu Ile Lys Arg Glu Val
1 5 10 15

Gln Leu Ser Glu Leu Lys Gly Lys Lys Val Ser Ile Asp Ala Tyr Asn
20 25 30

Ala Ile Tyr Gln Phe Leu Thr Ala Ile Arg Gln Pro Asp Gly Thr Pro
35 40 45

Leu Met Asp Ser Gln Gly Arg Val Thr Ser His Leu Ser Gly Ile Phe
50 55 60

Tyr Arg Thr Ile Ser Leu Leu Glu Glu Gly Val Ile Pro Ile Tyr Val
65 70 75 80

Phe Asp Gly Lys Pro Pro Glu Leu Lys Ala Gln Glu Leu Glu Arg Arg
85 90 95

Arg Lys Ile Lys Glu Glu Ala Glu Lys Lys Leu Glu Lys Ala Lys Glu
100 105 110

Glu Gly Glu Thr Lys Glu Leu Lys Lys Tyr Ser Gln Met Ala Thr Arg
115 120 125

Leu Thr Asn Asp Met Ala Glu Glu Ser Lys Lys Leu Leu Glu Ala Met
130 135 140

Gly Ile Pro Val Val Gln Ala Pro Ser Glu Gly Glu Ala Glu Ala Ala
145 150 155 160

Tyr Leu Cys Ser Gln Gly Tyr Thr Trp Ala Ala Ala Ser Gln Asp Tyr
165 170 175

Asp Ser Leu Leu Phe Gly Ala Asn Lys Leu Ile Arg Asn Leu Thr Leu
180 185 190

Thr Gly Lys Arg Lys Leu Pro Lys Lys Asp Val Tyr Val Glu Ile Lys
195 200 205

Pro Glu Leu Ile Glu Leu Glu Asp Leu Leu Lys Lys Phe Gly Ile Thr
210 215 220

Arg Glu Gln Leu Val Asp Ile Gly Ile Leu Ile Gly Thr Asp Tyr Asp
225 230 235 240

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```
Pro Asp Gly Ile Lys Gly Ile Gly Pro Val Thr Ala Leu Arg Ile Ile
               245                 250                 255

Lys Lys Tyr Gly Asn Ile Glu Lys Ala Val Glu Lys Gly Glu Leu Pro
            260                 265                 270

Lys Tyr Ile Leu Asp Leu Asn Ile Asn Glu Ile Arg Ser Ile Phe Leu
        275                 280                 285

Asn Pro Pro Val Val Lys Pro Glu Gly Ser Leu Asp Leu Lys Glu Pro
    290                 295                 300

Asn Glu Glu Glu Ile Lys Lys Ile Leu Ile Asp Glu His Asn Phe Ser
305                 310                 315                 320

Glu Asp Arg Val Thr Asn Gly Ile Glu Arg Leu Ile Lys Ala Gly Lys
               325                 330                 335

Glu Ala Lys Gly Ala Ser Arg Gln Ser Gly Leu Asp Gln Trp Phe
            340                 345                 350


<210> SEQ ID NO 338
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Acidianus brierleyi

<400> SEQUENCE: 338

cataccatgg gagtagattt atctgactta g                                  31


<210> SEQ ID NO 339
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Acidianus brierleyi

<400> SEQUENCE: 339

cttggtcgac ttaaaaccat tggtcaagtc cag                                33


<210> SEQ ID NO 340
<211> LENGTH: 1056
<212> TYPE: DNA
<213> ORGANISM: Acidianus brierleyi

<400> SEQUENCE: 340

atcggagtag atttatctga cttagttgaa gacgtaaaag ctgagataaa cttagctgag     60

ttgcgtggga aaaaagtaag tattgatgca tataatgcaa tatatcaatt tttgacagct    120

atacgccaac cagacggtac accacttata gattcacaag gtaaaataac aagccacctt    180

agtggaattt tttatcgaac cattaatcta atggaaaatg gtataatacc gatatatgtt    240

tttgatggaa aaccaccaga gcttaaatct gcagaattac aaagacgtaa aaaaataaaa    300

gaagaagcgg aaaagaagtt agagaaagca aaagaagagg gaaaaactac agagttaaaa    360

aagtattctc aaatggcaac cagacttaca aacgagatgg cagacgaagg aaaaaaattg    420

cttaaaagta tgggtattcc aatagtagaa gcaccgtctg aaggtgaagc ggaatcagca    480

tatattaacg caataggatt aagttttgct actgcaagcc aggattatga ttcactatta    540

tttggtgcga aaaatttgat aagaaactta actataactg gaaaaagaaa attacctaat    600

aaagacatat acgtcgaaat aaaacctgaa agaattgaac tcgaaccact acttaaaaag    660

cttggtataa caagagaaca attaatagat atagcgattt taattggaac agattatgat    720

ccttcaggga taaaaggaat aggccccaag accgcttata ggctaattaa gaaatatgga    780

agaatagaaa aaattattga agcgaatgaa attccaaaga attctattga tttcgatatt    840
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aatcaaataa ggcaactatt tctaaatccg aatgtgaaaa aaccagaaga gaatttagac 900

ttgcaaaatc ctgaagaaca agaaattata gaaattttag taaatcaaca taattttaat 960

gaagaaagag ttaaaagtgc attagaaaga ttaaataaag caataaaaga aactaaaggt 1020

ctctcaagac aaactggact tgaccaatgg ttttaa 1056

<210> SEQ ID NO 341
<211> LENGTH: 351
<212> TYPE: PRT
<213> ORGANISM: Acidianus brierleyi

<400> SEQUENCE: 341

Ile Gly Val Asp Leu Ser Asp Leu Val Glu Asp Val Lys Ala Glu Ile
1 5 10 15

Asn Leu Ala Glu Leu Arg Gly Lys Lys Val Ser Ile Asp Ala Tyr Asn
20 25 30

Ala Ile Tyr Gln Phe Leu Thr Ala Ile Arg Gln Pro Asp Gly Thr Pro
35 40 45

Leu Ile Asp Ser Gln Gly Lys Ile Thr Ser His Leu Ser Gly Ile Phe
50 55 60

Tyr Arg Thr Ile Asn Leu Met Glu Asn Gly Ile Ile Pro Ile Tyr Val
65 70 75 80

Phe Asp Gly Lys Pro Pro Glu Leu Lys Ser Ala Glu Leu Gln Arg Arg
85 90 95

Lys Lys Ile Lys Glu Glu Ala Glu Lys Lys Leu Glu Lys Ala Lys Glu
100 105 110

Glu Gly Lys Thr Thr Glu Leu Lys Lys Tyr Ser Gln Met Ala Thr Arg
115 120 125

Leu Thr Asn Glu Met Ala Asp Glu Gly Lys Lys Leu Leu Lys Ser Met
130 135 140

Gly Ile Pro Ile Val Glu Ala Pro Ser Glu Gly Glu Ala Glu Ser Ala
145 150 155 160

Tyr Ile Asn Ala Ile Gly Leu Ser Phe Ala Thr Ala Ser Gln Asp Tyr
165 170 175

Asp Ser Leu Leu Phe Gly Ala Lys Asn Leu Ile Arg Asn Leu Thr Ile
180 185 190

Thr Gly Lys Arg Lys Leu Pro Asn Lys Asp Ile Tyr Val Glu Ile Lys
195 200 205

Pro Glu Arg Ile Glu Leu Glu Pro Leu Leu Lys Lys Leu Gly Ile Thr
210 215 220

Arg Glu Gln Leu Ile Asp Ile Ala Ile Leu Ile Gly Thr Asp Tyr Asp
225 230 235 240

Pro Ser Gly Ile Lys Gly Ile Gly Pro Lys Thr Ala Tyr Arg Leu Ile
245 250 255

Lys Lys Tyr Gly Arg Ile Glu Lys Ile Ile Glu Ala Asn Glu Ile Pro
260 265 270

Lys Asn Ser Ile Asp Phe Asp Ile Asn Gln Ile Arg Gln Leu Phe Leu
275 280 285

Asn Pro Asn Val Lys Lys Pro Glu Glu Asn Leu Asp Leu Gln Asn Pro
290 295 300

Glu Glu Gln Glu Ile Ile Glu Ile Leu Val Asn Gln His Asn Phe Asn
305 310 315 320

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Glu Glu Arg Val Lys Ser Ala Leu Glu Arg Leu Asn Lys Ala Ile Lys
325 330 335

Glu Thr Lys Gly Leu Ser Arg Gln Thr Gly Leu Asp Gln Trp Phe
340 345 350

<210> SEQ ID NO 342
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Aeropyrum pernix

<400> SEQUENCE: 342

ttagccatgg gagtcaacct tagggag 27

<210> SEQ ID NO 343
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Aeropyrum pernix

<400> SEQUENCE: 343

gtaagtcgac tatccgaacc acatgtcgag 30

<210> SEQ ID NO 344
<211> LENGTH: 1053
<212> TYPE: DNA
<213> ORGANISM: Aeropyrum pernix

<400> SEQUENCE: 344

ttgggagtca accttaggga gttgattcct cccgaggcta ggagggaggt ggagcttagg 60

gctctctcgg ggtatgttct agcgcttgac gcgtataaca tgctctacca gttcctcacc 120

gccatcaggc agcccgacgg cactcccctt ttggataggg agggcagggt tacaagccac 180

ctcagcggcc tgttctacag gaccattaac ctggtggagg agggtattaa gcccgtctac 240

gtcttcgacg ggaagcctcc tgaaatgaag agccgggagg ttgaagagag gcttaggagg 300

aaggcggagg ctgaggcgag gtataggagg gctgtcgagg cgggagaggt tgaggaggct 360

aggaagtacg ctatgatggc tgcgaggctt acgagcgaca tggtggagga gtcgaaggag 420

ctgctggatg ctatggggat gccctgggtt caggcgcctg ccgagggtga ggctcaggca 480

gcctatatgg ctaggaaggg tgatgcatgg gcgacgggga gccaggacta cgatagcctc 540

ctgttcggct cgcctaggct tgtgagaaac ctagccataa caggtcgtag gaagctcccg 600

ggtagggatc agtatgtcga gataaagccg gagatcatag agctcgagcc tctgctcagc 660

aagctgggga taacaaggga gcagttgata gcggtgggta tcctcctcgg cacggactac 720

aaccccggcg gtgtgagggg ttatgggcct aagacagccc taaggcttgt taagagcctg 780

ggagacccga tgaaggtgtt ggcttccgtc ccacgggggg aatatgaccc ggattatctt 840

agaaaggtgt acgagtactt cttgaacccc cccgtcacag acgactacaa gattgagttt 900

aggaagccgg atcaggacaa ggttagggag attcttgtag agaggcacga cttcaatccc 960

gagagggtgg agagggccct cgagaggctg gggaaggctt acagggagaa gctcaggggc 1020

aggcagtcga ggctcgacat gtggttcgga tag 1053

<210> SEQ ID NO 345
<211> LENGTH: 350
<212> TYPE: PRT
<213> ORGANISM: Aeropyrum pernix

