

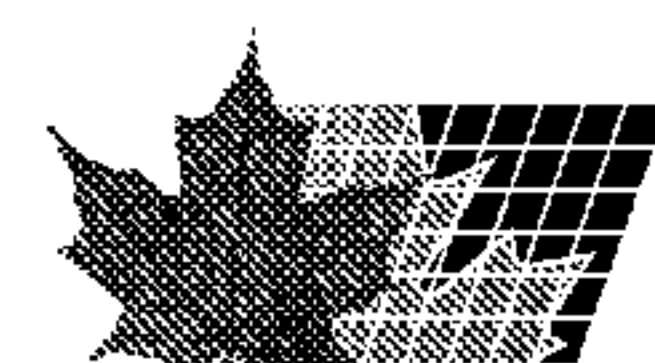


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(54) Titre : DOMAINES DE LIAISON DANS LES PROTEINES NOTCH ET DELTA
(54) Title: BINDING DOMAINS IN NOTCH AND DELTA PROTEINS

(57) **Abrégé/Abstract:**

The present invention relates to nucleotide sequences of the human Notch and Delta genes, and amino acid sequences of their encoded proteins, as well as fragments thereof containing an antigenic determinant or which are functionally active. The invention is also directed to fragments (termed herein "adhesive fragments"), and the sequences thereof, of the proteins ("toporythmic proteins") encoded by toporythmic genes which mediate homotypic or heterotypic binding to toporythmic proteins. Toporythmic genes, as used herein, refers to the genes Notch, Delta and Serrate, as well as other members of the Delta/Serrate family which may be identified, e.g., by the methods described herein. Antibodies to human Notch and to adhesive fragments are additionally provided.



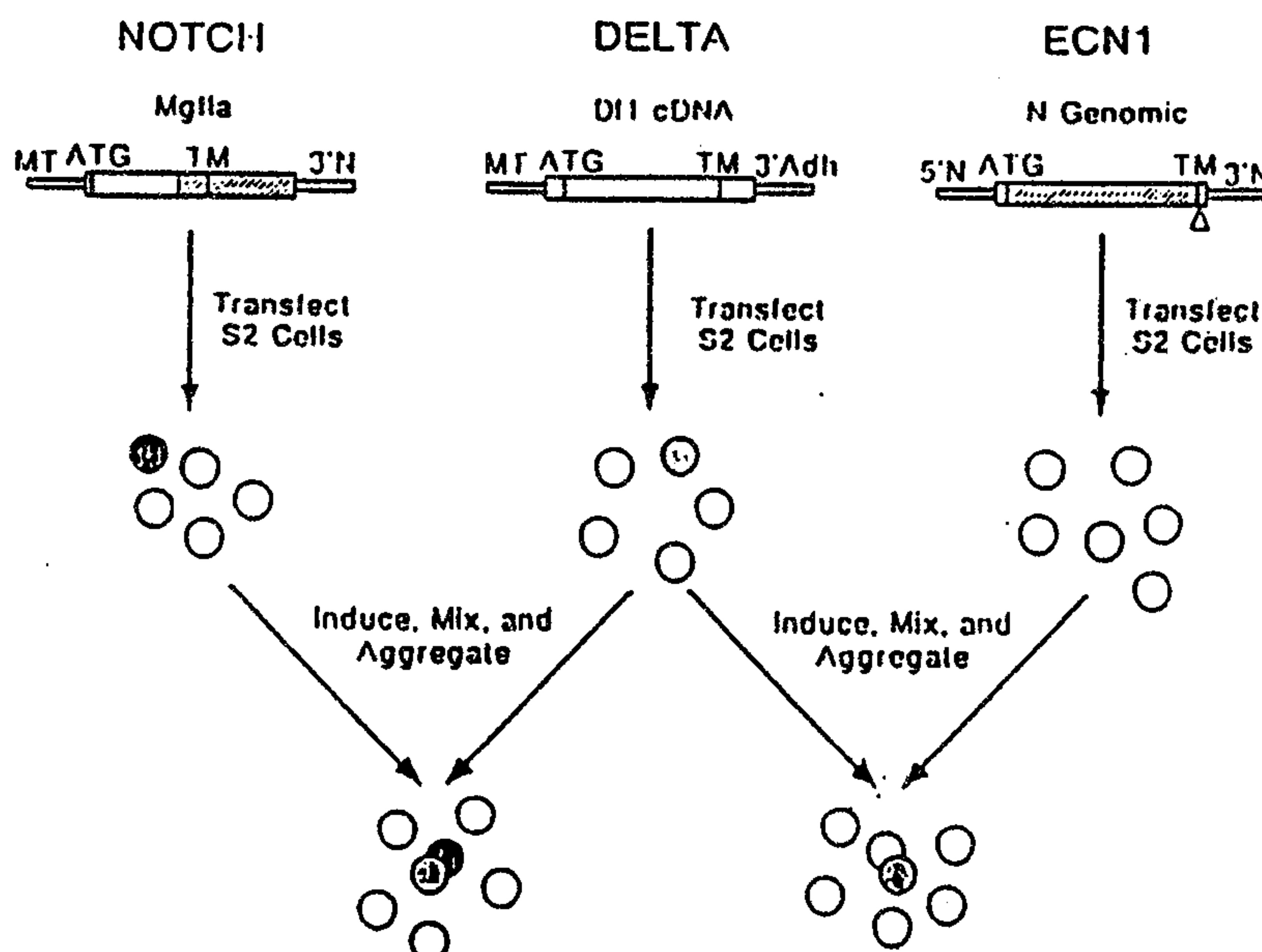
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(54) Title: BINDING DOMAINS IN NOTCH AND DELTA PROTEINS



(57) Abstract

The present invention relates to nucleotide sequences of the human *Notch* and *Delta* genes, and amino acid sequences of their encoded proteins, as well as fragments thereof containing an antigenic determinant or which are functionally active. The invention is also directed to fragments (termed herein "adhesive fragments"), and the sequences thereof, of the proteins ("toporythmic proteins") encoded by toporythmic genes which mediate homotypic or heterotypic binding to toporythmic proteins. Toporythmic genes, as used herein, refers to the genes *Notch*, *Delta* and *Serrate*, as well as other members of the *Delta/Serrate* family which may be identified, e.g., by the methods described herein. Antibodies to human *Notch* and to adhesive fragments are additionally provided.

BINDING DOMAINS IN NOTCH AND DELTA PROTEINS

This invention was made in part with the support of the United States government under Grant numbers GM 19093 and NS 26084 awarded by the Department of Health and Human Services. The United States government has certain rights in the invention.

1. INTRODUCTION

The present invention relates to the human Notch and Delta genes and their encoded products. The invention also relates to sequences (termed herein "adhesive sequences") within the proteins encoded by toporythmic genes which mediate homotypic or heterotypic binding to sequences within proteins encoded by toporythmic genes. Such genes include but are not limited to Notch, Delta, and Serrate.

2. BACKGROUND OF THE INVENTION

Genetic analyses in *Drosophila* have been extremely useful in dissecting the complexity of developmental pathways and identifying interacting loci. However, understanding the precise nature of the processes that underlie genetic interactions requires a knowledge of the biochemical properties of the protein products of the genes in question.

Null mutations in any one of the zygotic neurogenic loci -- Notch (N), Delta (Dl), mastermind (mam), Enhancer of Split (E(spl)), neuralized (neu), and big brain (bib) -- result in hypertrophy of the nervous system at the expense of ventral and lateral epidermal structures. This effect is due to the misrouting of epidermal precursor cells into a neuronal pathway, and implies that neurogenic gene function is necessary to divert cells within the neurogenic region from a neuronal fate to an

epithelial fate. Studies that assessed the effects of laser ablation of specific embryonic neuroblasts in grasshoppers (Doe and Goodman 1985, Dev. Biol. 111, 206-219) have shown that cellular interactions between neuroblasts and the surrounding accessory cells serve to inhibit these accessory cells from adopting a neuroblast fate. Together, these genetic and developmental observations have led to the hypothesis that the protein products of the neurogenic loci function as components of a cellular interaction mechanism necessary for proper epidermal development (Artavanis-Tsakonas, 1988, Trends Genet. 4, 95-100).

Sequence analyses (Wharton et al., 1985, Cell 43, 567-581; Kidd et al., 1986, Mol. Cell. Biol. 6, 3094-3108; Vassin et al., 1987, EMBO J. 6, 3431-3440; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735) have shown that two of the neurogenic loci, Notch and Delta, appear to encode transmembrane proteins that span the membrane a single time. The Notch gene encodes a ~300 kd protein (we use "Notch" to denote this protein) with a large N-terminal extracellular domain that includes 36 epidermal growth factor (EGF)-like tandem repeats followed by three other cysteine-rich repeats, designated Notch/lin-12 repeats (Wharton et al., 1985, Cell 43, 567-581; Kidd et al., 1986, Mol. Cell Biol. 6, 3094-3108; Yochem et al., 1988, Nature 335, 547-550). Delta encodes a ~100 kd protein (we use "Delta" to denote DLZM, the protein product of the predominant zygotic and maternal transcripts; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735) that has nine EGF-like repeats within its extracellular domain (Vassin et al., 1987, EMBO J. 6, 3431-3440; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735). Although little is known about the functional significance of these repeats, the EGF-like

motif has been found in a variety of proteins, including those involved in the blood clotting cascade (Furie and Furie, 1988, Cell 53, 505-518). In particular, this motif has been found in extracellular proteins such as the blood clotting factors IX and X (Rees et al., 1988, EMBO J. 7, 2053-2061; Furie and Furie, 1988, Cell 53, 505-518), in other Drosophila genes (Knust et al., 1987, EMBO J. 761-766; Rothberg et al., 1988, Cell 55, 1047-1059), and in some cell-surface receptor proteins, such as thrombomodulin (Suzuki et al., 1987, EMBO J. 6, 1891-1897) and LDL receptor (Sudhof et al., 1985, Science 228, 815-822). A protein binding site has been mapped to the EGF repeat domain in thrombomodulin and urokinase (Kurosawa et al., 1988, J. Biol. Chem 263, 5993-5996; Appella et al., 1987, J. Biol. Chem. 262, 4437-4440).

An intriguing array of interactions between Notch and Delta mutations has been described (Vassin, et al., 1985, J. Neurogenet. 2, 291-308; Shepard et al., 1989, Genetics 122, 429-438; Xu et al., 1990, Genes Dev., 4, 464-475). A number of genetic studies (summarized in Alton et al., 1989, Dev. Genet. 10, 261-272) has indicated that the gene dosages of Notch and Delta in relation to one another are crucial for normal development. A 50% reduction in the dose of Delta in a wild-type Notch background causes a broadening of the wing veins creating a "delta" at the base (Lindsley and Grell, 1968, Publication Number 627, Washington, D.C., Carnegie Institute of Washington). A similar phenotype is caused by a 50% increase in the dose of Notch in a wild-type Delta background (a "Confluens" phenotype; Welshons, 1965, Science 150, 1122-1129). This Delta phenotype is partially suppressed by a reduction in the Notch dosage. Recent work in our laboratories has shown

that lethal interactions between alleles that correlate with alterations in the EGF-like repeats in Notch can be rescued by reducing the dose of Delta (Xu et al., 1990, Genes Dev. 4, 464-475). Xu et al.
5 (1990, Genes Dev. 4, 464-475) found that null mutations at either Delta or mam suppress lethal interactions between heterozygous combinations of certain Notch alleles, known as the Abruptex (Ax) mutations. Ax alleles are associated with missense
10 mutations within the EGF-like repeats of the Notch extracellular domain (Kelley et al., 1987, Cell 51, 539-548; Hartley et al., 1987, EMBO J. 6, 3407-3417).

Notch is expressed on axonal processes during the outgrowth of embryonic neurons (Johansen et
15 al., 1989, J. Cell Biol. 109, 2427-2440; Kidd et al., 1989, Genes Dev. 3, 1113-1129).