-continued

<400> SEQUENCE: 345

```
Leu Gly Val Asn Leu Arg Glu Leu Ile Pro Pro Glu Ala Arg Arg Glu
  1               5                  10                  15

Val Glu Leu Arg Ala Leu Ser Gly Tyr Val Leu Ala Leu Asp Ala Tyr
             20                  25                  30

Asn Met Leu Tyr Gln Phe Leu Thr Ala Ile Arg Gln Pro Asp Gly Thr
         35                  40                  45

Pro Leu Leu Asp Arg Glu Gly Arg Val Thr Ser His Leu Ser Gly Leu
     50                  55                  60

Phe Tyr Arg Thr Ile Asn Leu Val Glu Glu Gly Ile Lys Pro Val Tyr
 65                  70                  75                  80

Val Phe Asp Gly Lys Pro Pro Glu Met Lys Ser Arg Glu Val Glu Glu
                 85                  90                  95

Arg Leu Arg Arg Lys Ala Glu Ala Glu Ala Arg Tyr Arg Arg Ala Val
            100                 105                 110

Glu Ala Gly Glu Val Glu Glu Ala Arg Lys Tyr Ala Met Met Ala Ala
        115                 120                 125

Arg Leu Thr Ser Asp Met Val Glu Glu Ser Lys Glu Leu Leu Asp Ala
    130                 135                 140

Met Gly Met Pro Trp Val Gln Ala Pro Ala Glu Gly Glu Ala Gln Ala
145                 150                 155                 160

Ala Tyr Met Ala Arg Lys Gly Asp Ala Trp Ala Thr Gly Ser Gln Asp
                165                 170                 175

Tyr Asp Ser Leu Leu Phe Gly Ser Pro Arg Leu Val Arg Asn Leu Ala
            180                 185                 190

Ile Thr Gly Arg Arg Lys Leu Pro Gly Arg Asp Gln Tyr Val Glu Ile
        195                 200                 205

Lys Pro Glu Ile Ile Glu Leu Glu Pro Leu Leu Ser Lys Leu Gly Ile
    210                 215                 220

Thr Arg Glu Gln Leu Ile Ala Val Gly Ile Leu Leu Gly Thr Asp Tyr
225                 230                 235                 240

Asn Pro Gly Gly Val Arg Gly Tyr Gly Pro Lys Thr Ala Leu Arg Leu
                245                 250                 255

Val Lys Ser Leu Gly Asp Pro Met Lys Val Leu Ala Ser Val Pro Arg
            260                 265                 270

Gly Glu Tyr Asp Pro Asp Tyr Leu Arg Lys Val Tyr Glu Tyr Phe Leu
        275                 280                 285

Asn Pro Pro Val Thr Asp Asp Tyr Lys Ile Glu Phe Arg Lys Pro Asp
    290                 295                 300

Gln Asp Lys Val Arg Glu Ile Leu Val Glu Arg His Asp Phe Asn Pro
305                 310                 315                 320

Glu Arg Val Glu Arg Ala Leu Glu Arg Leu Gly Lys Ala Tyr Arg Glu
                325                 330                 335

Lys Leu Arg Gly Arg Gln Ser Arg Leu Asp Met Trp Phe Gly
            340                 345                 350
```

<210> SEQ ID NO 346
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 346

-continued

cttaccatgg gcgctgatat aggagagc 28

<210> SEQ ID NO 347
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 347

tggagtcgac ttaaaaccac ctgtccagag 30

<210> SEQ ID NO 348
<211> LENGTH: 1008
<212> TYPE: DNA
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 348

atgggcgctg atataggaga gctcttgaag agggaagaag ttgagataga atacttttca 60

ggaaagaaga ttgcaataga tgcctttaac acgttatacc agttcctagc gacaataaga 120

cagcctgacg gaacaccttt gatggattca aagggtagga taacatctca cctttcagga 180

attctttata gggtttcaaa tatggtggag gtcggaataa agccgatatt tgtttttgat 240

ggagaaccgc ctgagttcaa aaagaaggag attgagagaa ggagaaaaat tagggaagaa 300

gctgagatca agtggaaaac agctttggat atagctgaag cgaggaagta tgcacagcaa 360

gctgtgagag ttgatgagta tattatcgaa tcttctaaga agcttttgaa tttgatggga 420

attcccatag ttcaggcacc ctcagaggga gaagctcagg ccgcatacat agttagaaag 480

ggtgatgcgg attacacagg ttcgcaagat tacgattccc ttcttttcgg ctcgccaaga 540

ctggcaagga atttggccat aactgggagg agaaagttgc ccggaaagaa cgtttacacc 600

gaagttaaac ccgaggtgat agacttagaa tacaacctga aaaagcttgg aattactaga 660

gaacagctaa ttgatatagc tttacttgta ggaacagact acaacgaggg ggttgagggg 720

ataggtgtta agaaggccta caagtacgtc aaggcttatg gagacatatt caaggttctg 780

agggttctga aggttaaagt tgaggagccc atagaggaga taagaaactt cttcttaaat 840

cctccggtga cagatgatta cgagataaag tttagggagc ccaatgtcga tggaataatt 900

gagtttctat gtgaggagca cgatttcagt agggagaggg ttgaaaaagc tgtagagaag 960

cttagagcca ttaaaagcga tcagcttact ctggacaggt ggttttaa 1008

<210> SEQ ID NO 349
<211> LENGTH: 335
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 349

Met Gly Ala Asp Ile Gly Glu Leu Leu Lys Arg Glu Glu Val Glu Ile
1 5 10 15

Glu Tyr Phe Ser Gly Lys Lys Ile Ala Ile Asp Ala Phe Asn Thr Leu
20 25 30

Tyr Gln Phe Leu Ala Thr Ile Arg Gln Pro Asp Gly Thr Pro Leu Met
35 40 45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Ile Leu Tyr Arg
50 55 60

Val Ser Asn Met Val Glu Val Gly Ile Lys Pro Ile Phe Val Phe Asp

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 65                  70                  75                  80

Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Ile Glu Arg Arg Arg Lys
                 85                  90                  95

Ile Arg Glu Glu Ala Glu Ile Lys Trp Lys Thr Ala Leu Asp Ile Ala
            100                 105                 110

Glu Ala Arg Lys Tyr Ala Gln Gln Ala Val Arg Val Asp Glu Tyr Ile
        115                 120                 125

Ile Glu Ser Ser Lys Lys Leu Leu Asn Leu Met Gly Ile Pro Ile Val
    130                 135                 140

Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Ile Val Arg Lys
145                 150                 155                 160

Gly Asp Ala Asp Tyr Thr Gly Ser Gln Asp Tyr Asp Ser Leu Leu Phe
                165                 170                 175

Gly Ser Pro Arg Leu Ala Arg Asn Leu Ala Ile Thr Gly Arg Arg Lys
            180                 185                 190

Leu Pro Gly Lys Asn Val Tyr Thr Glu Val Lys Pro Glu Val Ile Asp
        195                 200                 205

Leu Glu Tyr Asn Leu Lys Lys Leu Gly Ile Thr Arg Glu Gln Leu Ile
    210                 215                 220

Asp Ile Ala Leu Leu Val Gly Thr Asp Tyr Asn Glu Gly Val Glu Gly
225                 230                 235                 240

Ile Gly Val Lys Lys Ala Tyr Lys Tyr Val Lys Ala Tyr Gly Asp Ile
                245                 250                 255

Phe Lys Val Leu Arg Val Leu Lys Val Lys Val Glu Glu Pro Ile Glu
            260                 265                 270

Glu Ile Arg Asn Phe Phe Leu Asn Pro Pro Val Thr Asp Asp Tyr Glu
        275                 280                 285

Ile Lys Phe Arg Glu Pro Asn Val Asp Gly Ile Ile Glu Phe Leu Cys
    290                 295                 300

Glu Glu His Asp Phe Ser Arg Glu Arg Val Glu Lys Ala Val Glu Lys
305                 310                 315                 320

Leu Arg Ala Ile Lys Ser Asp Gln Leu Thr Leu Asp Arg Trp Phe
                325                 330                 335


<210> SEQ ID NO 350
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Methanococcus igneus

<400> SEQUENCE: 350

cattccatgg gagtgcagtt taatg                                          25


<210> SEQ ID NO 351
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Methanococcus igneus

<400> SEQUENCE: 351

cggagtcgac tcatctccca aaccatgc                                       28


<210> SEQ ID NO 352
<211> LENGTH: 981
<212> TYPE: DNA
<213> ORGANISM: Methanococcus igneus
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<400> SEQUENCE: 352

atgggagtgc agtttaatga tttaatccca aaaaaggaaa ttccaataaa gtacttatca 60

ggaaaaactg tggctataga tgggatgaat gtcctttatc aatttttatc aagtattaga 120

ttgagagatg ggtccccttt aaggaacagg aaaggagaga taacctcaac atacaatggc 180

atattttaca aaaccatata catgctcgaa aatgatataa caccggtatg ggtgtttgat 240

ggaaaaccgc caaaattgaa agagaaaacc agagaagaaa gaagaaaaat gagagaaaaa 300

gcaaaagagg aattcacaaa agcaaaagaa atggaaaata ttgatgagat gcaaaaatac 360

gcaaagagga tgaacttctt aacaaaggac atcgtagaga actcaaaaaa attattggat 420

ttgatggggg taccttatgt aaatgcccca gcagaagggg aaggacaagc atcatacatg 480

gcaaaaaagg gagatgtatt ctgtgttatt agtcaggact atgatgcttt gctttatggg 540

gccccaagga tagtgagaaa cttaacagca acaaaggaag agttggagtt aatagagctg 600

gaaaatgttt taaatgagtt gggcatttct catgatgatt taatagacat ggcaattttg 660

atagggactg attataatcc aaagggagtt aaaggcattg gtccaaaaaa agctctcgaa 720

atagtaaaat caaaaaacaa agaactctac ttaaaggctg ttgagaatta tgaagaaatt 780

aaaaatatat ttaaaaatcc aaaagttact gatgaataca gcatcaaatt aaaaaagcca 840

gataaagaag gtattataaa gtttttggtt gaggaaaatg atttctctat ggagagagtt 900

cagccacatg ttgaaaaact ctgtaaattg attgagaaaa aaaccaaaca agtaacatta 960

gatgcatggt ttgggagatg a 981

<210> SEQ ID NO 353
<211> LENGTH: 326
<212> TYPE: PRT
<213> ORGANISM: Methanococcus igneus

<400> SEQUENCE: 353

Met Gly Val Gln Phe Asn Asp Leu Ile Pro Lys Lys Glu Ile Pro Ile
1 5 10 15

Lys Tyr Leu Ser Gly Lys Thr Val Ala Ile Asp Gly Met Asn Val Leu
20 25 30

Tyr Gln Phe Leu Ser Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
35 40 45

Asn Arg Lys Gly Glu Ile Thr Ser Thr Tyr Asn Gly Ile Phe Tyr Lys
50 55 60

Thr Ile Tyr Met Leu Glu Asn Asp Ile Thr Pro Val Trp Val Phe Asp
65 70 75 80

Gly Lys Pro Pro Lys Leu Lys Glu Lys Thr Arg Glu Glu Arg Arg Lys
85 90 95

Met Arg Glu Lys Ala Lys Glu Glu Phe Thr Lys Ala Lys Glu Met Glu
100 105 110

Asn Ile Asp Glu Met Gln Lys Tyr Ala Lys Arg Met Asn Phe Leu Thr
115 120 125

Lys Asp Ile Val Glu Asn Ser Lys Lys Leu Leu Asp Leu Met Gly Val
130 135 140

Pro Tyr Val Asn Ala Pro Ala Glu Gly Glu Gly Gln Ala Ser Tyr Met
145 150 155 160

Ala Lys Lys Gly Asp Val Phe Cys Val Ile Ser Gln Asp Tyr Asp Ala
165 170 175

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Leu Leu Tyr Gly Ala Pro Arg Ile Val Arg Asn Leu Thr Ala Thr Lys
180 185 190

Glu Glu Leu Glu Leu Ile Glu Leu Glu Asn Val Leu Asn Glu Leu Gly
195 200 205

Ile Ser His Asp Asp Leu Ile Asp Met Ala Ile Leu Ile Gly Thr Asp
210 215 220

Tyr Asn Pro Lys Gly Val Lys Gly Ile Gly Pro Lys Lys Ala Leu Glu
225 230 235 240

Ile Val Lys Ser Lys Asn Lys Glu Leu Tyr Leu Lys Ala Val Glu Asn
245 250 255

Tyr Glu Glu Ile Lys Asn Ile Phe Lys Asn Pro Lys Val Thr Asp Glu
260 265 270

Tyr Ser Ile Lys Leu Lys Lys Pro Asp Lys Glu Gly Ile Ile Lys Phe
275 280 285

Leu Val Glu Glu Asn Asp Phe Ser Met Glu Arg Val Gln Pro His Val
290 295 300

Glu Lys Leu Cys Lys Leu Ile Glu Lys Lys Thr Lys Gln Val Thr Leu
305 310 315 320

Asp Ala Trp Phe Gly Arg
325

<210> SEQ ID NO 354
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus horikoshii

<400> SEQUENCE: 354

gataccatgg gtgttcctat cggtgac 27

<210> SEQ ID NO 355
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus horikoshii

<400> SEQUENCE: 355

cttggtcgac ttagggtttc tttttaacga acc 33

<210> SEQ ID NO 356
<211> LENGTH: 1032
<212> TYPE: DNA
<213> ORGANISM: Pyrococcus horikoshii

<400> SEQUENCE: 356

atgggtgttc ctatcggtga cctcgttccg aggaaggaga tagatcttga aaatctgtat 60

ggaaagaaga tagcgataga tgccctaaac gccatctatc agtttttatc aacgataaga 120

cagagggatg gaacaccact tatggactct aagggtagga taacctctca tttaagtggg 180

ctcttttata gaacgataaa tctaatggaa gccggtatta agccggccta cgtctttgat 240

ggaaagcctc cggaattcaa aaggaaggag ctcgaaaaaa ggagggaagc tagagaagag 300

gcagaactaa aatggaaaga agctctagcc aagggaaacc tggaggaagc taggaaatac 360

gctcaaaggg caactaaggt taatgaaatg ctaatcgaag atgcaaagaa gcttttgcaa 420

ctaatgggaa taccaataat tcaggctcca agtgaaggag aagcccaagc ggcatacatg 480

gcaagtaaag gggatgtcta cgcgtcagcg agtcaagatt atgattcact actctttggt 540

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gctccaaggt tgattaggaa tctgacaatt acgggaaaaa gaaagatgcc tgggaaagat 600

gtttacgttg aaataaagcc agagttagta gttctagatg aggtactaaa agagcttaag 660

ataacaagag aaaagcttat agaacttgca attctggttg ggactgacta taatcctggg 720

ggcgtaaagg ggataggacc taagaaggcc cttgagattg taagatattc aagggatccc 780

ctagcaaagt tccaaagaca gagcgatgtg gatctttacg ctattaagga attcttcctt 840

aaccctcctg tcactaatga atactcgctt agttggaagg agcctgatga ggaaggaata 900

ttaaaattcc tctgtgatga gcataatttt agcgaagaaa gggtaaaaaa tgggatagaa 960

agactaaaaa aggcgataaa agctggaaga caatcaacgc ttgagagttg gttcgttaaa 1020

aagaaaccct aa 1032

<210> SEQ ID NO 357
<211> LENGTH: 343
<212> TYPE: PRT
<213> ORGANISM: Pyrococcus horikoshii

<400> SEQUENCE: 357

Met Gly Val Pro Ile Gly Asp Leu Val Pro Arg Lys Glu Ile Asp Leu
1 5 10 15

Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
20 25 30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Arg Asp Gly Thr Pro Leu Met
35 40 45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
50 55 60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Ala Tyr Val Phe Asp
65 70 75 80

Gly Lys Pro Pro Glu Phe Lys Arg Lys Glu Leu Glu Lys Arg Arg Glu
85 90 95

Ala Arg Glu Glu Ala Glu Leu Lys Trp Lys Glu Ala Leu Ala Lys Gly
100 105 110

Asn Leu Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Lys Val Asn
115 120 125

Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Gln Leu Met Gly Ile
130 135 140

Pro Ile Ile Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
145 150 155 160

Ala Ser Lys Gly Asp Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
165 170 175

Leu Leu Phe Gly Ala Pro Arg Leu Ile Arg Asn Leu Thr Ile Thr Gly
180 185 190

Lys Arg Lys Met Pro Gly Lys Asp Val Tyr Val Glu Ile Lys Pro Glu
195 200 205

Leu Val Val Leu Asp Glu Val Leu Lys Glu Leu Lys Ile Thr Arg Glu
210 215 220

Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225 230 235 240

Gly Val Lys Gly Ile Gly Pro Lys Lys Ala Leu Glu Ile Val Arg Tyr
245 250 255

Ser Arg Asp Pro Leu Ala Lys Phe Gln Arg Gln Ser Asp Val Asp Leu

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            260                 265                 270

Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asn Glu Tyr
        275                 280                 285

Ser Leu Ser Trp Lys Glu Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
    290                 295                 300

Cys Asp Glu His Asn Phe Ser Glu Glu Arg Val Lys Asn Gly Ile Glu
305                 310                 315                 320

Arg Leu Lys Lys Ala Ile Lys Ala Gly Arg Gln Ser Thr Leu Glu Ser
                325                 330                 335

Trp Phe Val Lys Lys Lys Pro
            340
```

<210> SEQ ID NO 358
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Sulfolobus solfataricus

<400> SEQUENCE: 358

taagccatgg gtgtagattt aggcgaaata g 31

<210> SEQ ID NO 359
<211> LENGTH: 35
<212> TYPE: DNA
<213> ORGANISM: Sulfolobus solfataricus

<400> SEQUENCE: 359

actagtcgac ttaaaaccac tgatcaagac ctgtc 35

<210> SEQ ID NO 360
<211> LENGTH: 1056
<212> TYPE: DNA
<213> ORGANISM: Sulfolobus solfataricus

<400> SEQUENCE: 360

ataggtgtag atttaggcga aatagttgaa gatgttaaga gagagattaa cttaaatgag 60

atgaaaggaa agaaaattag tatagatgct tacaacacaa tttatcagtt tttagctgca 120

ataagacagc ctgatgggac acctttaatt gacagtaaag gcagaataac aagccattta 180

aatgggctat tttataggac tattagtata atagaaagtg gaataatccc catttttgta 240

tttgatggaa agccacctga aaagaagagt gaagaaatcg aaagaaggaa aagagctaag 300

gaggaggcag aaaagaaatt agagaaagct aagttagagg gggagtacag agaaattaga 360

aaatatgctc aggctgctgt tagattaagc aatgaaatgg tagaggaaag taaaaaacta 420

ttagatgcta tgggtatacc tgtagttcaa gctccaggag aaggagaggc tgaggcagct 480

tatataaatt caattgatct ttcttgggct gctgcaagcc aagattatga ttccttatta 540

tttggcgcta aaagattagt cagaaacata acaatttcag gtaaaagaaa gcttccaaat 600

aaggatgttt atgtagaaat aaagcctgag ttgatagaac tagagagttt attgaaaaaa 660

ctcggcatca atagagaaca gttaatagac attgcgattc ttataggtac agattacaat 720

ccagacggcg ttaaaggaat tggtgtaaag acggcattaa gaattataaa gaaatataat 780

aatatcgaga acgcaataga aaaaggtgaa attcaattat ctaaaataaa ctttgatata 840

cgagagataa gaaaattatt cattacacct gaagttaaaa agcctactga acgactagaa 900

ttagcagaat gtaatgaaag ggaaataata gaacttttgg ttaaaaatca tgattttaat 960

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gaagatcgtg taaataacgg aatagagaga ttaaagaagg ctataaaaga agctaagtct 1020

gttgaaaaac agacaggtct tgatcagtgg ttttaa 1056

<210> SEQ ID NO 361
<211> LENGTH: 351
<212> TYPE: PRT
<213> ORGANISM: Sulfolobus solfataricus

<400> SEQUENCE: 361

Ile Gly Val Asp Leu Gly Glu Ile Val Glu Asp Val Lys Arg Glu Ile
1 5 10 15

Asn Leu Asn Glu Met Lys Gly Lys Lys Ile Ser Ile Asp Ala Tyr Asn
20 25 30

Thr Ile Tyr Gln Phe Leu Ala Ala Ile Arg Gln Pro Asp Gly Thr Pro
35 40 45

Leu Ile Asp Ser Lys Gly Arg Ile Thr Ser His Leu Asn Gly Leu Phe
50 55 60

Tyr Arg Thr Ile Ser Ile Ile Glu Ser Gly Ile Ile Pro Ile Phe Val
65 70 75 80

Phe Asp Gly Lys Pro Pro Glu Lys Lys Ser Glu Glu Ile Glu Arg Arg
85 90 95

Lys Arg Ala Lys Glu Glu Ala Glu Lys Lys Leu Glu Lys Ala Lys Leu
100 105 110

Glu Gly Glu Tyr Arg Glu Ile Arg Lys Tyr Ala Gln Ala Ala Val Arg
115 120 125

Leu Ser Asn Glu Met Val Glu Glu Ser Lys Lys Leu Leu Asp Ala Met
130 135 140

Gly Ile Pro Val Val Gln Ala Pro Gly Glu Gly Glu Ala Glu Ala Ala
145 150 155 160

Tyr Ile Asn Ser Ile Asp Leu Ser Trp Ala Ala Ala Ser Gln Asp Tyr
165 170 175

Asp Ser Leu Leu Phe Gly Ala Lys Arg Leu Val Arg Asn Ile Thr Ile
180 185 190

Ser Gly Lys Arg Lys Leu Pro Asn Lys Asp Val Tyr Val Glu Ile Lys
195 200 205

Pro Glu Leu Ile Glu Leu Glu Ser Leu Leu Lys Lys Leu Gly Ile Asn
210 215 220

Arg Glu Gln Leu Ile Asp Ile Ala Ile Leu Ile Gly Thr Asp Tyr Asn
225 230 235 240

Pro Asp Gly Val Lys Gly Ile Gly Val Lys Thr Ala Leu Arg Ile Ile
245 250 255

Lys Lys Tyr Asn Asn Ile Glu Asn Ala Ile Glu Lys Gly Glu Ile Gln
260 265 270

Leu Ser Lys Ile Asn Phe Asp Ile Arg Glu Ile Arg Lys Leu Phe Ile
275 280 285

Thr Pro Glu Val Lys Lys Pro Thr Glu Arg Leu Glu Leu Ala Glu Cys
290 295 300

Asn Glu Arg Glu Ile Ile Glu Leu Leu Val Lys Asn His Asp Phe Asn
305 310 315 320

Glu Asp Arg Val Asn Asn Gly Ile Glu Arg Leu Lys Lys Ala Ile Lys
325 330 335

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Glu Ala Lys Ser Val Glu Lys Gln Thr Gly Leu Asp Gln Trp Phe
340 345 350

<210> SEQ ID NO 362
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Thermococcus gorgonarius

<400> SEQUENCE: 362

ctagccatgg gagttcagat aggtgagc 28

<210> SEQ ID NO 363
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Thermococcus gorgonarius

<400> SEQUENCE: 363

tggagtcgac taccgtgtga accagctttc 30

<210> SEQ ID NO 364
<211> LENGTH: 1023
<212> TYPE: DNA
<213> ORGANISM: Thermococcus gorgonarius

<400> SEQUENCE: 364

atgggagttc agataggtga gcttgtgcca aggaaggaga tcgaacttga agctctctac 60

gggaagaagg ttgcgatcga tgccttcaac gccatgtacc agttcctctc aacgataaga 120

cagcgcgatg gaactcctct aatggactcg aagggcagga taacctccca cctcagcggc 180

ttcttttaca ggacgatcaa cctcatggag gccggaataa agcccgccta cgtcttcgac 240

ggaaagccgc cggagttcaa gaagaaggag atagagaaaa ggagagaggc aagggaagaa 300

gccgaggaga agtggtacga ggcccttgaa aagggtgact tggaggaagc gaagaagtac 360

gcgatgaggg caacccgcgt taacgagcaa ctcataaacg atgccaaaaa gcttctcgaa 420

ctgatgggga ttccagtcgt gcaggcgccg agcgaaggtg aagctcaggc cgcatacatg 480

gccgccaaag gaaaggtcta cgcctccgcc agtcaggact acgattcgct cctcttcagc 540

gcgccgagac ttgtaaggaa cctcacgata acgggaagga gaaagctccc cggaaagaac 600

gtctacgtcg aagtgaagcc cgaactcatc gttctggatg aggttctcaa ggagctcggc 660

atagacaggg aaaagcttat agagctggcg attctggttg gaaccgacta caaccccggc 720

gggataaagg gtatcgggcc caagaaggcc ctgatgatag tcaagagaac caaagacccg 780

ctcaagaaat accagaagga gagcgacgtt gacctctacg ctataaagga gttctttctc 840

aacccgcctg ttaccgacga ctacgagctg agatggcgcg aacccgacga ggaggggatt 900

ctgaagttcc tctgcgacga gcacgacttc agcgaagagc gcgttaaaac cggccttgaa 960

agactgaaga aggcggtaaa gagcggaaaa cagagaacac ttgaaagctg gttcacacgg 1020

tag 1023

<210> SEQ ID NO 365
<211> LENGTH: 340
<212> TYPE: PRT
<213> ORGANISM: Thermococcus gorgonarius

<400> SEQUENCE: 365

Met Gly Val Gln Ile Gly Glu Leu Val Pro Arg Lys Glu Ile Glu Leu

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  1               5                  10                  15

Glu Ala Leu Tyr Gly Lys Lys Val Ala Ile Asp Ala Phe Asn Ala Met
             20                  25                  30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Arg Asp Gly Thr Pro Leu Met
         35                  40                  45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Phe Phe Tyr Arg
     50                  55                  60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Ala Tyr Val Phe Asp
 65                  70                  75                  80

Gly Lys Pro Pro Glu Phe Lys Lys Lys Glu Ile Glu Lys Arg Arg Glu
                 85                  90                  95

Ala Arg Glu Glu Ala Glu Glu Lys Trp Tyr Glu Ala Leu Glu Lys Gly
            100                 105                 110

Asp Leu Glu Glu Ala Lys Lys Tyr Ala Met Arg Ala Thr Arg Val Asn
        115                 120                 125

Glu Gln Leu Ile Asn Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
    130                 135                 140

Pro Val Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
145                 150                 155                 160

Ala Ala Lys Gly Lys Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
                165                 170                 175

Leu Leu Phe Ser Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
            180                 185                 190

Arg Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Val Lys Pro Glu
        195                 200                 205

Leu Ile Val Leu Asp Glu Val Leu Lys Glu Leu Gly Ile Asp Arg Glu
    210                 215                 220

Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225                 230                 235                 240

Gly Ile Lys Gly Ile Gly Pro Lys Lys Ala Leu Met Ile Val Lys Arg
                245                 250                 255

Thr Lys Asp Pro Leu Lys Lys Tyr Gln Lys Glu Ser Asp Val Asp Leu
            260                 265                 270

Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asp Tyr
        275                 280                 285

Glu Leu Arg Trp Arg Glu Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
    290                 295                 300

Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Thr Gly Leu Glu
305                 310                 315                 320

Arg Leu Lys Lys Ala Val Lys Ser Gly Lys Gln Arg Thr Leu Glu Ser
                325                 330                 335

Trp Phe Thr Arg
            340
```