A study has shown that certain Ax alleles of Notch can severely alter axon pathfinding during sensory neural outgrowth in the imaginal discs,
20 although it is not yet known whether aberrant Notch expression in the axon itself or the epithelium along which it grows is responsible for this defect (Palka et al., 1990, Development 109, 167-175).

25 3. SUMMARY OF THE INVENTION

The present invention relates to nucleotide sequences of the human Notch and Delta genes, and amino acid sequences of their encoded proteins, as well as fragments thereof containing an antigenic
30 determinant or which are functionally active. The invention is also directed to fragments (termed herein "adhesive fragments"), and the sequences thereof, of the proteins ("toporythmic proteins") encoded by toporythmic genes which mediate homotypic or
35 heterotypic binding to toporythmic proteins.

Toporythmic genes, as used herein, refers to the genes Notch, Delta, and Serrate, as well as other members of the Delta/Serrate family which may be identified, e.g., by the methods described in Section 5.3, infra.

- 5 Analogous and derivatives of the adhesive fragments which retain binding activity are also provided. Antibodies to human Notch and to adhesive fragments are additionally provided.

- 10 In specific embodiments, the adhesive fragment of Notch is that fragment comprising the Notch sequence most homologous to Drosophila Notch EGF-like repeats 11 and 12; the adhesive fragment of Delta mediating heterotypic binding is that fragment comprising the sequence most homologous to Drosophila
15 Delta amino acids 1-230; the adhesive fragment of Delta mediating homotypic binding is that fragment comprising the sequence most homologous to Drosophila Delta amino acids 32-230; and the adhesive fragment of Serrate is that fragment comprising the sequence most
20 homologous to Drosophila Serrate amino acids 85-283 or 79-282.

3.1. DEFINITIONS

- As used herein, the following terms shall
25 have the meanings indicated:

- | | | |
|----------|---|------------------------------|
| AA | = | amino acid |
| EGF | = | epidermal growth factor |
| ELR | = | EGF-like (homologous) repeat |
| IC | = | intracellular |
| 30 PCR | = | polymerase chain reaction |

- As used herein, underscoring the name of a gene shall indicate the gene, in contrast to its encoded protein product which is indicated by the name of the gene in the absence of any underscoring. For
35 example, "Notch" shall mean the Notch gene, whereas

"Notch" shall indicate the protein product of the Notch gene.

4. DESCRIPTION OF THE FIGURES

5 Figure 1. Expression Constructs and
Experimental Design for Examining Notch-Delta
Interactions. S2 cells at log phase growth were
transiently transfected with one of the three
constructs shown. Notch encoded by the MG11a minigene
10 (a cDNA/genomic chimeric construct: cDNA-derived
sequences are represented by stippling, genomically
derived sequences by diagonal-hatching (Ramos et al.,
1989, Genetics 123, 337-348)) was expressed following
insertion into the metallothionein promoter vector
15 pRmHa-3 (Bunch et al., 1988, Nucl. Acids Res. 16,
1043-1061). Delta encoded by the D11 cDNA (Kopczynski
et al., 1988, Genes Dev. 2, 1723-1735) was expressed
after insertion into the same vector. The
extracellular Notch (ECN1) variant was derived from a
20 genomic cosmid containing the complete Notch locus
(Ramos et al., 1989, Genetics 123, 337-348) by
deleting the coding sequence for amino acids 1790-2625
from the intracellular domain (denoted by δ ; Wharton
et al., 1985, Cell 43, 567-581), leaving 25 membrane-
25 proximal residues from the wild-type sequence fused to
a novel 59 amino acid tail (see Experimental
Procedures, Section 6.1, infra). This construct was
expressed under control of the Notch promoter region.
For constructs involving the metallothionein vector,
30 expression was induced with CuSO₄ following
transfection. Cells were then mixed, incubated under
aggregation conditions, and scored for their ability
to aggregate using specific antisera and
immunofluorescence microscopy to visualize expressing
35 cells. MT, metallothionein promoter; ATG, translation

start site; TM, transmembrane domain; 3' N, Notch gene polyadenylation signal; 3' Adh, polyadenylation signal from Adh gene; 5' N, Notch gene promoter region.

Figure 2. Expression of Notch and Delta in
5 Cultured Cells. (A) Lysates of nontransfected (S2) and Notch-transfected (N) cells induced with 0.7 mM CuSO₄ for 12-16 hr were prepared for sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), run on 3%-15% gradient gels, and blotted to
10 nitrocellulose. Notch was visualized using a monoclonal antibody (MAb C17.9C6) against the intracellular domain of Notch. Multiple bands below the major band at 300 kd may represent degradation products of Notch. (B) Lysates of nontransfected (S2)
15 and Delta-transfected (D1) cells visualized with a monoclonal antibody (MAb 201) against Delta. A single band of ~105 kd is detected. In both cases, there is no detectable endogenous Notch or Delta in the S2 cell line nor are there cross-reactive species. In each
20 lane, 10 µl of sample (prepared as described in Experimental Procedures) was loaded.

Figure 3. S2 Cells That Express Notch and Delta Form Aggregates. In all panels, Notch is shown in green and Delta in red.

- 25 (A) A single Notch⁺ cell. Note the prominent intracellular stain, including vesicular structures as well as an obviously unstained nucleus.
- (A) Bright-field micrograph of same field,
30 showing specificity of antibody staining.
- (B) A single Delta⁺ cell. Staining is primarily at the cell surface.
- (B) Bright-field micrograph of same field.

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(C) Aggregate of Delta⁺ cells from a 24 hr aggregation experiment. Note against that staining is primarily at the cell surface.

(D)-(F) An aggregate of Notch⁺ and Delta⁺ cells formed from a 1:1 mixture of singly transfected cell populations that was allowed to aggregate overnight at room temperature. (D) shows Notch⁺ cells in this aggregate; (E) shows Delta⁺ cells; and (F) is a double exposure showing both cell types. Bands of Notch and Delta are prominent at points of contact between Notch⁺ and Delta⁺ cells (arrows). In (F), these bands appear yellow because of the coincidence of green and red at these points. The apparently doubly stained single cell (•) is actually two cells (one on top of the other), one expressing Notch and the other Delta.

(G) and (H) Pseudocolor confocal micrographs of Notch⁺-Delta⁺ cell aggregates. Note that in (G) extensions (arrows) formed by at least two Delta⁺ cells completely encircle the Notch⁺ cell in the center of the aggregate. (H) shows an aggregate formed from a 2 hr aggregation experiment performed at 4°C. Intense bands of Notch are apparent within regions of contact with Delta⁺ cells.

(I) An aggregate composed of Delta⁺ cells and cells that express only the extracellular domain of Notch (ECN1 construct). Scale bar = 10 μm.

Figure 4. Notch and Delta are Associated in Cotransfected Cells. Staining for Notch is shown in the left column (A, C, and E) and that for Delta is shown in the right column (B, D, and F).

(A) and (B) S2 cell cotransfected with both Notch and Delta constructs. In general, there was a good correlation between Notch and Delta localization at the cell surface (arrows).

(C) and (D) Cotransfected cells were exposed to polyclonal anti-Notch antiserum (a 1:250 dilution of each anti-extracellular domain antiserum) for 1 hr at room temperature before fixation and staining with specific antisera. Note punctate staining of Notch and Delta and the correlation of their respective staining (arrows).

(E) and (F) Cells cotransfected with the extracellular Notch (ECN1) and Delta constructs, induced, and then patched using anti-Notch polyclonal antisera. There was a close correlation between ECN1 and Delta staining at the surface as observed for full-length Notch. Scale bar = 10 μ m.

Figure 5. Coimmunoprecipitation Shows that Delta and Notch are Associated in Lysates from Transfected S2 and Drosophila Embryonic Cells. In all experiments, Delta was precipitated from NP-40/deoxycholate lysates using a polyclonal anti-Delta rat antiserum precipitated with fixed Staph A cells, and proteins in the precipitated fraction were visualized on Western blots (for details, see Experimental Procedures). Lanes 1, 2, 3, and 5: Notch visualized with MAb C17.9C6; Lanes 4 and 6: Delta visualized using MAb 201.

In (A), lanes 1 and 2 are controls for these experiments. Lane 1 shows a polyclonal anti-Delta immunoprecipitation from cells that express Notch alone visualized for Notch. No Notch was detectable in this sample, indicating that the polyclonal anti-Delta does not cross-react with Notch. Lane 2 shows Notch-Delta cotransfected cells immunoprecipitated with Staph A without initial treatment with anti-Delta antiserum and visualized for Notch, demonstrating that Notch is not precipitated nonspecifically by the Staph A or secondary antibody. Lane 3 shows protein

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precipitated with anti-Delta antiserum visualized for Delta (Dl), and lane 4 shows the same sample visualized for Notch (N). Lane 4 shows that Notch coprecipitates with immunoprecipitated Delta. Note
5 that Notch appears as a doublet as is typical for Notch in immunoprecipitates.

(B) shows the same experiment using embryonic lysates rather than transfected cell lysates. Lane 5 shows protein precipitated with anti-
10 Delta antiserum visualized for Delta (Dl), and lane 6 shows the same sample visualized for Notch (N). These lanes demonstrate that Notch and Delta are stably associated in embryo lysates. Bands (in all lanes) below the Delta band are from Staph A (SA) and the
15 anti-Delta antiserum heavy (H) and light (L) chains.

Figure 6. Notch Expression Constructs and the Deletion Mapping of the Delta/Serrate Binding Domain. S2 cells in log phase growth were transiently transfected with the series of expression constructs
20 shown; the drawings represent the predicted protein products of the various Notch deletion mutants created. All expression constructs were derived from construct #1 pMtNMg. Transiently transfected cells
were mixed with Delta expressing cells from the stably
25 transformed line L49-6-7 or with transiently transfected Serrate expressing cells, induced with CuSO₄, incubated under aggregation conditions and then scored for their ability to aggregate using specific antisera and immunofluorescence microscopy.

30 Aggregates were defined as clusters of four or more cells containing both Notch and Delta/Serrate expressing cells. The values given for % Aggregation refer to the percentage of all Notch expressing cells found in such clusters either with Delta (Dl) (left
35 column) or with Serrate (Ser) (right column). The

various Notch deletion constructs are represented diagrammatically with splice lines indicating the ligation junctions. Each EGF repeat is denoted as a stippled rectangular box and numbers of the EGF repeats on either side of a ligation junction are noted. At the ligation junctions, partial EGF repeats produced by the various deletions are denoted by open boxes and closed brackets (for example see #23 Δ Cla+EGF(10-12)). Constructs #3-13 represent the ClaI deletion series. As diagrammed, four of the ClaI sites, in repeats 7, 9, 17 and 26, break the repeat in the middle, immediately after the third cysteine (denoted by open box repeats; see Figure 7 for further clarification), while the fifth and most 3' site breaks neatly between EGF repeats 30 and 31 (denoted by closed box repeat 31; again see Figure 7). In construct #15 split, EGF repeat 14 which carries the split point mutation, is drawn as a striped box. In construct #33 Δ Cla+XEGF(10-13), the Xenopus Notch derived EGF repeats are distinguished from Drosophila repeats by a different pattern of shading. SP, signal peptide; EGF, epidermal growth factor repeat; N, Notch/lin-12 repeat; TM, transmembrane domain; cdc10, cdc10/ankyrin repeats; PA, putative nucleotide binding consensus sequence; opa, polyglutamine stretch termed opa; Dl, Delta; Ser, Serrate.

Figure 7. Detailed Structure of Notch Deletion Constructs #19-24: Both EGF Repeats 11 and 12 are Required for Notch-Delta Aggregation. EGF repeats 10-13 are diagrammed at the top showing the regular spacing of the six cysteine residues (C). PCR products generated for these constructs (names and numbers as given in Figure 6) are represented by the heavy black lines and the exact endpoints are noted relative to the various EGF repeats. Ability to

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aggregate with Delta is recorded as (+) or (-) for each construct. The PCR fragments either break the EGF repeats in the middle, just after the third cysteine in the same place as four out of the five
5 ClaI sites, or exactly in between two repeats in the same place as the most C-terminal ClaI site.

Figure 8. Comparison of Amino Acid Sequence of EGF Repeats 11 and 12 from Drosophila and Xenopus Notch. The amino acid sequence of EGF repeats 11 and
10 12 of Drosophila Notch (Wharton et al., 1985, Cell 43:567-581; Kidd et al., 1986, Mol. Cell Biol. 6:3094-3108) is aligned with that of the same two EGF repeats from Xenopus Notch (Coffman et al., 1990, Science 249:1438-1441). Identical amino acids are boxed. The
15 six conserved cysteine residues of each EGF repeat and the Ca⁺⁺ binding consensus residues (Rees et al., 1988, EMBO J. 7:2053-2061) are marked with an asterisk (*). The leucine to proline change found in the Xenopus PCR clone that failed to aggregate is noted
20 underneath.

Figure 9. Constructs Employed in this Study. Schematic diagrams of the Delta variants defined in Table IV are shown. Extracellular, amino-
proximal terminus is to the left in each case. S,
25 signal peptide; "EGF", EGF-like motifs; M, membrane-spanning helix; H, stop-transfer sequence; solid lines, other Delta sequences; hatched lines, neuroglial sequences. Arrowheads indicate sites of translatable linker insertions. Sca, ScaI; Nae, NaeI;
30 Bam, BamHI; Bgl, BglII; ELR, EGF-like repeat; Bst, BstEII; Dde, DdeI; Stu, StuI; NG1-NG5, Delta-neuroglial chimeras.

Figure 9A. Dependence of Aggregation on Input DNA Amounts. A, Heterotypic aggregation
35 observed using S2 cell populations transiently

transfected, respectively, with varied amounts of pMTD11 DNA (2, 4, 10 or 20 μ g/plate) that were subsequently incubated under aggregation conditions with S2 cell populations transiently transfected with a constant amount of pMtNMg DNA (20 μ g/plate). Data presented are mean fraction (%) of Delta cells in aggregates of four or more cells $\pm$ standard error for each input DNA amount (N = 3 replicates, except 2 μ g and 10 μ g inputs for which N = 2). A minimum of 100 Delta-expressing cells were counted for each replicate. B, Homotypic aggregation observed using S2 cell populations transiently transfected, respectively, with varied amounts of pMTD11 DNA (2, 4, 10 or 20 μ g/plate) that were subsequently incubated under aggregation conditions. Data presented are mean fraction (%) of Delta cells in aggregates of four or more cells $\pm$ standard error for each input DNA amount (N = 3 replicates). A minimum of 500 Delta-expressing cells were counted for each replicate.

Figure 10. Delta-Serrate Amino-Terminal Sequence Alignment. Residues are numbered on the basis of conceptual translation of Delta (D1, upper sequence (SEQ ID NO:3); beginning at amino acid 24, ending at amino acid 226) and Serrate (Ser, lower sequence (SEQ ID NO:4); beginning at amino acid 85, ending at amino acid 283) coding sequences. Vertical lines between the two sequences indicates residues that are identical within the Delta and Serrate sequences, as aligned. Dots represent gaps in the alignment. Boxes enclose cysteine residues within the aligned regions. N1, amino-proximal domain 1; N2, amino-proximal domain 2; N3, amino-proximal domain 3. Translatable insertions associated with STU B [replacement of Delta amino acid 132 (A) with GKIFP] and NAE B [insertion of RKIF between Delta amino acid

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197 and amino acid 198] constructs, respectively, are depicted above the wild type Delta sequence.

Figure 11. Potential Geometries of Delta-Notch Interactions. A, Potential register of Delta (left) and Notch (right) molecules interacting between opposing plasma membranes. B, Potential register of Delta (left) and Notch (right) molecules interacting within the same plasma membranes. ELR, EGF-like repeat; open boxes, EGF-like repeats; dotted boxes, LNR repeats; solid boxes, membrane-spanning helices. Delta amino-terminal domain and Delta and Notch intracellular domains represented by ovals.

Figure 12. Potential Geometries of Delta-Delta Interactions. A and B, Potential register of Delta molecules interacting between opposing plasma membranes. B, Potential register of Delta molecules interacting within the same plasma membranes. Open boxes, EGF-like repeats; solid boxes, membrane-spanning helices. Delta amino-terminal extracellular and intracellular domains represented by ovals.

Figure 13. Primary Nucleotide Sequence of the Delta cDNA D11 (SEQ ID NO:5) and Delta amino acid sequence (SEQ ID NO:6) The DNA sequence of the 5'-3' strand of the D11 cDNA is shown, which contains a number of corrections in comparison to that presented in Kopczynski et al. (1988, Genes Dev. 2, 1723-1735).

Figure 14. Primary Nucleotide Sequence of the Neuroglian cDNA 1B7A-250 (SEQ ID NO:7). This is the DNA sequence of a portion of the 5'-3' strand of the 1B7A-250 cDNA (A.J. Bieber, pers. comm.; Hortsch et al., 1990, Neuron 4, 697-709). Nucleotide 2890 corresponds to the first nucleotide of an isoleucine codon that encodes amino acid 952 of the conceptually translated neuroglian-long form protein.

Figure 15. Nucleic Acid Sequence Homologies Between Serrate and Delta. A portion of the Drosophila Serrate nucleotide sequence (SEQ ID NO:8), with the encoded Serrate protein sequence (SEQ ID NO:9) written below, (Fleming et al., 1990, Genes & Dev. 4, 2188-2201 at 2193-94) is shown. The four regions showing high sequence homology with the Drosophila Delta sequence are numbered above the line and indicated by brackets. The total region of homology spans nucleotide numbers 627 through 1290 of the Serrate nucleotide sequence (numbering as in Figure 4 of Fleming et al., 1990, Genes & Dev. 4, 2188-2201).

Figure 16. Primers used for PCR in the Cloning of Human Notch. The sequence of three primers used for PCR to amplify DNA in a human fetal brain cDNA library are shown. The three primers, cdc1 (SEQ ID NO:10), cdc2 (SEQ ID NO:11), and cdc3 (SEQ ID NO:12), were designed to amplify either a 200 bp or a 400 bp fragment as primer pairs cdc1/cdc2 or cdc1/cdc3, respectively. I: inosine.

Figure 17. Schematic Diagram of Human Notch Clones. A schematic diagram of human Notch is shown. Heavy bold-face lines below the diagram show that portion of the Notch sequence contained in each of the four cDNA clones. The location of the primers used in PCR, and their orientation, are indicated by arrows.

Figure 18. Human Notch Sequences Aligned with Drosophila Notch Sequence. Numbered vertical lines correspond to Drosophila Notch coordinates. Horizontal lines below each map show where clones lie relative to stretches of sequence (thick horizontal lines).

Figure 19. Nucleotide Sequences of Human Notch Contained in Plasmid cDNA Clone hN2k. Figure

19A: The DNA sequence (SEQ ID NO:13) of a portion of the human Notch insert is shown, starting at the EcoRI site at the 3' end, and proceeding in the 3' to 5' direction. Figure 19B: The DNA sequence (SEQ ID NO:14) of a portion of the human Notch insert is shown, starting at the EcoRI site at the 5' end, and proceeding in the 5' to 3' direction. Figure 19C: The DNA sequence (SEQ ID NO:15) of a portion of the human Notch insert is shown, starting 3' of the sequence shown in Figure 19B, and proceeding in the 5' to 3' direction. The sequences shown are tentative, subject to confirmation by determination of overlapping sequences.

Figure 20. Nucleotide Sequences of Human Notch Contained in Plasmid cDNA clone hN3k. Figure 20A: The DNA sequence (SEQ ID NO:16) of a portion of the human Notch insert is shown, starting at the EcoRI site at the 3' end, and proceeding in the 3' to 5' direction. Figure 20B: The DNA sequence (SEQ ID NO:17) of a portion of the human Notch insert is shown, starting at the EcoRI site at the 5' end, and proceeding in the 5' to 3' direction. Figure 20C: The DNA sequence (SEQ ID NO:18) of a portion of the human Notch insert is shown, starting 3' of the sequence shown in Figure 20B, and proceeding in the 5' to 3' direction. Figure 20D: The DNA sequence (SEQ ID NO:19) of a portion of the human Notch insert is shown, starting 5' of the sequence shown in Figure 20A, and proceeding in the 3' to 5' direction. The sequences shown are tentative, subject to confirmation by determination of overlapping sequences.

Figure 21. Nucleotide Sequences of Human Notch Contained in Plasmid cDNA clone hN4k. Figure 21A: The DNA sequence (SEQ ID NO:20) of a portion of the human Notch insert is shown, starting at the EcoRI

site at the 5' end, and proceeding in the 5' to 3' direction. Figure 21B: The DNA sequence (SEQ ID NO:21) of a portion of the human Notch insert is shown, starting near the 3' end, and proceeding in the 3' to 5' direction. The sequences shown are tentative, subject to confirmation by determination of overlapping sequences.

Figure 22. Nucleotide Sequences of Human Notch Contained in Plasmid cDNA Clone hN5k. Figure 22A: The DNA sequence (SEQ ID NO:22) of a portion of the human Notch insert is shown, starting at the EcoRI site at the 5' end, and proceeding in the 5' to 3' direction. Figure 22B: The DNA sequence (SEQ ID NO:23) of a portion of the human Notch insert is shown, starting near the 3' end, and proceeding in the 3' to 5' direction. Figure 22C: The DNA sequence (SEQ ID NO:24) of a portion of the human Notch insert is shown, starting 3' of the sequence shown in Figure 22A, and proceeding in the 5' to 3' direction. Figure 22D: The DNA sequence (SEQ ID NO:25) of a portion of the human Notch insert is shown, starting 5' of the sequence shown in Figure 22B, and proceeding in the 3' to 5' direction. The sequences shown are tentative, subject to confirmation by determination of overlapping sequences.

Figure 23. DNA (SEQ ID NO:31) and Amino Acid (SEQ ID NO:34) Sequences of Human Notch Contained in Plasmid cDNA Clone hN3k.

Figure 24. DNA (SEQ ID NO:33) and Amino Acid (SEQ ID NO:34) Sequences of Human Notch Contained in Plasmid cDNA Clone hN5k.

Figure 25. Comparison of hN5k With Other Notch Homologs. Figure 25A. Schematic representation of Drosophila Notch. Indicated are the signal sequence (signal), the 36 EGF-like repeats, the three

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Notch/lin-12 repeats, the transmembrane domain (TM), the six CDC10 repeats, the OPA repeat, and the PEST (proline, glutamic acid, serine, threonine)-rich region. Figure 25B. Alignment of the deduced amino acid sequence of hN5k with sequences of other Notch homologs. Amino acids are numbered on the left side. The cdc10 and PEST-rich regions are both boxed, and individual cdc10 repeats are marked. Amino acids which are identical in three or more sequences are highlighted. The primers used to clone hN5k are indicated below the sequences from which they were designed. The nuclear localization sequence (NLS), casein kinase II (CKII), and cdc2 kinase (cdc2) sites of the putative CcN motif of the vertebrate Notch homologs are boxed. The possible bipartite nuclear targeting sequence (BNTS) and proximal phosphorylation sites of Drosophila Notch are also boxed.

5. DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to nucleotide sequences of the human Notch and Delta genes, and amino acid sequences of their encoded proteins. The invention further relates to fragments (termed herein, "adhesive fragments") of the proteins encoded by toporythmic genes which mediate homotypic or heterotypic binding to toporythmic proteins or adhesive fragments thereof. Toporythmic genes, as used herein, shall mean the genes Notch, Delta, and Serrate, as well as other members of the Delta/Serrate family which may be identified, e.g. by the methods described in Section 5.3, infra.

The nucleic acid and amino acid sequences and antibodies thereto of the invention can be used for the detection and quantitation of mRNA for human Notch and Delta and adhesive molecules, to study

expression thereof, to produce human Notch and Delta and adhesive sequences, in the study and manipulation of differentiation processes.