<210> SEQ ID NO 366
<211> LENGTH: 32
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 366

taacgaattc ggtgcagaca taggcgaact ac 32

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<210> SEQ ID NO 367
<211> LENGTH: 33
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 367

cggtgtcgac tcaggaaaac cacctctcaa gcg 33

<210> SEQ ID NO 368
<211> LENGTH: 37
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 368

cacaggaaac agaccatggg tgcagacata ggcgaac 37

<210> SEQ ID NO 369
<211> LENGTH: 1017
<212> TYPE: DNA
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 369

atgggtgcag acataggcga actactcgag agagaagaag ttgaacttga gtacttctcc 60

gggagaaaaa tagctattga tgcttttaac actctttacc agttcatatc tatcataagg 120

caacctgacg gcactccttt gaaggattct cagggtagaa tgacctcaca cctctccggc 180

atcctgtacc gcgtgtcaaa catgatcgag gttggaatga gacccatttt cgttttcgat 240

ggtgagcctc ctgttttcaa gcagaaggag atagaggaac gaaaggaaag aagagctgaa 300

gcagaggaga agtggatcgc tgcgatagag agaggagaga agtacgcaaa gaagtacgct 360

caggcagcgg cgagggttga tgaatacatc gtcgagtcgt caaagaagct gcttgagtat 420

atgggagttc catgggttca ggcgccgagt gagggagagg cacaggctgc atacatggca 480

gcgaagggcg atgtagattt tactggctcg caggattacg actcgcttct cttcggcagc 540

ccaaagcttg caagaaatct cgcgattact ggaaagagga agctgcccgg aaagaatgtt 600

tacgttgagg tcaaaccaga gataatagac ttaaacggca acctgagaag gcttggaata 660

acaagggaac agctcgtcga tatcgcgttg ctcgtgggaa cggactacaa cgaaggagtg 720

aagggcgttg gggtcaagaa ggcctacaag tacataaaaa cctacggaga tgttttcaaa 780

gctctcaagg ccttaaaggt agagcaggag aacatagagg agataagaaa cttcttcctg 840

aacccgcctg ttacgaacaa ctacagcctc cacttcggaa agccagacga tgagaagatt 900

atcgagttcc tgtgtgaaga gcacgacttt agcaaggata gggtagagaa ggccgttgag 960

aagctgaaag caggaatgca agcctcgcaa tcaacgcttg agaggtggtt ttcctga 1017

<210> SEQ ID NO 370
<211> LENGTH: 338
<212> TYPE: PRT
<213> ORGANISM: Archaeoglobus veneficus

<400> SEQUENCE: 370

Met Gly Ala Asp Ile Gly Glu Leu Leu Glu Arg Glu Glu Val Glu Leu
1 5 10 15

Glu Tyr Phe Ser Gly Arg Lys Ile Ala Ile Asp Ala Phe Asn Thr Leu
20 25 30

Tyr Gln Phe Ile Ser Ile Ile Arg Gln Pro Asp Gly Thr Pro Leu Lys

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```
         35                  40                  45

Asp Ser Gln Gly Arg Met Thr Ser His Leu Ser Gly Ile Leu Tyr Arg
     50                  55                  60

Val Ser Asn Met Ile Glu Val Gly Met Arg Pro Ile Phe Val Phe Asp
 65                  70                  75                  80

Gly Glu Pro Pro Val Phe Lys Gln Lys Glu Ile Glu Glu Arg Lys Glu
                 85                  90                  95

Arg Arg Ala Glu Ala Glu Glu Lys Trp Ile Ala Ala Ile Glu Arg Gly
            100                 105                 110

Glu Lys Tyr Ala Lys Lys Tyr Ala Gln Ala Ala Ala Arg Val Asp Glu
        115                 120                 125

Tyr Ile Val Glu Ser Ser Lys Lys Leu Leu Glu Tyr Met Gly Val Pro
    130                 135                 140

Trp Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met Ala
145                 150                 155                 160

Ala Lys Gly Asp Val Asp Phe Thr Gly Ser Gln Asp Tyr Asp Ser Leu
                165                 170                 175

Leu Phe Gly Ser Pro Lys Leu Ala Arg Asn Leu Ala Ile Thr Gly Lys
            180                 185                 190

Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Val Lys Pro Glu Ile
        195                 200                 205

Ile Asp Leu Asn Gly Asn Leu Arg Arg Leu Gly Ile Thr Arg Glu Gln
    210                 215                 220

Leu Val Asp Ile Ala Leu Leu Val Gly Thr Asp Tyr Asn Glu Gly Val
225                 230                 235                 240

Lys Gly Val Gly Val Lys Lys Ala Tyr Lys Tyr Ile Lys Thr Tyr Gly
                245                 250                 255

Asp Val Phe Lys Ala Leu Lys Ala Leu Lys Val Glu Gln Glu Asn Ile
            260                 265                 270

Glu Glu Ile Arg Asn Phe Phe Leu Asn Pro Pro Val Thr Asn Asn Tyr
        275                 280                 285

Ser Leu His Phe Gly Lys Pro Asp Asp Glu Lys Ile Ile Glu Phe Leu
    290                 295                 300

Cys Glu Glu His Asp Phe Ser Lys Asp Arg Val Glu Lys Ala Val Glu
305                 310                 315                 320

Lys Leu Lys Ala Gly Met Gln Ala Ser Gln Ser Thr Leu Glu Arg Trp
                325                 330                 335

Phe Ser


<210> SEQ ID NO 371
<211> LENGTH: 36
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 371

ctaagaattc ggagtagact taaaagacat tatacc                              36


<210> SEQ ID NO 372
<211> LENGTH: 29
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 372
```

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agttgtcgac tacttcggct tactgaacc 29

<210> SEQ ID NO 373
<211> LENGTH: 34
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 373

caggaaacag accatgggag tagacttaaa agac 34

<210> SEQ ID NO 374
<211> LENGTH: 1062
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 374

atgggagtag acttaaaaga cattatacca ggcgaagcta aaacggttat cgaggatctc 60

aggatcctac atggcaagat tatagtgata gatggctata acgcattata ccagttccta 120

gctgcaatca gacaaccgga tgggacccct ctaatggata acaacgggag gatcacgagt 180

catttaagcg gtttattcta tagaaccata aatatcgttg aggcagggat aaaaccagtc 240

tacgtgtttg atggtaaacc ccctgaattg aaggcgaggg agatagagag gaggaaagcc 300

gttaaggagg aggcagcaaa gaagtacgag gaagccgttc aatccggaga cctcgagctc 360

gcgaggagat acgcaatgat gtcggccaag ctgacagagg aaatggtgag ggatgctaaa 420

tcattactag acgcaatggg tattccatgg gttcaagcac cagcggaggg cgaggctcag 480

gcagcctata ttgttaagaa gggggatgcc tatgcatccg cctcacagga ttacgatagc 540

ttgctattcg gctcccctaa gctcgttaga aacctgacca taagcggtag aagaaagcta 600

ccgagaaaaa acgagtatgt tgaagtaaag ccggagctca tagagctcga caaactcctt 660

gttcagctag gtataaccct tgagaacctc atcgatatag gtatactcct ggggacagat 720

tacaatccag acggcttcga aggcataggc cccaagaagg ctcttcaact agttaaggca 780

tacgggggaa tcgagaagat accgaaaccc attttgaagt cgccgataga agtagatgtt 840

atagcaataa agaaatactt ccttcaacca caggtaacag acaactacag gattgaatgg 900

catacccccg atcccgatgc agtgaaaaga atattggtgg atgaacatga tttcagtata 960

gatagagtta gcacagcgct tgagagatac gtgaaggcct ttaaagaaaa tatacgggga 1020

gaacagaaag gtctctctaa atggttcagt aagccgaagt ag 1062

<210> SEQ ID NO 375
<211> LENGTH: 353
<212> TYPE: PRT
<213> ORGANISM: Desulfurococcus amylolyticus

<400> SEQUENCE: 375

Met Gly Val Asp Leu Lys Asp Ile Ile Pro Gly Glu Ala Lys Thr Val
1 5 10 15

Ile Glu Asp Leu Arg Ile Leu His Gly Lys Ile Ile Val Ile Asp Gly
20 25 30

Tyr Asn Ala Leu Tyr Gln Phe Leu Ala Ala Ile Arg Gln Pro Asp Gly
35 40 45

Thr Pro Leu Met Asp Asn Asn Gly Arg Ile Thr Ser His Leu Ser Gly
50 55 60

-continued