For clarity of disclosure, and not by way of limitation, the detailed description of the invention will be divided into the following sub-sections:

- (i) Identification of and the sequences of toporythmic protein domains that mediate binding to toporythmic protein domains;
- (ii) The cloning and sequencing of human Notch and Delta;
- (iii) Identification of additional members of the Delta/Serrate family;
- (iv) The expression of toporythmic genes;
- (v) Identification and purification of the expressed gene product; and
- (vi) Generation of antibodies to toporythmic proteins and adhesive sequences thereof.

5.1. IDENTIFICATION OF AND THE SEQUENCES OF TOPORYTHMIC PROTEIN DOMAINS THAT MEDIATE BINDING TO TOPORYTHMIC PROTEIN DOMAINS

The invention provides for toporythmic protein fragments, and analogs or derivatives thereof, which mediate homotypic or heterotypic binding (and thus are termed herein "adhesive"), and nucleic acid sequences relating to the foregoing.

In a specific embodiment, the adhesive fragment of Notch is that comprising the portion of Notch most homologous to ELR 11 and 12, i.e., amino acid numbers 447 through 527 (SEQ ID NO:1) of the Drosophila Notch sequence (see Figure 8). In another specific embodiment, the adhesive fragment of Delta mediating homotypic binding is that comprising the

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portion of Delta most homologous to about amino acid numbers 32-230 of the Drosophila Delta sequence (SEQ ID NO:6). In yet another specific embodiment, the adhesive fragment of Delta mediating binding to Notch is that comprising the portion of Delta most homologous to about amino acid numbers 1-230 of the Drosophila Delta sequence (SEQ ID NO:6). In a specific embodiment relating to an adhesive fragment of Serrate, such fragment is that comprising the portion of Serrate most homologous to about amino acid numbers 85-283 or 79-282 of the Drosophila Serrate sequence (see Figure 10 (SEQ ID NO:4), and Figure 15 (SEQ ID NO:9)).

The nucleic acid sequences encoding toporythmic adhesive domains can be isolated from porcine, bovine, feline, avian, equine, or canine, as well as primate sources and any other species in which homologs of known toporythmic genes [including but not limited to the following genes (with the publication of sequences in parentheses): Notch (Wharton et al., 1985, Cell 43, 567-581), Delta (Vassin et al., 1987, EMBO J. 6, 3431-3440; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735; note corrections to the Kopczynski, et al. sequence found in Figure 13 hereof (SEQ ID NO:5 and SEQ ID NO:6)) and Serrate (Fleming et al., 1990, Genes & Dev. 4, 2188-2201)] can be identified. Such sequences can be altered by substitutions, additions or deletions that provide for functionally equivalent (adhesive) molecules. Due to the degeneracy of nucleotide coding sequences, other DNA sequences which encode substantially the same amino acid sequence as the adhesive sequences may be used in the practice of the present invention. These include but are not limited to nucleotide sequences comprising all or portions of the Notch, Delta, or Serrate genes which

are altered by the substitution of different codons that encode a functionally equivalent amino acid residue within the sequence, thus producing a silent change. Likewise, the adhesive protein fragments or derivatives thereof, of the invention include, but are not limited to, those containing, as a primary amino acid sequence, all or part of the amino acid sequence of the adhesive domains including altered sequences in which functionally equivalent amino acid residues are substituted for residues within the sequence resulting in a silent change. For example, one or more amino acid residues within the sequence can be substituted by another amino acid of a similar polarity which acts as a functional equivalent, resulting in a silent alteration. Substitutes for an amino acid within the sequence may be selected from other members of the class to which the amino acid belongs. For example, the nonpolar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, phenylalanine, tryptophan and methionine. The polar neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine. The positively charged (basic) amino acids include arginine, lysine and histidine. The negatively charged (acidic) amino acids include aspartic acid and glutamic acid.

Adhesive fragments of toporythmic proteins and potential derivatives, analogs or peptides related to adhesive toporythmic protein sequences, can be tested for the desired binding activity e.g., by the in vitro aggregation assays described in the examples herein. Adhesive derivatives or adhesive analogs of adhesive fragments of toporythmic proteins include but are not limited to those peptides which are substantially homologous to the adhesive fragments, or

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whose encoding nucleic acid is capable of hybridizing to the nucleic acid sequence encoding the adhesive fragments, and which peptides and peptide analogs have positive binding activity e.g., as tested in vitro by
5 an aggregation assay such as described in the examples sections infra. Such derivatives and analogs are envisioned and within the scope of the present invention.

The adhesive-protein related derivatives,
10 analogs, and peptides of the invention can be produced by various methods known in the art. The manipulations which result in their production can occur at the gene or protein level. For example, the cloned adhesive protein-encoding gene sequence can be
15 modified by any of numerous strategies known in the art (Maniatis, T., 1990, Molecular Cloning, A Laboratory Manual, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, New York). The sequence can be cleaved at appropriate sites with
20 restriction endonuclease(s), followed by further enzymatic modification if desired, isolated, and ligated in vitro. In the production of the gene encoding a derivative, analog, or peptide related to
an adhesive domain, care should be taken to ensure
25 that the modified gene remains within the same translational reading frame as the adhesive protein, uninterrupted by translational stop signals, in the gene region where the desired adhesive activity is encoded.

30 Additionally, the adhesive-encoding nucleic acid sequence can be mutated in vitro or in vivo, to create and/or destroy translation, initiation, and/or termination sequences, or to create variations in coding regions and/or form new restriction
35 endonuclease sites or destroy preexisting ones, to

facilitate further in vitro modification. Any technique for mutagenesis known in the art can be used, including but not limited to, in vitro site-directed mutagenesis (Hutchinson, C., et al., 1978, J. Biol. Chem 253, 6551), use of TAB® linkers (Pharmacia), etc.

Manipulations of the adhesive sequence may also be made at the protein level. Included within the scope of the invention are toporythmic protein fragments, analogs or derivatives which are differentially modified during or after translation, e.g., by glycosylation, acetylation, phosphorylation, proteolytic cleavage, linkage to an antibody molecule or other cellular ligand, etc. Any of numerous chemical modifications may be carried out by known techniques, including but not limited to specific chemical cleavage by cyanogen bromide, trypsin, chymotrypsin, papain, V8 protease, NaBH₄; acetylation, formylation, oxidation, reduction; metabolic synthesis in the presence of tunicamycin; etc.

In addition, analogs and peptides related to adhesive fragments can be chemically synthesized. For example, a peptide corresponding to a portion of a toporythmic protein which mediates the desired aggregation activity in vitro can be synthesized by use of a peptide synthesizer.

Another specific embodiment of the invention relates to fragments or derivatives of a Delta protein which have the ability to bind to a second Delta protein or fragment or derivative thereof, but do not bind to Notch. Such binding or lack thereof can be assayed in vitro as described in Section 8. By way of example, but not limitation, such a Delta derivative is that containing an insertion of the tetrapeptide

Arg-Lys-Ile-Phe between Delta residues 198 and 199 of the Drosophila protein.

5.2. THE CLONING AND SEQUENCING OF
HUMAN NOTCH AND DELTA

5 The invention further relates to the amino acid sequences of human Notch and human Delta and fragments and derivatives thereof which comprise an antigenic determinant (i.e., can be recognized by an antibody) or which are functionally active, as well as
10 nucleic acid sequences encoding the foregoing. "Functionally active" material as used herein refers to that material displaying one or more known functional activities associated with the full-length (wild-type) protein product, e.g., in the case of
15 Notch, binding to Delta, binding to Serrate, antigenicity (binding to an anti-Notch antibody), etc.

In specific embodiments, the invention provides fragments of a human Notch protein consisting
20 of at least 40 amino acids, or of at least 77 amino acids. In other embodiments, the proteins of the invention comprise or consist essentially of the intracellular domain, transmembrane region, extracellular domain, cdc10 region, Notch/lin-12
25 repeats, or the EGF-homologous repeats, or any combination of the foregoing, of a human Notch protein. Fragments, or proteins comprising fragments, lacking some or all of the EGF-homologous repeats of human Notch are also provided.

30 In other specific embodiments, the invention is further directed to the nucleotide sequences and subsequences of human Notch and human Delta consisting of at least 25 nucleotides, at least 50 nucleotides, or at least 121 nucleotides. Nucleic acids encoding
35 the proteins and protein fragments described above are also provided, as well as nucleic acids complementary

to and capable of hybridizing to such nucleic acids. In one embodiment, such a complementary sequence may be complementary to a human Notch cDNA sequence of at least 25 nucleotides, or of at least 121 nucleotides.

5 In a preferred aspect, the invention relates to cDNA sequences encoding human Notch or a portion thereof. In a specific embodiment, the invention relates to the nucleotide sequence of the human Notch gene or cDNA, in particular, comprising those sequences depicted in

10 Figures 19, 20, 21 and/or 22 (SEQ ID NO:13 through NO:25), or contained in plasmids hN3k, hN4k, or hN5k (see Section 9, infra), and the encoded Notch protein sequences. As is readily apparent, as used herein, a

15 "nucleic acid encoding a fragment or portion of a Notch protein" shall be construed as referring to a nucleic acid encoding only the recited fragment or portion of the Notch protein and not other portions of the Notch protein.

In a preferred, but not limiting, aspect of

20 the invention, a human Notch DNA sequence can be cloned and sequenced by the method described in Section 9, infra.

A preferred embodiment for the cloning of

human Delta, presented as a particular example but not

25 by way of limitation follows:

A human expression library is constructed by methods known in the art. For example, human mRNA is isolated, cDNA is made and ligated into an expression vector (e.g., a bacteriophage derivative) such that it

30 is capable of being expressed by the host cell into which it is then introduced. Various screening assays can then be used to select for the expressed human Delta product. In one embodiment, selection can be carried out on the basis of positive binding to the

35 adhesive domain of human Notch, (i.e., that portion of

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human Notch most homologous to Drosophila ELR 11 and 12 (SEQ ID NO:1)). In an alternative embodiment, anti-Delta antibodies can be used for selection.

5 In another preferred aspect, PCR is used to amplify the desired sequence in the library, prior to selection. For example, oligonucleotide primers representing part of the adhesive domains encoded by a homologue of the desired gene can be used as primers in PCR.

10 The above-methods are not meant to limit the following general description of methods by which clones of human Notch and Delta may be obtained.

Any human cell can potentially serve as the nucleic acid source for the molecular cloning of the
15 Notch and Delta gene. The DNA may be obtained by standard procedures known in the art from cloned DNA (e.g., a DNA "library"), by chemical synthesis, by cDNA cloning, or by the cloning of genomic DNA, or fragments thereof, purified from the desired human
20 cell. (See, for example Maniatis et al., 1982, Molecular Cloning, A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York; Glover, D.M. (ed.), 1985, DNA Cloning: A Practical Approach, MRL Press, Ltd., Oxford, U.K. Vol. I, II.)
25 Clones derived from genomic DNA may contain regulatory and intron DNA regions in addition to coding regions; clones derived from cDNA will contain only exon sequences. Whatever the source, the gene should be molecularly cloned into a suitable vector for
30 propagation of the gene.

In the molecular cloning of the gene from genomic DNA, DNA fragments are generated, some of which will encode the desired gene. The DNA may be cleaved at specific sites using various restriction
35 enzymes. Alternatively, one may use DNase in the

presence of manganese to fragment the DNA, or the DNA can be physically sheared, as for example, by sonication. The linear DNA fragments can then be separated according to size by standard techniques, including but not limited to, agarose and polyacrylamide gel electrophoresis and column chromatography.