```
Leu Phe Tyr Arg Thr Ile Asn Ile Val Glu Ala Gly Ile Lys Pro Val
 65                  70                  75                  80

Tyr Val Phe Asp Gly Lys Pro Pro Glu Leu Lys Ala Arg Glu Ile Glu
                 85                  90                  95

Arg Arg Lys Ala Val Lys Glu Glu Ala Ala Lys Lys Tyr Glu Glu Ala
            100                 105                 110

Val Gln Ser Gly Asp Leu Glu Leu Ala Arg Arg Tyr Ala Met Met Ser
        115                 120                 125

Ala Lys Leu Thr Glu Glu Met Val Arg Asp Ala Lys Ser Leu Leu Asp
    130                 135                 140

Ala Met Gly Ile Pro Trp Val Gln Ala Pro Ala Glu Gly Glu Ala Gln
145                 150                 155                 160

Ala Ala Tyr Ile Val Lys Lys Gly Asp Ala Tyr Ala Ser Ala Ser Gln
                165                 170                 175

Asp Tyr Asp Ser Leu Leu Phe Gly Ser Pro Lys Leu Val Arg Asn Leu
            180                 185                 190

Thr Ile Ser Gly Arg Arg Lys Leu Pro Arg Lys Asn Glu Tyr Val Glu
        195                 200                 205

Val Lys Pro Glu Leu Ile Glu Leu Asp Lys Leu Leu Val Gln Leu Gly
    210                 215                 220

Ile Thr Leu Glu Asn Leu Ile Asp Ile Gly Ile Leu Leu Gly Thr Asp
225                 230                 235                 240

Tyr Asn Pro Asp Gly Phe Glu Gly Ile Gly Pro Lys Lys Ala Leu Gln
                245                 250                 255

Leu Val Lys Ala Tyr Gly Gly Ile Glu Lys Ile Pro Lys Pro Ile Leu
            260                 265                 270

Lys Ser Pro Ile Glu Val Asp Val Ile Ala Ile Lys Lys Tyr Phe Leu
        275                 280                 285

Gln Pro Gln Val Thr Asp Asn Tyr Arg Ile Glu Trp His Thr Pro Asp
    290                 295                 300

Pro Asp Ala Val Lys Arg Ile Leu Val Asp Glu His Asp Phe Ser Ile
305                 310                 315                 320

Asp Arg Val Ser Thr Ala Leu Glu Arg Tyr Val Lys Ala Phe Lys Glu
                325                 330                 335

Asn Ile Arg Gly Glu Gln Lys Gly Leu Ser Lys Trp Phe Ser Lys Pro
            340                 345                 350

Lys
```

<210> SEQ ID NO 376
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Pyrobaculum aerophilum

<400> SEQUENCE: 376

cgttgaattc ggagttactg agttgggtaa g 31

<210> SEQ ID NO 377
<211> LENGTH: 34
<212> TYPE: DNA
<213> ORGANISM: Pyrobaculum aerophilum

<400> SEQUENCE: 377

tactgtcgac agaaaaagga gtcgagagag gaag 34

-continued

<210> SEQ ID NO 378
<211> LENGTH: 1041
<212> TYPE: DNA
<213> ORGANISM: Pyrobaculum aerophilum

<400> SEQUENCE: 378

gtgggagtta ctgagttggg taagcttatt ggcaaagagg tccgccgcga ggttaaactg 60

gaaagtctct cgggcaagtg tattgccctt gacgcgtaca acgccttgta ccaattcctt 120

gcgtctatta gacagccaga tgggacgcct ctaatggaca gagctgggag gattactagt 180

catctctcgg gtttgttcta ccgtactatc aacctccttg aggccggcat taggcctgtt 240

tatgtttttg atgggaagcc tcccgaattt aaactggctg aaattgaaga aaggaggaag 300

acgcgtgaga aggccatgga agaggtgttg agggccatta aggaggggag gagggaagac 360

gtggctaaat acgccaaaag ggctgttttt attaccagcg aaatggtgga cgaggccaag 420

aggctgctga gctatatggg cgtaccctgg gtccaagctc caagcgaggg ggaggcgcaa 480

gcggcttata tggctagaaa aggacactgc tgggccgtgg gaagccagga ttacgattcg 540

ctgttatttg gatcccccaa gttagtcaga aatctagcgg tatcccctaa gcgtaaaatt 600

ggagaagagg taatagagct cacgccggaa attattgagc tagacgccgt cctcagggct 660

ttgaggctaa agaacagaga gcaactaata gacttggcta ttttactcgg cacagattac 720

aacccagacg gcgttcccgg agtgggcccc cagaaggcgt taaaactaat atgggaattt 780

ggatcgcttg aaaaactatt agaaactgta ttaaaggggg cgtatttccc cattgacccc 840

ctggagataa agaagttctt cctcaatccc ccagtcactg atcaatacgc cactgaggtg 900

agagacccag acgaggcggc cctcaaggac tttcttatac gcgaacacga cttcagcgag 960

gagagggtgt ctaaggcact tgagaggctg agaaaagccc gggggaagtt aaaaacttcc 1020

tctctcgact ccttttttcta a 1041

<210> SEQ ID NO 379
<211> LENGTH: 346
<212> TYPE: PRT
<213> ORGANISM: Pyrobaculum aerophilum

<400> SEQUENCE: 379

Val Gly Val Thr Glu Leu Gly Lys Leu Ile Gly Lys Glu Val Arg Arg
1 5 10 15

Glu Val Lys Leu Glu Ser Leu Ser Gly Lys Cys Ile Ala Leu Asp Ala
20 25 30

Tyr Asn Ala Leu Tyr Gln Phe Leu Ala Ser Ile Arg Gln Pro Asp Gly
35 40 45

Thr Pro Leu Met Asp Arg Ala Gly Arg Ile Thr Ser His Leu Ser Gly
50 55 60

Leu Phe Tyr Arg Thr Ile Asn Leu Leu Glu Ala Gly Ile Arg Pro Val
65 70 75 80

Tyr Val Phe Asp Gly Lys Pro Pro Glu Phe Lys Leu Ala Glu Ile Glu
85 90 95

Glu Arg Arg Lys Thr Arg Glu Lys Ala Met Glu Glu Val Leu Arg Ala
100 105 110

Ile Lys Glu Gly Arg Arg Glu Asp Val Ala Lys Tyr Ala Lys Arg Ala
115 120 125

-continued

```
Val Phe Ile Thr Ser Glu Met Val Asp Glu Ala Lys Arg Leu Leu Ser
    130                 135                 140

Tyr Met Gly Val Pro Trp Val Gln Ala Pro Ser Glu Gly Glu Ala Gln
145                 150                 155                 160

Ala Ala Tyr Met Ala Arg Lys Gly His Cys Trp Ala Val Gly Ser Gln
                165                 170                 175

Asp Tyr Asp Ser Leu Leu Phe Gly Ser Pro Lys Leu Val Arg Asn Leu
            180                 185                 190

Ala Val Ser Pro Lys Arg Lys Ile Gly Glu Glu Val Ile Glu Leu Thr
        195                 200                 205

Pro Glu Ile Ile Glu Leu Asp Ala Val Leu Arg Ala Leu Arg Leu Lys
    210                 215                 220

Asn Arg Glu Gln Leu Ile Asp Leu Ala Ile Leu Leu Gly Thr Asp Tyr
225                 230                 235                 240

Asn Pro Asp Gly Val Pro Gly Val Gly Pro Gln Lys Ala Leu Lys Leu
                245                 250                 255

Ile Trp Glu Phe Gly Ser Leu Glu Lys Leu Leu Glu Thr Val Leu Lys
            260                 265                 270

Gly Ala Tyr Phe Pro Ile Asp Pro Leu Glu Ile Lys Lys Phe Phe Leu
        275                 280                 285

Asn Pro Pro Val Thr Asp Gln Tyr Ala Thr Glu Val Arg Asp Pro Asp
    290                 295                 300

Glu Ala Ala Leu Lys Asp Phe Leu Ile Arg Glu His Asp Phe Ser Glu
305                 310                 315                 320

Glu Arg Val Ser Lys Ala Leu Glu Arg Leu Arg Lys Ala Arg Gly Lys
                325                 330                 335

Leu Lys Thr Ser Ser Leu Asp Ser Phe Phe
            340                 345


<210> SEQ ID NO 380
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 380

tcatgaattc ggagtccaga ttggtgagct t                                  31


<210> SEQ ID NO 381
<211> LENGTH: 32
<212> TYPE: DNA
<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 381

gattgtcgac tcacttttta aaccagctgt cc                                 32


<210> SEQ ID NO 382
<211> LENGTH: 39
<212> TYPE: DNA
<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 382

aagctcacca atctggactc ccatggtctg tttcctgtg                          39


<210> SEQ ID NO 383
<211> LENGTH: 1023
<212> TYPE: DNA
```

-continued

<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 383

atgggagtcc agattggtga gcttttacca agaaaagagc ttgagcttga aaatttaaat 60

gggagaaaag ttgcgataga tgcatttaac gctatttacc agtttctctc aacaataaga 120

caacgagatg ggactccttt aatggattcc aagggaagaa taacgtccca tctttcaggg 180

ctttttttaca ggactataaa cctaatggaa gcgggaataa agcctgcgta tgtattcgat 240

gggaagcctc cagagttcaa gaaaaaagag cttgaaaaaa gagctgaggc tagggaggaa 300

gcgcaggaaa aatgggagga agccctagca aggggagact tagaagaggc gaagaaatat 360

gcacagcggg cgagcaaagt aaatgagatg cttatcgagg atgctaagaa gcttttggag 420

cttatgggca tcccatgggt gcaggctcct agcgaaggtg aagcgcaggc agcttatatg 480

gcatctaaag ggcacgtttg ggcctcggcg agccaggact acgactcgct cctcttcgga 540

acaccaaggc tagtgagaaa cctcaccata actggaaaga gaaagcttcc tgggaaggat 600

atttacgtag aagttaaacc ggagctcata gttcttgaag aggtgttaaa ggagcttaag 660

ataacgaggg agaagttggt agagcttgca attctcgtgg gaacggacta caatcctgga 720

ggcataaaag ggattggacc aaaaaaggcc cttgaaatag tcaaatactc caaagatcct 780

ctggcaaagt accaaaaaat gagcgatgtt gatctctatg caataaagga gttcttccta 840

aacccgccga caacagacga atacaagctc gaatggaaaa tgcccgatga agaaggaata 900

ctgaagtttc tctgtgatga gcacgatttc agtgaagaaa gagttaaaaa cggcttagaa 960

aggcttaaaa aagcggttaa ggcaggaaga cagtttacgc tggacagctg gtttaaaaag 1020

tga 1023

<210> SEQ ID NO 384
<211> LENGTH: 340
<212> TYPE: PRT
<213> ORGANISM: Thermococcus litoralis

<400> SEQUENCE: 384

Met Gly Val Gln Ile Gly Glu Leu Leu Pro Arg Lys Glu Leu Glu Leu
1 5 10 15

Glu Asn Leu Asn Gly Arg Lys Val Ala Ile Asp Ala Phe Asn Ala Ile
20 25 30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Arg Asp Gly Thr Pro Leu Met
35 40 45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
50 55 60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Ala Tyr Val Phe Asp
65 70 75 80

Gly Lys Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Ala Glu
85 90 95

Ala Arg Glu Glu Ala Gln Glu Lys Trp Glu Glu Ala Leu Ala Arg Gly
100 105 110

Asp Leu Glu Glu Ala Lys Lys Tyr Ala Gln Arg Ala Ser Lys Val Asn
115 120 125

Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
130 135 140

Pro Trp Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met

-continued