Once the DNA fragments are generated, identification of the specific DNA fragment containing the desired gene may be accomplished in a number of ways. For example, if an amount of a portion of a Notch or Delta (of any species) gene or its specific RNA, or a fragment thereof e.g., the adhesive domain, is available and can be purified and labeled, the generated DNA fragments may be screened by nucleic acid hybridization to the labeled probe (Benton, W. and Davis, R., 1977, Science 196, 180; Grunstein, M. And Hogness, D., 1975, Proc. Natl. Acad. Sci. U.S.A. 72, 3961). Those DNA fragments with substantial homology to the probe will hybridize. It is also possible to identify the appropriate fragment by restriction enzyme digestion(s) and comparison of fragment sizes with those expected according to a known restriction map if such is available. Further selection can be carried out on the basis of the properties of the gene. Alternatively, the presence of the gene may be detected by assays based on the physical, chemical, or immunological properties of its expressed product. For example, cDNA clones, or DNA clones which hybrid-select the proper mRNAs, can be selected which produce a protein that, e.g., has similar or identical electrophoretic migration, isoelectric focusing behavior, proteolytic digestion maps, in vitro aggregation activity ("adhesiveness") or antigenic properties as known for Notch or Delta.

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If an antibody to Notch or Delta is available, the Notch or Delta protein may be identified by binding of labeled antibody to the putatively Notch or Delta synthesizing clones, in an ELISA (enzyme-linked immunosorbent assay)-type procedure.

The Notch or Delta gene can also be identified by mRNA selection by nucleic acid hybridization followed by in vitro translation. In this procedure, fragments are used to isolate complementary mRNAs by hybridization. Such DNA fragments may represent available, purified Notch or Delta DNA of another species (e.g., Drosophila). Immunoprecipitation analysis or functional assays (e.g., aggregation ability in vitro; see examples infra) of the in vitro translation products of the isolated products of the isolated mRNAs identifies the mRNA and, therefore, the complementary DNA fragments that contain the desired sequences. In addition, specific mRNAs may be selected by adsorption of polysomes isolated from cells to immobilized antibodies specifically directed against Notch or Delta protein. A radiolabelled Notch or Delta cDNA can be synthesized using the selected mRNA (from the adsorbed polysomes) as a template. The radiolabelled mRNA or cDNA may then be used as a probe to identify the Notch or Delta DNA fragments from among other genomic DNA fragments.

Alternatives to isolating the Notch or Delta genomic DNA include, but are not limited to, chemically synthesizing the gene sequence itself from a known sequence or making cDNA to the mRNA which encodes the Notch or Delta gene. For example, RNA for cDNA cloning of the Notch or Delta gene can be isolated from cells which express Notch or Delta.

Other methods are possible and within the scope of the invention.

The identified and isolated gene can then be inserted into an appropriate cloning vector. A large
5 number of vector-host systems known in the art may be used. Possible vectors include, but are not limited to, plasmids or modified viruses, but the vector system must be compatible with the host cell used. Such vectors include, but are not limited to,
10 bacteriophages such as lambda derivatives, or plasmids such as PBR322 or pUC plasmid derivatives. The insertion into a cloning vector can, for example, be accomplished by ligating the DNA fragment into a cloning vector which has complementary cohesive
15 termini. However, if the complementary restriction sites used to fragment the DNA are not present in the cloning vector, the ends of the DNA molecules may be enzymatically modified. Alternatively, any site desired may be produced by ligating nucleotide
20 sequences (linkers) onto the DNA termini; these ligated linkers may comprise specific chemically synthesized oligonucleotides encoding restriction endonuclease recognition sequences. In an alternative method, the cleaved vector and Notch or Delta gene may
25 be modified by homopolymeric tailing. Recombinant molecules can be introduced into host cells via transformation, transfection, infection, electroporation, etc., so that many copies of the gene sequence are generated.

30 In an alternative method, the desired gene may be identified and isolated after insertion into a suitable cloning vector in a "shot gun" approach. Enrichment for the desired gene, for example, by size fractionization, can be done before insertion into the
35 cloning vector.

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In specific embodiments, transformation of host cells with recombinant DNA molecules that incorporate the isolated Notch or Delta gene, cDNA, or synthesized DNA sequence enables generation of multiple copies of the gene. Thus, the gene may be obtained in large quantities by growing transformants, isolating the recombinant DNA molecules from the transformants and, when necessary, retrieving the inserted gene from the isolated recombinant DNA.

10 The human Notch and Delta sequences provided by the instant invention include those nucleotide sequences encoding substantially the same amino acid sequences as found in human Notch and in human Delta, and those encoded amino acid sequences with functionally equivalent amino acids, all as described supra in Section 5.1 for adhesive portions of toporythmic proteins.

5.3. IDENTIFICATION OF ADDITIONAL MEMBERS OF THE DELTA/SERRATE FAMILY

20

A rational search for additional members of the Delta/Serrate gene family may be carried out using an approach that takes advantage of the existence of the conserved segments of strong homology between Serrate and Delta (see Figure 10, SEQ ID NO:3 and NO:4). For example, additional members of this gene family may be identified by selecting, from among a diversity of nucleic acid sequences, those sequences that are homologous to both Serrate and Delta (see Figure 13 (SEQ ID NO:5), and Figure 15 (SEQ ID NO:8)), and further identifying, from among the selected sequences, those that also contain nucleic acid sequences which are non-homologous to Serrate and Delta. The term "non-homologous" may be construed to mean a region which contains at least about 6

35

contiguous nucleotides in which at least about two nucleotides differ from Serrate and Delta sequence.

For example, a preferred specific embodiment of the invention provides the following method.

- 5 Corresponding to two conserved segments between Delta and Serrate, Delta AA 63-73 and Delta AA 195-206 (see Figure 13, SEQ ID NO:6), sets of degenerate oligonucleotide probes of about 10-20 nucleotides may be synthesized, representing all of the possible
- 10 coding sequences for the amino acids found in either Delta and Serrate for about three to seven contiguous codons. In another embodiment, oligonucleotides may be obtained corresponding to parts of the four highly conserved regions between Delta and Serrate shown in
- 15 Figure 15 (SEQ ID NO:8 and NO:9), i.e., that represented by Serrate AA 124-134, 149-158, 214-219, and 250-259. The synthetic oligonucleotides may be utilized as primers to amplify by PCR sequences from a source (RNA or DNA) of potential interest. (PCR can
- 20 be carried out, e.g., by use of a Perkin-Elmer Cetus thermal cycler and Taq polymerase (Gene Amp[™])). This might include mRNA or cDNA or genomic DNA from any eukaryotic species that could express a polypeptide closely related to Serrate and Delta. By carrying out
- 25 the PCR reactions, it may be possible to detect a gene or gene product sharing the above-noted segments of conserved sequence between Serrate and Delta. If one chooses to synthesize several different degenerate primers, it may still be possible to carry out a
- 30 complete search with a reasonably small number of PCR reactions. It is also possible to vary the stringency of hybridization conditions used in priming the PCR reactions, to allow for greater or lesser degrees of nucleotide sequence similarity between the unknown
- 35 gene and Serrate or Delta. If a segment of a

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previously unknown member of the Serrate/Delta gene family is amplified successfully, that segment may be molecularly cloned and sequenced, and utilized as a probe to isolate a complete cDNA or genomic clone.

5 This, in turn, will permit the determination of the unknown gene's complete nucleotide sequence, the analysis of its expression, and the production of its protein product for functional analysis. In this fashion, additional genes encoding "adhesive" proteins
10 may be identified.

In addition, the present invention provides for the use of the Serrate/Delta sequence homologies in the design of novel recombinant molecules which are members of the Serrate/Delta gene family but which may
15 not occur in nature. For example, and not by way of limitation, a recombinant molecule can be constructed according to the invention, comprising portions of both Serrate and Delta genes. Such a molecule could exhibit properties associated with both Serrate and
20 Delta and portray a novel profile of biological activities, including agonists as well as antagonists. The primary sequence of Serrate and Delta may also be used to predict tertiary structure of the molecules using computer simulation (Hopp and Woods, 1981, Proc.
25 Natl. Acad. Sci. U.S.A. 78, 3824-3828); Serrate/Delta chimeric recombinant genes could be designed in light of correlations between tertiary structure and biological function. Likewise, chimeric genes comprising portions of any one or more members of the
30 toporythmic gene family (e.g., Notch) may be constructed.

5.4. THE EXPRESSION OF TOPORYTHMIC GENES

The nucleotide sequence coding for an
35 adhesive fragment of a toporythmic protein

(preferably, Notch, Serrate, or Delta), or an adhesive analog or derivative thereof, or human Notch or Delta or a functionally active fragment or derivative thereof, can be inserted into an appropriate

5 expression vector, i.e., a vector which contains the necessary elements for the transcription and translation of the inserted protein-coding sequence. The necessary transcriptional and translational

10 signals can also be supplied by the native toporythmic gene and/or its flanking regions. A variety of host-vector systems may be utilized to express the protein-coding sequence. These include but are not limited to mammalian cell systems infected with virus (e.g.,

15 vaccinia virus, adenovirus, etc.); insect cell systems infected with virus (e.g., baculovirus); microorganisms such as yeast containing yeast vectors, or bacteria transformed with bacteriophage, DNA, plasmid DNA, or cosmid DNA. The expression elements of vectors vary in their strengths and specificities.

20 Depending on the host-vector system utilized, any one of a number of suitable transcription and translation elements may be used. In a specific embodiment, the adhesive portion of the Notch gene, e.g., that encoding EGF-like repeats 11 and 12, is expressed. In

25 another embodiment, the adhesive portion of the Delta gene, e.g., that encoding amino acids 1-230, is expressed. In other specific embodiments, the human Notch or human Delta gene is expressed, or a sequence encoding a functionally active portion of human Notch

30 or Delta. In yet another embodiment, the adhesive portion of the Serrate gene is expressed.

Any of the methods previously described for the insertion of DNA fragments into a vector may be used to construct expression vectors containing a

35 chimeric gene consisting of appropriate

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transcriptional/translational control signals and the protein coding sequences. These methods may include in vitro recombinant DNA and synthetic techniques and in vivo recombinants (genetic recombination).

- 5 Expression of nucleic acid sequence encoding a toporythmic protein or peptide fragment may be regulated by a second nucleic acid sequence so that the toporythmic protein or peptide is expressed in a host transformed with the recombinant DNA molecule.
- 10 For example, expression of a toporythmic protein may be controlled by any promoter/enhancer element known in the art. Promoters which may be used to control toporythmic gene expression include, but are not limited to, the SV40 early promoter region (Bernoist
- 15 and Chambon, 1981, Nature 290, 304-310), the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto, et al., 1980, Cell 22, 787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, Proc. Natl. Acad. Sci. U.S.A. 78, 1441-
- 20 1445), the regulatory sequences of the metallothionein gene (Brinster et al., 1982, Nature 296, 39-42); prokaryotic expression vectors such as the β -lactamase promoter (Villa-Kamaroff, et al., 1978, Proc. Natl. Acad. Sci. U.S.A. 75, 3727-3731), or the tac promoter
- 25 (DeBoer, et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80, 21-25); see also "Useful proteins from recombinant bacteria" in Scientific American, 1980, 242, 74-94; plant expression vectors comprising the nopaline synthetase promoter region (Herrera-Estrella et al.,
- 30 Nature 303, 209-213) or the cauliflower mosaic virus 35S RNA promoter (Gardner, et al., 1981, Nucl. Acids Res. 9, 2871), and the promoter of the photosynthetic enzyme ribulose biphosphate carboxylase (Herrera-Estrella et al., 1984, Nature 310, 115-120); promoter
- 35 elements from yeast or other fungi such as the Gal 4

promoter, the ADC (alcohol dehydrogenase) promoter, PGK (phosphoglycerol kinase) promoter, alkaline phosphatase promoter, and the following animal transcriptional control regions, which exhibit tissue specificity and have been utilized in transgenic animals: elastase I gene control region which is active in pancreatic acinar cells (Swift et al., 1984, Cell 38, 639-646; Ornitz et al., 1986, Cold Spring Harbor Symp. Quant. Biol. 50, 399-409; MacDonald, 1987, Hepatology 7, 425-515); insulin gene control region which is active in pancreatic beta cells (Hanahan, 1985, Nature 315, 115-122), immunoglobulin gene control region which is active in lymphoid cells (Grosschedl et al., 1984, Cell 38, 647-658; Adames et al., 1985, Nature 318, 533-538; Alexander et al., 1987, Mol. Cell. Biol. 7, 1436-1444), mouse mammary tumor virus control region which is active in testicular, breast, lymphoid and mast cells (Leder et al., 1986, Cell 45, 485-495), albumin gene control region which is active in liver (Pinkert et al., 1987, Genes and Devel. 1, 268-276), alpha-fetoprotein gene control region which is active in liver (Krumlauf et al., 1985, Mol. Cell. Biol. 5, 1639-1648; Hammer et al., 1987, Science 235, 53-58; alpha 1-antitrypsin gene control region which is active in the liver (Kelsey et al., 1987, Genes and Devel. 1, 161-171), beta-globin gene control region which is active in myeloid cells (Mogram et al., 1985, Nature 315, 338-340; Kollias et al., 1986, Cell 46, 89-94; myelin basic protein gene control region which is active in oligodendrocyte cells in the brain (Readhead et al., 1987, Cell 48, 703-712); myosin light chain-2 gene control region which is active in skeletal muscle (Sani, 1985, Nature 314, 283-286), and gonadotropic releasing hormone gene control region which is active

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in the hypothalamus (Mason et al., 1986, Science 234, 1372-1378).