```
145                 150                 155                 160

Ala Ser Lys Gly His Val Trp Ala Ser Ala Ser Gln Asp Tyr Asp Ser
                165                 170                 175

Leu Leu Phe Gly Thr Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
            180                 185                 190

Lys Arg Lys Leu Pro Gly Lys Asp Ile Tyr Val Glu Val Lys Pro Glu
        195                 200                 205

Leu Ile Val Leu Glu Glu Val Leu Lys Glu Leu Lys Ile Thr Arg Glu
    210                 215                 220

Lys Leu Val Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225                 230                 235                 240

Gly Ile Lys Gly Ile Gly Pro Lys Lys Ala Leu Glu Ile Val Lys Tyr
                245                 250                 255

Ser Lys Asp Pro Leu Ala Lys Tyr Gln Lys Met Ser Asp Val Asp Leu
            260                 265                 270

Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Thr Thr Asp Glu Tyr
        275                 280                 285

Lys Leu Glu Trp Lys Met Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
    290                 295                 300

Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu
305                 310                 315                 320

Arg Leu Lys Lys Ala Val Lys Ala Gly Arg Gln Phe Thr Leu Asp Ser
                325                 330                 335

Trp Phe Lys Lys
            340
```

<210> SEQ ID NO 385
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 385

```
cttggaattc ggcgtcgacc taagggaact c                                  31
```

<210> SEQ ID NO 386
<211> LENGTH: 34
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 386

```
aggtctgcag ttaaccctgc ttaccgggct tagc                               34
```

<210> SEQ ID NO 387
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 387

```
caggaaacag accatgggcg tcgacctaag g                                  31
```

<210> SEQ ID NO 388
<211> LENGTH: 1071
<212> TYPE: DNA
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 388

-continued

atgggcgtcg acctaaggga actcatccca gacgacgcca agatcattat agaggatctg 60

aggaccctac ggggcagggt tatcgcgata gacggctata acgcgctcta ccagttccta 120

gccgccatca ggcagcccga cgggacgccc ctaatggatg gaagcggcag gatcaccagc 180

cacctcagcg ggctcttcta caggacgata aacattgtgg aggcagggat taaacccgta 240

tacgtcttcg atggtaaacc ccccgagttg aaggcgaagg agatagagag gagaagggtt 300

gtcagggagg aggctgcgag aaagtatgag gaggcagtgc aagccggcga cttagagtca 360

gctagaaggt atgcgatgat gtcggctagg ctcaccgatg aaatggtgag ggatgcaaaa 420

gccctgctcg acgccatggg gataccgtgg gttcaagccc cggctgaggg cgaggcgcag 480

gcagcgtaca tggctaggaa gggcgacgcc tacgcctctg catcccagga ctacgatagc 540

ctcctcttcg ggtcgccccg cctagtgagg aatctcacta taagtggccg taggaagctc 600

ccgagaagag aggagtatgt cgaggtgaag cccgaggtaa tagagctcga taaactgctt 660

tcaaagctgg gcgtaaccta tgagaacctg gtggacatag gcatcctcct ggggacggat 720

tacaacccag acggcttcga gggcattgga cccaagaagg cgcttcaatt agtgaaggtc 780

tacgggagcg ttgagaagat accgaagccc ctcttgaaat cccctgttga agtagatgtc 840

gcagcgataa aaaagtactt cctgcaaccc caggtgacag acaactatag gcttgaatgg 900

cgtaacccgg atcccgaggc tgtgaaacgc atacttgtcg gcgaacacga tttcagcgct 960

gagagagtca acgcagccct cgacaggtat cttaaagcct tcagggagaa cataaggggc 1020

gaacagaagg ggctgtcgaa gtggttcgct aagcccggta agcagggtta a 1071

<210> SEQ ID NO 389
<211> LENGTH: 356
<212> TYPE: PRT
<213> ORGANISM: Desulfurococcus mobilis

<400> SEQUENCE: 389

Met Gly Val Asp Leu Arg Glu Leu Ile Pro Asp Asp Ala Lys Ile Ile
1 5 10 15

Ile Glu Asp Leu Arg Thr Leu Arg Gly Arg Val Ile Ala Ile Asp Gly
20 25 30

Tyr Asn Ala Leu Tyr Gln Phe Leu Ala Ala Ile Arg Gln Pro Asp Gly
35 40 45

Thr Pro Leu Met Asp Gly Ser Gly Arg Ile Thr Ser His Leu Ser Gly
50 55 60

Leu Phe Tyr Arg Thr Ile Asn Ile Val Glu Ala Gly Ile Lys Pro Val
65 70 75 80

Tyr Val Phe Asp Gly Lys Pro Pro Glu Leu Lys Ala Lys Glu Ile Glu
85 90 95

Arg Arg Arg Val Val Arg Glu Glu Ala Ala Arg Lys Tyr Glu Glu Ala
100 105 110

Val Gln Ala Gly Asp Leu Glu Ser Ala Arg Arg Tyr Ala Met Met Ser
115 120 125

Ala Arg Leu Thr Asp Glu Met Val Arg Asp Ala Lys Ala Leu Leu Asp
130 135 140

Ala Met Gly Ile Pro Trp Val Gln Ala Pro Ala Glu Gly Glu Ala Gln
145 150 155 160

Ala Ala Tyr Met Ala Arg Lys Gly Asp Ala Tyr Ala Ser Ala Ser Gln
165 170 175

-continued

```
Asp Tyr Asp Ser Leu Leu Phe Gly Ser Pro Arg Leu Val Arg Asn Leu
            180                 185                 190

Thr Ile Ser Gly Arg Arg Lys Leu Pro Arg Arg Glu Glu Tyr Val Glu
        195                 200                 205

Val Lys Pro Glu Val Ile Glu Leu Asp Lys Leu Leu Ser Lys Leu Gly
    210                 215                 220

Val Thr Tyr Glu Asn Leu Val Asp Ile Gly Ile Leu Leu Gly Thr Asp
225                 230                 235                 240

Tyr Asn Pro Asp Gly Phe Glu Gly Ile Gly Pro Lys Lys Ala Leu Gln
                245                 250                 255

Leu Val Lys Val Tyr Gly Ser Val Glu Lys Ile Pro Lys Pro Leu Leu
            260                 265                 270

Lys Ser Pro Val Glu Val Asp Val Ala Ala Ile Lys Lys Tyr Phe Leu
        275                 280                 285

Gln Pro Gln Val Thr Asp Asn Tyr Arg Leu Glu Trp Arg Asn Pro Asp
    290                 295                 300

Pro Glu Ala Val Lys Arg Ile Leu Val Gly Glu His Asp Phe Ser Ala
305                 310                 315                 320

Glu Arg Val Asn Ala Ala Leu Asp Arg Tyr Leu Lys Ala Phe Arg Glu
                325                 330                 335

Asn Ile Arg Gly Glu Gln Lys Gly Leu Ser Lys Trp Phe Ala Lys Pro
            340                 345                 350

Gly Lys Gln Gly
        355
```

<210> SEQ ID NO 390
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Pyrodictium brockii

<400> SEQUENCE: 390

tagcgaattc ggcgtcaacc tccgcgag 28

<210> SEQ ID NO 391
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Pyrodictium brockii

<400> SEQUENCE: 391

cattctgcag ctagcggcgc agccacgc 28

<210> SEQ ID NO 392
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Pyrodictium brockii

<400> SEQUENCE: 392

caggaaacag accatgggcg tcaacctccg c 31

<210> SEQ ID NO 393
<211> LENGTH: 1053
<212> TYPE: DNA
<213> ORGANISM: Pyrodictium brockii

<400> SEQUENCE: 393

gtgggcgtca acctccgcga gatcataccc aaggaggctg taacggaaat agagctcgac 60

-continued

tcgctgcgct acaaggttgt agccatagac gcctacaacg cgctctacca gttcctcacc 120

gcgataaggc agccggacgg cacgccgctc atggactcgc gtggcagggt caccagccat 180

ctcagcggcc tcttctaccg caccataaac ctggccgagc acggggtaaa ggtggtctac 240

gtcttcgacg ggaagccgcc ggagatgaag tatctcgaga tagagaggag gaagcgtgtc 300

aaggcggagg ctgtgcggaa gtacgaggag gcagtgaaga ggggcgacca ggaggcggcg 360

aggcgctacg cccaggcagc ggcgagactc accgacgaga tggtggagga cgctaagaag 420

ctgctggagg ccatggggat accctacgtg caggcgccgg cggaggggga ggcgcaggcc 480

gcctacatgg cccggaaggg cgacgcctgg gccgcggcga gccaggacta cgactccctg 540

ctcttcgggg ccccgaggct tgcccggaac ctcgctataa cgggtaagag gaagctgccc 600

aggaagaacg tctacgtaga ggttaagccg gagctggtgg agctcgagaa gctgctcaag 660

gcactgggca ttaccaggga gcagttgata gccctaggca tactcatagg caccgactac 720

aacccggacg gcgtccgggg gatcgggccc aagacggcgc tgaagatggt gcagacccac 780

cgggaccccg tgaagctcct ccaggggctc ccgcgccacg agttcccggt cgacccactg 840

aagatctacg agtacttcct gaacccccca gtgaccagcg actataagct cgagtggagg 900

gagcccgacg agaagagggt cctcgagata ctcgtggagg agcacgactt caacccggag 960

cgtgttaaga acgccctgga gaggctgcgg agggcgtacc gcgagcactt ccagggccgc 1020

cagatgggtc tggatgcgtg gctgcgccgc tag 1053

<210> SEQ ID NO 394
<211> LENGTH: 350
<212> TYPE: PRT
<213> ORGANISM: Pyrodictium brockii

<400> SEQUENCE: 394

Val Gly Val Asn Leu Arg Glu Ile Ile Pro Lys Glu Ala Val Thr Glu
1 5 10 15

Ile Glu Leu Asp Ser Leu Arg Tyr Lys Val Val Ala Ile Asp Ala Tyr
20 25 30

Asn Ala Leu Tyr Gln Phe Leu Thr Ala Ile Arg Gln Pro Asp Gly Thr
35 40 45

Pro Leu Met Asp Ser Arg Gly Arg Val Thr Ser His Leu Ser Gly Leu
50 55 60

Phe Tyr Arg Thr Ile Asn Leu Ala Glu His Gly Val Lys Val Val Tyr
65 70 75 80

Val Phe Asp Gly Lys Pro Pro Glu Met Lys Tyr Leu Glu Ile Glu Arg
85 90 95

Arg Lys Arg Val Lys Ala Glu Ala Val Arg Lys Tyr Glu Glu Ala Val
100 105 110

Lys Arg Gly Asp Gln Glu Ala Ala Arg Arg Tyr Ala Gln Ala Ala Ala
115 120 125

Arg Leu Thr Asp Glu Met Val Glu Asp Ala Lys Lys Leu Leu Glu Ala
130 135 140

Met Gly Ile Pro Tyr Val Gln Ala Pro Ala Glu Gly Glu Ala Gln Ala
145 150 155 160

Ala Tyr Met Ala Arg Lys Gly Asp Ala Trp Ala Ala Ala Ser Gln Asp
165 170 175

-continued

```
Tyr Asp Ser Leu Leu Phe Gly Ala Pro Arg Leu Ala Arg Asn Leu Ala
            180                 185                 190

Ile Thr Gly Lys Arg Lys Leu Pro Arg Lys Asn Val Tyr Val Glu Val
        195                 200                 205

Lys Pro Glu Leu Val Glu Leu Glu Lys Leu Leu Lys Ala Leu Gly Ile
    210                 215                 220

Thr Arg Glu Gln Leu Ile Ala Leu Gly Ile Leu Ile Gly Thr Asp Tyr
225                 230                 235                 240

Asn Pro Asp Gly Val Arg Gly Ile Gly Pro Lys Thr Ala Leu Lys Met
                245                 250                 255

Val Gln Thr His Arg Asp Pro Val Lys Leu Leu Gln Gly Leu Pro Arg
            260                 265                 270

His Glu Phe Pro Val Asp Pro Leu Lys Ile Tyr Glu Tyr Phe Leu Asn
        275                 280                 285

Pro Pro Val Thr Ser Asp Tyr Lys Leu Glu Trp Arg Glu Pro Asp Glu
    290                 295                 300

Lys Arg Val Leu Glu Ile Leu Val Glu Glu His Asp Phe Asn Pro Glu
305                 310                 315                 320

Arg Val Lys Asn Ala Leu Glu Arg Leu Arg Arg Ala Tyr Arg Glu His
                325                 330                 335

Phe Gln Gly Arg Gln Met Gly Leu Asp Ala Trp Leu Arg Arg
            340                 345                 350
```

<210> SEQ ID NO 395
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 395

```
cataccatgg gactagctga actccgag                                          28
```

<210> SEQ ID NO 396
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 396

```
tggatctaga tcagaagaac gcgtccaggg                                        30
```

<210> SEQ ID NO 397
<211> LENGTH: 985
<212> TYPE: DNA
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 397

```
ttgggactag ctgaactccg agaactgatc gaacccgaag agacggacct gagagccctc     60

gccggtcggg agatcgctat cgacgcgttc aacgccctgt atcaattcct gaccacgatc    120

atgaaggacg gacgacctct catggactcg aggggcagga ttaccagcca cttaaatggc    180

ctcctgtata ggaccgtgaa cttggtcgaa gagggtatca agccggtata cgtgttcgat    240

ggtgagcccc cggacctgaa gcgtgaaacg ctggagcgtc gacgggaacg gaaggaggag    300

gcgatggaga aactgaggcg ggccaaaacg aaggaggagc gggagaagta cgcccgacaa    360

gtcgccagac tcgacgagtc gttggtggaa gacgcgaaga ggctgttgga tctcatgggc    420

atcccgtggg tacaggcccc ctcggaagga gaggcgcagt gcgcgtatat ggcgaggtgc    480
```

-continued

```
ggggacgtat gggcgacagg cagccaagac tacgactcgc tgcttttcgg cagccccagg    540

ttggttcgca acatcacgat agtcggaaag cggaagcatc cacacaccgg cgagatcata    600

gaggtcaagc ccgagatcat gaggttggag gacgtgctcg accagctggg attggaatcg    660

agggagcagc tggtggacct agcgatcctt ttgggcacgg actacaaccc ggatggagta    720

cccgggattg gtccgaagcg cgcgctgcag ttgatcagga agtacgggtc gctagacgag    780

cttaaggaca ccgacatctg gcctaagatc gagcggcacc tgccggtgga accggagaag    840

ctcaaaaggc tctttctcga gccggaagtt acggacgact accagctaga ctgggacgaa    900

cccgaccaaa agggactggt cgagttcctg gttgaggagc gtgatttctt ccaggatcga    960

gtccgccgcg ccgtcgagcg tctga                                          985
```

<210> SEQ ID NO 398
<211> LENGTH: 328
<212> TYPE: PRT
<213> ORGANISM: Methanopyrus kandleri

<400> SEQUENCE: 398

```
Leu Gly Leu Ala Glu Leu Arg Glu Leu Ile Glu Pro Glu Glu Thr Asp
  1               5                  10                  15

Leu Arg Ala Leu Ala Gly Arg Glu Ile Ala Ile Asp Ala Phe Asn Ala
             20                  25                  30

Leu Tyr Gln Phe Leu Thr Thr Ile Met Lys Asp Gly Arg Pro Leu Met
         35                  40                  45

Asp Ser Arg Gly Arg Ile Thr Ser His Leu Asn Gly Leu Leu Tyr Arg
     50                  55                  60

Thr Val Asn Leu Val Glu Glu Gly Ile Lys Pro Val Tyr Val Phe Asp
 65                  70                  75                  80

Gly Glu Pro Pro Asp Leu Lys Arg Glu Thr Leu Glu Arg Arg Arg Glu
                 85                  90                  95

Arg Lys Glu Glu Ala Met Glu Lys Leu Arg Arg Ala Lys Thr Lys Glu
            100                 105                 110

Glu Arg Glu Lys Tyr Ala Arg Gln Val Ala Arg Leu Asp Glu Ser Leu
        115                 120                 125

Val Glu Asp Ala Lys Arg Leu Leu Asp Leu Met Gly Ile Pro Trp Val
    130                 135                 140

Gln Ala Pro Ser Glu Gly Glu Ala Gln Cys Ala Tyr Met Ala Arg Cys
145                 150                 155                 160

Gly Asp Val Trp Ala Thr Gly Ser Gln Asp Tyr Asp Ser Leu Leu Phe
                165                 170                 175

Gly Ser Pro Arg Leu Val Arg Asn Ile Thr Ile Val Gly Lys Arg Lys
            180                 185                 190

His Pro His Thr Gly Glu Ile Ile Glu Val Lys Pro Glu Ile Met Arg
        195                 200                 205

Leu Glu Asp Val Leu Asp Gln Leu Gly Leu Glu Ser Arg Glu Gln Leu
    210                 215                 220

Val Asp Leu Ala Ile Leu Leu Gly Thr Asp Tyr Asn Pro Asp Gly Val
225                 230                 235                 240

Pro Gly Ile Gly Pro Lys Arg Ala Leu Gln Leu Ile Arg Lys Tyr Gly
                245                 250                 255

Ser Leu Asp Glu Leu Lys Asp Thr Asp Ile Trp Pro Lys Ile Glu Arg
```

-continued

```
            260                 265                 270

His Leu Pro Val Glu Pro Glu Lys Leu Lys Arg Leu Phe Leu Glu Pro
        275                 280                 285

Glu Val Thr Asp Asp Tyr Gln Leu Asp Trp Asp Glu Pro Asp Gln Lys
    290                 295                 300

Gly Leu Val Glu Phe Leu Val Glu Glu Arg Asp Phe Phe Gln Asp Arg
305                 310                 315                 320