Expression vectors containing toporythmic gene inserts can be identified by three general approaches: (a) nucleic acid hybridization, (b) presence or absence of "marker" gene functions, and (c) expression of inserted sequences. In the first approach, the presence of a foreign gene inserted in an expression vector can be detected by nucleic acid hybridization using probes comprising sequences that are homologous to an inserted toporythmic gene. In the second approach, the recombinant vector/host system can be identified and selected based upon the presence or absence of certain "marker" gene functions (e.g., thymidine kinase activity, resistance to antibiotics, transformation phenotype, occlusion body formation in baculovirus, etc.) caused by the insertion of foreign genes in the vector. For example, if the toporythmic gene is inserted within the marker gene sequence of the vector, recombinants containing the toporythmic insert can be identified by the absence of the marker gene function. In the third approach, recombinant expression vectors can be identified by assaying the foreign gene product expressed by the recombinant. Such assays can be based, for example, on the physical or functional properties of the toporythmic gene product in vitro assay systems, e.g., aggregation (adhesive) ability (see Sections 6-8, infra).

Once a particular recombinant DNA molecule is identified and isolated, several methods known in the art may be used to propagate it. Once a suitable host system and growth conditions are established, recombinant expression vectors can be propagated and prepared in quantity. As previously explained, the

expression vectors which can be used include, but are not limited to, the following vectors or their derivatives: human or animal viruses such as vaccinia virus or adenovirus; insect viruses such as

5 baculovirus; yeast vectors; bacteriophage vectors (e.g., lambda), and plasmid and cosmid DNA vectors, to name but a few.

In addition, a host cell strain may be chosen which modulates the expression of the inserted
10 sequences, or modifies and processes the gene product in the specific fashion desired. Expression from certain promoters can be elevated in the presence of certain inducers; thus, expression of the genetically engineered toporythmic protein may be controlled.

15 Furthermore, different host cells have characteristic and specific mechanisms for the translational and post-translational processing and modification (e.g., glycosylation, cleavage) of proteins. Appropriate cell lines or host systems can be chosen to ensure the
20 desired modification and processing of the foreign protein expressed. For example, expression in a bacterial system can be used to produce an unglycosylated core protein product. Expression in yeast will produce a glycosylated product. Expression
25 in mammalian cells can be used to ensure "native" glycosylation of a heterologous mammalian toporythmic protein. Furthermore, different vector/host expression systems may effect processing reactions such as proteolytic cleavages to different extents.

30 In other specific embodiments, the adhesive toporythmic protein, fragment, analog, or derivative may be expressed as a fusion, or chimeric protein product (comprising the protein, fragment, analog, or derivative joined to a heterologous protein sequence).

35 Such a chimeric product can be made by ligating the

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appropriate nucleic acid sequences encoding the desired amino acid sequences to each other by methods known in the art, in the proper coding frame, and expressing the chimeric product by methods commonly known in the art. Alternatively, such a chimeric product may be made by protein synthetic techniques, e.g., by use of a peptide synthesizer.

Both cDNA and genomic sequences can be cloned and expressed.

10 In other embodiments, a human Notch cDNA sequence may be chromosomally integrated and expressed. Homologous recombination procedures known in the art may be used.

15 5.4.1. IDENTIFICATION AND PURIFICATION
OF THE EXPRESSED GENE PRODUCT

Once a recombinant which expresses the toporythmic gene sequence is identified, the gene product may be analyzed. This can be achieved by assays based on the physical or functional properties of the product, including radioactive labelling of the product followed by analysis by gel electrophoresis.

20 Once the toporythmic protein is identified, it may be isolated and purified by standard methods including chromatography (e.g., ion exchange, affinity, and sizing column chromatography), centrifugation, differential solubility, or by any other standard technique for the purification of proteins. The functional properties may be evaluated using any suitable assay, including, but not limited to, aggregation assays (see Sections 6-8).

5.5. GENERATION OF ANTIBODIES TO TOPORYTHMIC
PROTEINS AND ADHESIVE SEQUENCES THEREOF

35 According to the invention, toporythmic protein fragments or analogs or derivatives thereof

which mediate homotypic or heterotypic binding, or human Notch or human Delta proteins or fragments thereof, may be used as an immunogen to generate anti-toporythmic protein antibodies. Such antibodies can
5 be polyclonal or monoclonal. In a specific embodiment, antibodies specific to EGF-like repeats 11 and 12 of Notch may be prepared. In other embodiments, antibodies reactive with the "adhesive portion" of Delta can be generated. One example of
10 such antibodies may prevent aggregation in an in vitro assay. In another embodiment, antibodies specific to human Notch are produced.

Various procedures known in the art may be used for the production of polyclonal antibodies to a
15 toporythmic protein or peptide. In a particular embodiment, rabbit polyclonal antibodies to an epitope of the human Notch protein encoded by a sequence depicted in Figure 19, 20, 21 or 22 (SEQ ID NO:13 through NO:25), or a subsequence thereof, can be
20 obtained. For the production of antibody, various host animals can be immunized by injection with the native toporythmic protein, or a synthetic version, or fragment thereof, including but not limited to rabbits, mice, rats, etc. Various adjuvants may be
25 used to increase the immunological response, depending on the host species, and including but not limited to Freund's (complete and incomplete), mineral gels such as aluminum hydroxide, surface active substances such as lysolecithin, pluronic polyols, polyanions,
30 peptides, oil emulsions, keyhold limpet hemocyanins, dinitrophenol, and potentially useful human adjuvants such as BCG (bacille Calmette-Guerin) and corynebacterium parvum.

For preparation of monoclonal antibodies
35 directed toward a toporythmic protein sequence, any

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technique which provides for the production of antibody molecules by continuous cell lines in culture may be used. For example, the hybridoma technique originally developed by Kohler and Milstein (1975, Nature 256, 495-497), as well as the trioma technique, the human B-cell hybridoma technique (Kozbor et al., 1983, Immunology Today 4, 72), and the EBV-hybridoma technique to produce human monoclonal antibodies (Cole et al., 1985, in Monoclonal Antibodies and Cancer Therapy, Alan R. Liss, Inc., pp. 77-96).

Antibody fragments which contain the idiotype of the molecule can be generated by known techniques. For example, such fragments include but are not limited to: the $F(ab')_2$ fragment which can be produced by pepsin digestion of the antibody molecule; the Fab' fragments which can be generated by reducing the disulfide bridges of the $F(ab')_2$ fragment, and the Fab fragments which can be generated by treating the antibody molecule with papain and a reducing agent.

In the production of antibodies, screening for the desired antibody can be accomplished by techniques known in the art, e.g. ELISA (enzyme-linked immunosorbent assay). For example, to select antibodies which recognize the adhesive domain of a toporythmic protein, one may assay generated hybridomas for a product which binds to a protein fragment containing such domain. For selection of an antibody specific to human Notch, one can select on the basis of positive binding to human Notch and a lack of binding to Drosophila Notch.

The foregoing antibodies can be used in methods known in the art relating to the localization and activity of the protein sequences of the invention. For example, various immunoassays known in the art can be used, including but not limited to

competitive and non-competitive assay systems using techniques such as radioimmunoassays, ELISA (enzyme linked immunosorbent assay), "sandwich" immunoassays, precipitin reactions, gel diffusion precipitin
5 reactions, immunodiffusion assays, agglutination assays, fluorescent immunoassays, protein A immunoassays, and immunoelectrophoresis assays, to name but a few.

10 5.6. DELIVERY OF AGENTS INTO NOTCH-EXPRESSING CELLS

The invention also provides methods for delivery of agents into Notch-expressing cells. As discussed in Section 8 *infra*, upon binding to a Notch protein on the surface of a Notch-expressing cell,
15 Delta protein appears to be taken up into the Notch-expressing cell. The invention thus provides for delivery of agents into a Notch-expressing cell by conjugation of an agent to a Delta protein or an adhesive fragment or derivative thereof capable of
20 binding to Notch, and exposing a Notch-expressing cell to the conjugate, such that the conjugate is taken up by the cell. The conjugated agent can be, but is not limited to, a label or a biologically active agent. .
The biologically active agent can be a therapeutic
25 agent, a toxin, a chemotherapeutic, a growth factor, an enzyme, a hormone, a drug, a nucleic acid, (e.g., antisense DNA or RNA), etc. In one embodiment, the label can be an imaging agent, including but not limited to heavy metal contrast agents for x-ray
30 imaging, magnetic resonance imaging agents, and radioactive nuclides (i.e., isotopes) for radio-imaging. In a preferred aspect, the agent is conjugated to a site in the amino terminal half of the Delta molecule.

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The Delta-agent conjugate can be delivered to the Notch-expressing cell by exposing the Notch-expressing cell to cells expressing the Delta-agent conjugate or exposing the Notch-expressing cell to the Delta-agent conjugate in a solution, suspension, or other carrier. Where delivery is in vivo, the Delta-agent conjugate can be formulated in a pharmaceutically acceptable carrier or excipient, to comprise a pharmaceutical composition. The pharmaceutically acceptable carrier can comprise, saline, phosphate buffered saline, etc. The Delta-agent conjugate can be formulated as a liquid, tablet, pill, powder, in a slow-release form, in a liposome, etc., and can be administered orally, intravenously, intramuscularly, subcutaneously, intraperitoneally, to name but a few routes, with the preferred choice readily made based on the knowledge of one skilled in the art.

6. MOLECULAR INTERACTIONS BETWEEN THE PROTEIN PRODUCTS OF THE NEUROGENIC LOCI NOTCH AND DELTA, TWO EGF-HOMOLOGOUS GENES IN DROSOPHILA

To examine the possibility of intermolecular association between the products of the Notch and Delta genes, we studied the effects of their expression on aggregation in Drosophila Schneider's 2 (S2) cells (Fehon et al., 1990, Cell 61, 523-534). We present herein direct evidence of intermolecular interactions between Notch and Delta, and describe an assay system that will be used in dissecting the components of this interaction. We show that normally nonadhesive Drosophila S2 cultured cells that express Notch bind specifically to cells that express Delta, and that this aggregation is calcium dependent. Furthermore, while cells that express Notch do not bind to one another, cells that express Delta do bind

to one another, suggesting that Notch and Delta can compete for binding to Delta at the cell surface. We also present evidence indicating that Notch and Delta form detergent-soluble complexes both in cultured
5 cells and embryonic cells, suggesting that Notch and Delta interact directly at the molecular level in vitro and in vivo. Our analyses suggest that Notch and Delta proteins interact at the cell surface via their extracellular domains.

10

6.1. EXPERIMENTAL PROCEDURES

6.1.1. EXPRESSION CONSTRUCTS

For the Notch expression construct, the 6 kb HpaI fragment from the 5' end of the Notch coding
15 sequence in MgIIa (Ramos et al., 1989, Genetics 123, 337-348) was blunt-end ligated into the metallothionein promoter vector pRmHa-3 (Bunch, et al., 1988, Nucl. Acids Res. 16, 1043-1061) after the vector had been cut with EcoRI and the ends were
20 filled with the Klenow fragment of DNA polymerase I (Maniatis et al., 1982, Molecular Cloning: A Laboratory Manual (Cold Spring Harbor, New York: Cold Spring Harbor Laboratory)). A single transformant, incorrectly oriented, was isolated. DNA from this
25 transformant was then digested with SacI, and a resulting 3 kb fragment was isolated that contained the 5' end of the Notch coding sequence fused to the polylinker from pRmHa-3. This fragment was then ligated into the SacI site of pRmHa-3 in the correct
30 orientation. DNA from this construct was digested with KpnI and XbaI to remove most of the Notch sequence and all of the Adh polyadenylation signal in pRmHa-3 and ligated to an 11 kb KpnI-XbaI fragment from MgIIa containing the rest of the Notch coding
35 sequence and 3' sequences necessary for

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polyadenylation. In the resulting construct, designated pMtNMg, the metallothionein promoter in pRmHa-3 is fused to Notch sequences starting 20 nucleotides upstream of the translation start site.

5 For the extracellular Notch construct (ECN1), the CosP479BE Notch cosmid (Ramos et al., 1989, Genetics 123, 337-348), which contains all Notch genomic sequences necessary for normal Notch function in vivo, was partially digested with AatII. Fragment
10 ends were made blunt using the exonuclease activity of T4 DNA polymerase (Maniatis et al., 1982, Molecular Cloning: A Laboratory Manual (Cold Spring Harbor, New York: Cold Spring Harbor Laboratory)), and the fragments were then redigested completely with StuI.
15 The resulting fragments were separated in a low melting temperature agarose gel (SeaPlaque, FMC BioProducts), and the largest fragment was excised. This fragment was then blunt-end ligated to itself. This resulted in an internal deletion of the Notch
20 coding sequences from amino acid 1790 to 2625 inclusive (Wharton et al., 1985, Cell 43, 567-581), and a predicted frameshift that produces a novel 59 amino acid carboxyl terminus. (The ligated junction of this construct has not been checked by sequencing.)

25 For the Delta expression construct, the D11 cDNA (Kopczynski et al., 1988, Genes Dev. 2, 1723-1735), which includes the complete coding capacity for Delta, was inserted into the EcoRI site of pRmHa-3. This construct was called pMTD11.

30

6.1.2. ANTIBODY PREPARATION

Hybridoma cell line C17.9C6 was obtained from a mouse immunized with a fusion protein based on a 2.1 kb SalI-HindIII fragment that includes coding
35 sequences for most of the intracellular domain of

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Notch (amino acids 1791-2504; Wharton et al., 1985, Cell 43, 567-581). The fragment was subcloned into pUR289 (Ruther and Muller-Hill, 1983, EMBO J. 2, 1791-1794), and then transferred into the pATH 1 expression
5 vector (Dieckmann and Tzagoloff, 1985, J. Biol. Chem. 260, 1513-1520) as a BglIII-HindIII fragment. Soluble fusion protein was expressed, precipitated by 25% $(\text{NH}_4)_2\text{SO}_4$, resuspended in 6 M urea, and purified by preparative isoelectric focusing using a Rotofor™ (Bio-
10 Rad) (for details, see Fehon, 1989, Rotofor™ Review No. 7, Bulletin 1518, Richmond, California: Bio-Rad Laboratories).

Mouse polyclonal antisera were raised against the extracellular domain of Notch using four
15 BstYI fragments of 0.8 kb (amino acids 237-501: Wharton et al., 1985, Cell 43, 567-581), 1.1 kb (amino acids 501-868), 0.99 kb (amino acids 868-1200), and 1.4 kb (amino acids 1465-1935) length, which spanned
20 from the fifth EGF-like repeat across the transmembrane domain, singly inserted in-frame into the appropriate pGEX expression vector (Smith and Johnson, 1988, Gene 67, 31-40). Fusion proteins were purified on glutathione-agarose beads (SIGMA). Mouse and rat antisera were precipitated with 50% $(\text{NH}_4)_2\text{SO}_4$
25 and resuspended in PBS (150 mM NaCl, 14 mM Na_2HPO_4 , 6 mM NaH_2PO_4) with 0.02% NaN_3 .

Hybridoma cell line 201 was obtained from a mouse immunized with a fusion protein based on a 0.54 kb ClaI fragment that includes coding sequences from
30 the extracellular domain of Delta (Kopczynski et al., 1988, Genes Dev. 2, 1723-1735) subcloned into the ClaI site within the lacZ gene of pUR 288 (Ruther and Muller-Hill, 1983, EMBO J. 2, 1791-1794). This fragment includes sequences extending from the fourth
35 through the ninth EGF-like repeats in Delta (amino

acids 350-529). Fusion protein was prepared by isolation of inclusion bodies (Gilmer et al., 1982, Proc. Natl. Acad. Sci. USA 79, 2152-2156); inclusion bodies were solubilized in urea (Carroll and Laughon, 5 1987, in DNA Cloning, Volume III, D.M. Glover, ed. (Oxford: IRL Press), pp. 89-111) before use in immunization.

Rat polyclonal antisera were obtained following immunization with antigen derived from the 10 same fusion protein construct. In this case, fusion protein was prepared by lysis of IPTG-induced cells in SDS-Laemmli buffer (Carroll and Laughon, 1987, in DNA Cloning, Volume III, D.M. Glover, ed. (Oxford: IRL Press), pp. 89-111), separation of proteins by SDS- 15 PAGE, excision of the appropriate band from the gel, and electroelution of antigen from the gel slice for use in immunization (Harlow and Lane, 1988, Antibodies: A Laboratory Manual (Cold Spring Harbor, New York: Cold Spring Harbor Laboratory)).

20

6.1.3. CELL CULTURE AND TRANSFECTION

The S2 cell line (Schneider, 1972, J. Embryol. Exp. Morph. 27, 353-365) was grown in M3 medium (prepared by Hazleton Co.) supplemented with 25 2.5 mg/ml Bacto-Peptone (Difco), 1 mg/ml TC YeastolateTM (Difco), 11% heat-inactivated fetal calf serum (FCS) (Hyclone), and 100 U/ml penicillin-100 µg/ml streptomycin-0.25 µg/ml fungizoneTM (Hazleton). Cells growing in log phase at $\sim 2 \times 10^6$ cells/ml were 30 transfected with 20 µg of DNA-calcium phosphate coprecipitate in 1 ml per 5 ml of culture as previously described (Wigler et al., 1979, Proc. Natl. Acad. Sci. USA 78, 1373-1376), with the exception that BES buffer (SIGMA) was used in place of HEPES buffer 35 (Chen and Okayama, 1987, Mol. Cell. Biol. 7, 2745-

2752). After 16-18 hr, cells were transferred to conical centrifuge tubes, pelleted in a clinical centrifuge at full speed for 30 seconds, rinsed once with 1/4 volume of fresh complete medium, resuspended
5 in their original volume of complete medium, and returned to the original flask. Transfected cells were then allowed to recover for 24 hr before induction.

10 6.1.4. AGGREGATION ASSAYS

Expression of the Notch and Delta metallothionein constructs was induced by the addition of CuSO_4 to 0.7 mM. Cells transfected with the ECN1 construct were treated similarly. Two types of
15 aggregation assays were used. In the first assay, a total of 3 ml of cells ($5-10 \times 10^6$ cells/ml) was placed in a 25 ml Erlenmeyer flask and rotated at 40-50 rpm on a rotary shaker for 24-48 hr at room temperature. For these experiments, cells were mixed 1-4 hr after
20 induction began and induction was continued throughout the aggregation period. In the second assay, ~0.6 ml of cells were placed in a 0.6 ml Eppendorf™ tube (leaving a small bubble) after an overnight induction (12-16 hr) at room temperature and rocked gently for
25 1-2 hr at 4°C. The antibody inhibition and Ca^{2+} dependence experiments were performed using the latter assay. For Ca^{2+} dependence experiments, cells were first collected and rinsed in balanced saline solution (BSS) with 11% FCS (BSS-FCS; FCS was dialyzed against
30 0.9% NaCl, 5mM Tris [pH 7.5]) or in Ca^{2+} free BSS-FCS containing 10 mM EGTA (Snow et al., 1989, Cell 59, 313-323) and then resuspended in the same medium at the original volume. For the antibody inhibition experiments, Notch-transfected cells were collected
35 and rinsed in M3 medium and then treated before

aggregation in M3 medium for 1 hr at 4°C with a 1:250 dilution of immune or preimmune sera from each of the four mice immunized with fusion proteins containing segments from the extracellular domain of Notch (see
5 Antibody Preparation above).

6.1.5. IMMUNOFLUORESCENCE

Cells were collected by centrifugation (3000 rpm for 20 seconds in an Eppendorf™ microcentrifuge)
10 and fixed in 0.6 ml Eppendorf™ tubes with 0.5 ml of freshly made 2% paraformaldehyde in PBS for 10 min at room temperature. After fixing, cells were collected by centrifugation, rinsed twice in PBS, and stained for 1 hr in primary antibody in PBS with 0.1% saponin
15 (SIGMA) and 1% normal goat serum (Pocono Rabbit Farm, Canadensis, PA). Monoclonal antibody supernatants were diluted 1:10 and mouse or rat sera were diluted 1:1000 for this step. Cells were then rinsed once in PBS and stained for 1 hr in specific secondary
20 antibodies (double-labeling grade goat anti-mouse and goat anti-rat, Jackson Immunoresearch) in PBS-saponin-normal goat serum. After this incubation, cells were rinsed twice in PBS and mounted on slides in 90% glycerol, 10% 1 M Tris (pH 8.0), and 0.5% n-propyl
25 gallate. Cells were viewed under epifluorescence on a Leitz Orthoplan™ 2 microscope.

Confocal micrographs were taken using the Bio-Rad MRC 500 system connected to a Zeiss Axiovert™ compound microscope. Images were collected using the
30 BHS and GHS filter sets, aligned using the ALIGN program, and merged using MERGE. Fluorescent bleed-through from the green into the red channel was reduced using the BLEED program (all software provided by Bio-Rad). Photographs were obtained directly from
35 the computer monitor using Kodak Ektar™ 125 film.

6.1.6. CELL LYSATES, IMMUNOPRECIPITATIONS, AND WESTERN BLOTS

Nondenaturing detergent lysates of tissue culture and wild-type Canton-S embryos were prepared on ice in ~10 cell vol of lysis buffer (300 mM NaCl, 50 mM Tris [pH 8.0], 0.5% NP-40, 0.5% deoxycholate, 1 mM CaCl₂, 1 mM MgCl₂) with 1 mM phenylmethanesulfonyl fluoride (PMSF) and diisopropyl fluorophosphate diluted 1:2500 as protease inhibitors. Lysates were sequentially triturated using 18G, 21G, and 25G needles attached to 1 cc tuberculin syringes and then centrifuged at full speed in a microfuge 10 min at 4°C to remove insoluble material. Immunoprecipitation was performed by adding ~1 µg of antibody (1-2 µl of polyclonal antiserum) to 250-500 µl of cell lysate and incubating for 1 hr at 4°C with agitation. To this mixture, 15 µg of goat anti-mouse antibodies (Jackson Immunoresearch; these antibodies recognize both mouse and rat IgG) were added and allowed to incubate for 1 hr at 4°C with agitation. This was followed by the addition of 100 µl of fixed *Staphylococcus aureus* (Staph A) bacteria (ZysorbinTM, Zymed; resuspended according to manufacturer's instructions), which had been collected, washed five times in lysis buffer, and incubated for another hour. Staph A-antibody complexes were then pelleted by centrifugation and washed three times in lysis buffer followed by two 15 min washes in lysis buffer. After being transferred to a new tube, precipitated material was suspended in 50 µl of SDS-PAGE sample buffer, boiled immediately for 10 min, run on 3%-15% gradient gels, blotted to nitrocellulose, and detected using monoclonal antibodies and HRP-conjugated goat anti-mouse secondary antibodies as previously described (Johansen et al., 1989, J. Cell Biol. 109, 2427-2440). For total cellular protein samples used on Western blots

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(Figure 2), cells were collected by centrifugation, lysed in 10 cell vol of sample buffer that contained 1 mM PMSF, and boiled immediately.