Val Arg Arg Ala Val Glu Arg Leu
                325
```

<210> SEQ ID NO 399
<211> LENGTH: 28
<212> TYPE: DNA
<213> ORGANISM: Thermococcus zilligii

<400> SEQUENCE: 399

cgatccatgg gagttcagat cggtgagc 28

<210> SEQ ID NO 400
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Thermococcus zilligii

<400> SEQUENCE: 400

caggctgcag tcaccttccg aaccagctct c 31

<210> SEQ ID NO 401
<211> LENGTH: 1023
<212> TYPE: DNA
<213> ORGANISM: Thermococcus zilligii

<400> SEQUENCE: 401

atgggagttc agatcggtga gctcgtgccg aggaaggaga tagggctgga aaaccttcat 60

gggaaaaaag ttgcagttga tgccttcaac gccatgtacc agtttctctc gacgataagg 120

cagcctgatg ggactccttt aatggactcg aagggcagga taacctctca tctcagcggc 180

ttcttctata ggacaataaa cctgatggag gccggaataa aacccgccta cgtcttcgac 240

gggaagccac cggagttcaa gaagaaggag atagagaaga ggagggaggc aagggaagag 300

gcagaagaga agtggcagga ggcccttgag aagggcgacc tggaggaggc gaagaagtac 360

gcgatgaggg caacccgcgt taacgaggag ctcataagcg atgccaaaaa gcttcttgag 420

ctaatgggca ttccggttgt ccaggcaccg agcgagggag aggctcaggc ggcctacatg 480

gccgcaaagg gcaaggttta cgcctcagcg agccaggatt atgactcact cctcttcagc 540

gcgccgaaac tcgtgagaaa cctcacgata acgggaagaa ggaagctgcc ggggaaggat 600

gtctacgttg aagtgaagcc cgagctgatc gtcctggaag aggttctcaa ggagcttggc 660

atagaccggg agaaactcat agagctggcg attcttgtgg ggacggacta caaccccggg 720

gggataaagg gcatcgggcc caagaaggcc cttatgatag tcaagagaat caatgacccg 780

ctcaggaagt acagcaatga gagtgaggtc gacctctacg cgataaagga gttctttctc 840

aatccccccg ttacagatga ctacgagctg agatggcgcg agcccgatga agatgggatt 900

ctaaggtttc tctgtgagga gcacgacttc agcgaggaga gggttaaggg tggccttgaa 960

aggctgagga aagcggtgga gagtggaaag cagagaacgc ttgagagctg gttcggaagg 1020

-continued

tga 1023

<210> SEQ ID NO 402
<211> LENGTH: 340
<212> TYPE: PRT
<213> ORGANISM: Thermococcus zilligii

<400> SEQUENCE: 402

Met Gly Val Gln Ile Gly Glu Leu Val Pro Arg Lys Glu Ile Gly Leu
1 5 10 15

Glu Asn Leu His Gly Lys Lys Val Ala Val Asp Ala Phe Asn Ala Met
20 25 30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Pro Asp Gly Thr Pro Leu Met
35 40 45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Phe Phe Tyr Arg
50 55 60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Ala Tyr Val Phe Asp
65 70 75 80

Gly Lys Pro Pro Glu Phe Lys Lys Lys Glu Ile Glu Lys Arg Arg Glu
85 90 95

Ala Arg Glu Glu Ala Glu Glu Lys Trp Gln Glu Ala Leu Glu Lys Gly
100 105 110

Asp Leu Glu Glu Ala Lys Lys Tyr Ala Met Arg Ala Thr Arg Val Asn
115 120 125

Glu Glu Leu Ile Ser Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
130 135 140

Pro Val Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
145 150 155 160

Ala Ala Lys Gly Lys Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
165 170 175

Leu Leu Phe Ser Ala Pro Lys Leu Val Arg Asn Leu Thr Ile Thr Gly
180 185 190

Arg Arg Lys Leu Pro Gly Lys Asp Val Tyr Val Glu Val Lys Pro Glu
195 200 205

Leu Ile Val Leu Glu Glu Val Leu Lys Glu Leu Gly Ile Asp Arg Glu
210 215 220

Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
225 230 235 240

Gly Ile Lys Gly Ile Gly Pro Lys Lys Ala Leu Met Ile Val Lys Arg
245 250 255

Ile Asn Asp Pro Leu Arg Lys Tyr Ser Asn Glu Ser Glu Val Asp Leu
260 265 270

Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asp Tyr
275 280 285

Glu Leu Arg Trp Arg Glu Pro Asp Glu Asp Gly Ile Leu Arg Phe Leu
290 295 300

Cys Glu Glu His Asp Phe Ser Glu Glu Arg Val Lys Gly Gly Leu Glu
305 310 315 320

Arg Leu Arg Lys Ala Val Glu Ser Gly Lys Gln Arg Thr Leu Glu Ser
325 330 335

Trp Phe Gly Arg
340

-continued

<210> SEQ ID NO 403
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 403

ttttcaactg ccgtga 16

<210> SEQ ID NO 404
<211> LENGTH: 36
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 404

tcacggcagt tggtgcgcct cggaacgagg cgcaca 36

<210> SEQ ID NO 405
<211> LENGTH: 45
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 405

ttttcaactg cttagagaat ctaagcagtt ggtgcgcctc gttaa 45

<210> SEQ ID NO 406
<211> LENGTH: 21
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 406

aacgaggcgc acatttttt t 21

<210> SEQ ID NO 407
<211> LENGTH: 30
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 407

ccgaagcacg cacaaagcgg tgtgtcacga 30

<210> SEQ ID NO 408
<211> LENGTH: 25
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 408

gcgccgaggc cgttctctag cgtga 25

<210> SEQ ID NO 409
<211> LENGTH: 36
<212> TYPE: DNA

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<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (3)
<223> OTHER INFORMATION: The n at this position can be a, c, t, or g.

<400> SEQUENCE: 409

tcnctgccgg ttttccggca gagacctcgg cgcact 36

<210> SEQ ID NO 410
<211> LENGTH: 55
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Description of Artificial Sequence: Synthetic

<400> SEQUENCE: 410

gtatacagcg tcacgctaga gaacggcgtg acccaccgct ttgtgcgtgc ttcgg 55

1. A method for detecting a target nucleic acid, comprising:

a) generating a cleavage structure that is cleavable by Mja FEN-1 endonuclease, wherein said cleavage structure comprises:

i. said target nucleic acid; and

ii. a displaced 5' nucleic acid arm;

b) cleaving said cleavage structure with a thermostable 5' nuclease that lacks synthetic activity to release said displaced 5' nucleic acid arm; and

c) detecting the cleavage of said cleavage structure to detect said target nucleic acid.

2. The method of claim 1, wherein a plurality of said cleavage structures are formed and cleaved.

3. The method of claim 2, wherein a plurality of cleavage structures are formed on a single copy of said target nucleic acid.

4. The method of claim 2, wherein said plurality of cleavage structures are formed and cleaved under isothermal conditions.

5. The method of claim 1, wherein said displaced 5' nucleic acid arm comprises are region that is complementary to said target nucleic acid.

6. The method of claim 5, wherein said thermostable 5' nuclease comprises a FEN-1 endonuclease.

7. The method of claim 5, wherein said thermostable 5' nuclease comprises a polymerase having 5' nuclease activity.

8. The method of claim 7, wherein said polymerase is derived from an organism of the genus *Thermus*.

9. The method of claim 8, wherein said organism comprises *Thermus aquaticus*.

10. The method of claim 1, wherein said target nucleic acid comprises a nucleic acid isolated from a biological sample.

11. The method of claim 10, wherein said biological sample comprises an infectious disease organism.

12. The method of claim 1, wherein said target nucleic acid comprises DNA.

13. The method of claim 1, wherein said target nucleic acid comprises RNA.

14. The method of claim 1, wherein said target nucleic acid comprises a synthetic nucleic acid molecule.

15. The method of claim 14, wherein said synthetic nucleic acid molecule is generated in a polymerase chain reaction.

16. The method of claim 1, wherein at least one nucleic acid molecule in said cleavage structure comprises a nucleotide analog.

17. The method of claim 16, wherein said non-natural nucleotide comprises a degenerate nucleotide.

18. The method of claim 1, wherein said cleavage structure comprises said target nucleic acid hybridized to a probe nucleic acid, said probe nucleic acid comprising said displaced 5' nucleic acid arm.

19. The method of claim 18, wherein said probe nucleic acid comprises a label.

20. The method of claim 19, wherein said label comprises a fluorescent label.

21. The method of claim 18, wherein said cleavage structure further comprises an upstream nucleic acid molecule hybridized to said target nucleic acid, said upstream nucleic acid molecule having a 3' moiety that overlaps with a region of the target nucleic that is hybridized to said probe nucleic acid.

22. The method of claim 21, wherein said 3' moiety of said upstream nucleic acid molecule comprises a nucleotide.

23. The method of claim 22, wherein said nucleotide is complementary to said target nucleic acid.

24. The method of claim 22, wherein said 3' moiety of said upstream nucleic acid molecule comprises a 3' terminal nucleotide that is not complementary to said target nucleic acid.

25. The method of claim 22, wherein said 3' moiety of said upstream nucleic acid molecule consists of a 3' terminal nucleotide that is not complementary to said target nucleic acid.

26. The method of claim 1, wherein said detecting the cleavage of said cleavage structure comprises detection of fluorescence.

27. The method of claim 1, wherein said detecting the cleavage of said cleavage structure comprises detection of mass.

28. The method of claim 1, wherein said detecting the cleavage of said cleavage structure comprises detection of fluorescence energy transfer.

29. The method of claim 1, wherein said detecting the cleavage of said cleavage structure comprises detection selected from the group consisting of detection of radioactivity, luminescence, phosphorescence, fluorescence polarization, and charge.

30. The method of claim 1, wherein said detecting the cleavage of said cleavage structure comprises directly detecting a nucleic acid fragment generated by cleavage of said cleavage structure.

31. The method of claim 30, wherein said fragment comprises said displaced 5' nucleic acid arm.

32. The method of claim 30, wherein said fragment comprises two or more nucleotides.

33. The method of claim 1, wherein said detecting the cleavage of said cleavage structure comprises indirectly detecting a nucleic acid fragment generated by cleavage of said cleavage structure.

34. The method of claim 33, wherein said indirectly detecting comprises hybridizing said nucleic acid fragment to a template nucleic acid to form a detection complex.

35. The method of claim 34, wherein said detection complex is configured to be bound by a protein.

36. The method of claim 35, wherein said protein is a ligase.

37. The method of claim 35, wherein said protein is a polymerase.

38. The method of claim 36, wherein said polymerase is a DNA polymerase.

39. The method of claim 36, wherein said polymerase is an RNA polymerase.

40. The method of claim 1, wherein at least one nucleic acid molecule in said cleavage structure is attached to a solid support.

41. A method for detecting a target nucleic acid, comprising:

a) generating a cleavage structure that is cleavable by Mja FEN-1 endonuclease, wherein said cleavage structure comprises:

iii. said target nucleic acid; and

iv. a displaced 5' nucleic acid arm;

b) cleaving said cleavage structure with a thermostable FEN-1 nuclease to release said displaced 5' nucleic acid arm; and

c) detecting the cleavage of said cleavage structure to detect said target nucleic acid.

42. The method of claim 41, wherein a plurality of said cleavage structures are formed and cleaved.

43. The method of claim 42, wherein a plurality of cleavage structures are formed on a single copy of said target nucleic acid.

44. The method of claim 42, wherein said plurality of cleavage structures are formed and cleaved under isothermal conditions.

45. The method of claim 41, wherein said target nucleic acid comprises a nucleic acid isolated from a biological sample.

46. The method of claim 45, wherein said biological sample comprises an infectious disease organism.

47. The method of claim 41, wherein said target nucleic acid comprises DNA.

48. The method of claim 41, wherein said target nucleic acid comprises RNA.

49. The method of claim 41, wherein said target nucleic acid comprises a synthetic nucleic acid molecule.

50. The method of claim 49, wherein said synthetic nucleic acid molecule is generated in a polymerase chain reaction.

51. The method of claim 41, wherein at least one nucleic acid molecule in said cleavage structure comprises a nucleotide analog.

52. The method of claim 51, wherein said nucleotide analog comprises a degenerate nucleotide.

53. The method of claim 41, wherein said cleavage structure comprises said target nucleic acid hybridized to a probe nucleic acid, said probe nucleic acid comprising said displaced 5' nucleic acid arm.

54. The method of claim 53, wherein said probe nucleic acid comprises a label.

55. The method of claim 54, wherein said label comprises a fluorescent label.

56. The method of claim 53, wherein said cleavage structure further comprises an upstream nucleic acid molecule hybridized to said target nucleic acid, said upstream nucleic acid molecule having a 3' moiety that overlaps with a region of the target nucleic that is hybridized to said probe nucleic acid.

57. The method of claim 56, wherein said 3' moiety comprises a nucleotide.

58. The method of claim 56, wherein said 3' moiety of said upstream nucleic acid molecule comprises a nucleotide that is complementary to said target nucleic acid.

59. The method of claim 56, wherein said 3' moiety of said upstream nucleic acid molecule comprises a 3' terminal nucleotide that is not complementary to said target nucleic acid.

60. The method of claim 56, wherein said 3' moiety of said upstream nucleic acid molecule consists of a 3' terminal nucleotide that is not complementary to said target nucleic acid.

61. The method of claim 41, wherein said detecting the cleavage of said cleavage structure comprises detection of fluorescence.

62. The method of claim 41, wherein said detecting the cleavage of said cleavage structure comprises detection of mass.

63. The method of claim 41, wherein said detecting the cleavage of said cleavage structure comprises detection of fluorescence energy transfer.

64. The method of claim 41, wherein said detecting the cleavage of said cleavage structure comprises detection selected from the group consisting of detection of radioactivity, luminescence, phosphorescence, fluorescence polarization, and charge.

65. The method of claim 41, wherein said detecting the cleavage of said cleavage structure comprises directly detecting a nucleic acid fragment generated by cleavage of said cleavage structure.

66. The method of claim 65, wherein said fragment comprises said displaced 5' nucleic acid arm.

67. The method of claim 65, wherein said fragment comprises two or more nucleotides.

68. The method of claim 41, wherein said detecting the cleavage of said cleavage structure comprises indirectly detecting a nucleic acid fragment generated by cleavage of said cleavage structure.

69. The method of claim 68, wherein said indirectly detecting comprises hybridizing said nucleic acid fragment to a template nucleic acid to form a detection complex.

70. The method of claim 69, wherein said detection complex is configured to be bound by a protein.

71. The method of claim 70, wherein said protein is a ligase.

72. The method of claim 70, wherein said protein is a polymerase.

73. The method of claim 72, wherein said polymerase is a DNA polymerase.

74. The method of claim 72, wherein said polymerase is an RNA polymerase.

75. The method of claim 41, wherein at least one nucleic acid molecule in said cleavage structure is attached to a solid support.

* * * * *