5

6.2. RESULTS

6.2.1. THE EXPRESSION OF NOTCH AND DELTA IN CULTURED CELLS

To detect interactions between Notch and Delta, we examined the behavior of cells expressing these proteins on their surfaces using an aggregation assay. We chose the S2 cell line (Schneider, 1972, J. Embryol. Exp. Morph. 27, 353-365) for these studies for several reasons. First, these cells are relatively nonadhesive, grow in suspension, and have been used previously in a similar assay to study fasciclin III function (Snow et al., 1989, Cell 59, 313-323). Second, they are readily transfectable, and an inducible metallothionein promoter vector that has been designed for expression of exogenous genes in Drosophila cultured cells is available (Bunch et al., 1988, Nucl. Acids Res. 16, 1043-1061). Third, S2 cells express an aberrant Notch message and no detectable Notch due to a rearrangement of the 5' end of the Notch coding sequence (see below). These cells also express no detectable Delta (see below).

25

Schematic drawings of the constructs used are shown in Figure 1 (see Experimental Procedures, Section 6.1, for details). To express Notch in cultured cells, the Notch minigene MG11a, described in Ramos et al. (1989, Genetics 123, 337-348) was inserted into the metallothionein promoter vector pRmHa-3 (Bunch et al., 1988, Nucl. Acids Res. 16, 1043-1061). The Delta expression construct was made by inserting D11 cDNA, which contains the entire coding sequence for Delta from the major embryonic Delta transcript (5.4Z; Kopczynski et al., 1988, Genes

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Dev. 2, 1723-1735), into the same vector. A third construct, designated ECN1 for "extracellular Notch 1", contains the 5' Notch promoter region and 3' Notch polyadenylation signal together with coding capacity
5 for the extracellular and transmembrane regions of the Notch gene from genomic sequences, but lacks coding sequences for 835 amino acids of the ~1000 amino acid intracellular domain. In addition, due to a predicted frameshift, the remaining 78 carboxy-terminal amino
10 acid residues are replaced by a novel 59 amino acid carboxyterminal tail (see Experimental Procedures).

For all of the experiments described in this paper, expression constructs were transfected into S2 cells and expressed transiently rather than in stable
15 transformants. Expressing cells typically composed 1%-5% of the total cell population, as judged by immunofluorescent staining (data not shown). A Western blot of proteins expressed after transfection is shown in Figure 2. Nontransfected cells do not
20 express detectable levels of Notch or Delta. However, after transfection, proteins of the predicted apparent molecular weights are readily detectable using monoclonal antibodies specific for each of these proteins, respectively. In the case of Notch,
25 multiple bands were apparent in transfected cells below the ~300 kd full-length product. We do not yet know whether these bands represent degradation of Notch during sample preparation or perhaps synthesis or processing intermediates of Notch that are present
30 within cells, but we consistently detect them in samples from transfected cells and from embryos. In addition, we performed immunofluorescent staining of live transfected cells with antibodies specific for the extracellular domains of each protein to test for
35 cell surface expression of these proteins. In each

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case we found surface staining as expected for a surface antigen. Taken together, these results clearly show that the Notch and Delta constructs support expression of proteins of the expected sizes and subcellular localization.

6.2.2. CELLS THAT EXPRESS NOTCH AND DELTA AGGREGATE

To test the prediction that Notch and Delta interact, we designed a simple aggregation assay to detect these interactions between proteins expressed on the surface of S2 cells. We reasoned that if Notch and Delta are able to form stable heterotypic complexes at the cell surface, then cells that express these proteins might bind to one another and form aggregates under appropriate conditions. A similar assay system has recently been described for the fasciclin III protein (Snow et al., 1989, Cell 59, 313-323).

S2 cells in log phase growth were separately transfected with either the Notch or Delta metallothionein promoter construct. After induction with CuSO_4 , transfected cells were mixed in equal numbers and allowed to aggregate overnight at room temperature (for details, see Experimental Procedures, Section 6.1). Alternatively, in some experiments intended to reduce metabolic activity, cells were mixed gently at 4°C for 1-2 hr. To determine whether aggregates had formed, cells were processed for immunofluorescence microscopy using antibodies specific for each gene product and differently labeled fluorescent secondary antibodies. As previously mentioned, expressing cells usually constituted less than 5% of the total cell population because we used transient rather than stable transformants. The remaining cells either did not express a given protein

or expressed at levels too low for detection by immunofluorescence microscopy. As controls, we performed aggregations with only a single type of transfected cell.

5 Figure 3 shows representative photomicrographs from aggregation experiments, and Table I presents the results in numerical form. As is apparent from Figure 3C and Table I, while Notch-expressing (Notch⁺) cells alone do not form aggregates
10 in our assay, Delta-expressing (Delta⁺) cells do.

15

20

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30

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TABLE I
PERCENTAGES OF NOTCH⁺ AND DELTA⁺ CELLS IN AGGREGATES^a

	Notch ⁺		Delta ⁺		Notch ⁺ -Delta	
	Control Cells ^b	Aggregated Cells ^c	Control Cells ^b	Aggregated Cells ^c	Overall ^d N Cells ^e	DI Cells ^f
Experiment 1	0	0	19	37	32	26
Experiment 2	-	1	-	40	54	47
Experiment 3	0	-	12	-	43	42
Experiment 4	5	5	20	-	47	41
Experiment 5 ^g	-	2	-	48	71	66
Experiment 6 ^h	0	0	13	61	63	60
						42
						79
						44
						59
						82
						73

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- ^a Aggregates defined as clusters of four or more expressing cells. For all values, at least 100 expressing cell units (single cells or cell clusters) were scored. Notch⁺, Notch-expressing; Delta⁺, Delta expressing.
- ^b Control cells taken directly from transfection flasks without incubation in the aggregation assay.
- ^c Control cells after incubation in the aggregation assay.
- ^d Combined aggregation data for both Notch⁺ and Delta⁺ cells in Notch⁺-Delta⁺ aggregates.
- ^e Aggregation data for Notch⁺ cells in Notch⁺-Delta⁺ aggregates.
- ^f Aggregation data for Delta⁺ cells in Notch⁺-Delta⁺ aggregates.
- ^g Cells from this experiment from same transfection as Experiment 4.
- ^h Data from 48 hr aggregation experiments. All other data are from 24 hr aggregation experiments.

The tendency for Delta⁺ cells to aggregate was apparent even in nonaggregated control samples (Table I), where cell clusters of 4-8 cells that probably arose from adherence between mitotic sister cells commonly occurred. However, clusters were more common after incubation under aggregation conditions (e.g., 19% of Delta⁺ cells in aggregates before incubation vs. 37% of Delta⁺ cells in aggregates after incubation; Experiment 1 in Table I), indicating that Delta⁺ cells are able to form stable contacts with one another in this assay. It is important to note that while nonstaining cells constituted over 90% of the cells in our transient transfections, we never found them within aggregates. On rare occasions, nonstaining cells were found at the edge of an aggregate. Due to the common occurrence of weakly staining cells at the edges of aggregates, it is likely that these apparently nonexpressing cells were transfected but expressed levels of Delta insufficient to be detected by immunofluorescence.

In remarkable contrast to control experiments with Notch⁺ cells alone, aggregation of mixtures of Notch⁺ and Delta⁺ cells resulted in the formation of clusters of up to 20 or more cells (Figures 3D-3H, Table I). As Table I shows, the fraction of expressing cells found in clusters of four or more stained cells after 24 hr of aggregation ranged from 32%-54% in mixtures of Notch⁺ and Delta⁺ cells. This range was similar to that seen for Delta⁺ cells alone (37%-40%) but very different from that for Notch⁺ cells alone (only 0%-5%). Although a few clusters that consisted only of Delta⁺ cells were found, Notch⁺ cells were never found in clusters of greater than four to five cells unless Delta⁺ cells were also present. Again, all cells within these

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clusters expressed either Notch or Delta, even though transfected cells composed only a small fraction of the total cell population. At 48 hr (Table I, experiments 5 and 6), the degree of aggregation
5 appeared higher (63%-71%), suggesting that aggregation had not yet reached a maximum after 24 hr under these conditions. Also, cells cotransfected with Notch and Delta constructs (so that all transfected cells express both proteins) aggregated in a similar fashion
10 under the same experimental conditions.

These results indicate that the aggregation observed in these experiments requires the expression of Notch and Delta and is not due to the fortuitous expression of another interacting protein in
15 nontransfected S2 cells. We further tested the specificity of this interaction by diluting Notch⁺ and Delta⁺ cells 10-fold with nontransfected S2 cells and allowing them to aggregate for 24 hr at room temperature. In this experiment, 39% of the
20 expressing cells were found in aggregates with other expressing cells, although they composed less than 0.1% of the total cell population. Not surprisingly, however, these aggregates were smaller on average than those found in standard aggregation experiments. In
25 addition, to control for the possibility that Notch⁺ cells are nonspecifically recruited into the Delta⁺ aggregates because they overexpress a single type of protein on the cell surface, we mixed Delta⁺ cells with cells that expressed neuroglian, a transmembrane
30 cell-surface protein (Bieber et al., 1989, Cell 59, 447-460), under the control of the metallothionein promoter (this metallothionein-neuroglian construct was kindly provided by A. Bieber and C. Goodman). We observed no tendency for neuroglian⁺ cells to adhere
35 to Delta⁺ aggregates, indicating that Notch-Delta

aggregation is not merely the result of high levels of protein expression on the cell surface.

We also tested directly for Notch involvement in the aggregation process by examining the effect of a mixture of polyclonal antisera directed against fusion proteins that spanned almost the entire extracellular domain of Notch on aggregation (see Experimental Procedures, Section 6.1). To minimize artifacts that might arise due to a metabolic response to patching of surface antigens, antibody treatment and the aggregation assay were performed at 4°C in these experiments. Notch⁺ cells were incubated with either preimmune or immune mouse sera for 1 hr, Delta⁺ cells were added, and aggregation was performed for 1-2 hr. While Notch⁺ cells pretreated with preimmune sera aggregated with Delta⁺ cells (in one of three experiments, 23% of the Notch⁺ cells were in Notch⁺-Delta⁺ cell aggregates), those treated with immune sera did not (only 2% of Notch⁺ cells were in aggregates). This result suggests that the extracellular domain of Notch is required for Notch⁺-Delta⁺ cell aggregation, although we cannot rule out the possibility that the reduced aggregation was due to inhibitory steric or membrane structure effects resulting from exposure of Notch⁺ cells to the antiserum.

Three other observations worth noting are apparent in Figure 3. First, while Delta was almost always apparent only at the cell surface (Figures 3B and 3C), Notch staining was always apparent both at the cell surface and intracellularly, frequently associated with vesicular structures (Figure 3A). Second, we consistently noted a morphological difference between Delta⁺ and Notch⁺ cells in mixed aggregates that were incubated overnight. Delta⁺

cells often had long extensions that completely surrounded adjacent Notch⁺ cells, while Notch⁺ cells were almost always rounded in appearance without noticeable cytoplasmic extensions (Figure 3G). Third, Notch and Delta often appeared to gather within regions of contact between Notch⁺ and Delta⁺ cells, producing a sharp band of immunofluorescent staining (Figures 3D-3F). These bands were readily visible in optical sections viewed on the confocal microscope (Figure 3H), indicating that they were not merely due to a whole-mount artifact. We also observed that these bands formed rapidly (within 2 hr of mixing cells) and at 4°C, indicating that their formation probably did not depend upon cellular metabolism. These observations would be expected if, within regions of cell contact, Notch and Delta bind to one another and therefore become immobilized. This pattern of expression is also consistent with that observed for other proteins that mediate cell aggregation (Takeichi, 1988, Development 102, 639-655; Snow et al., 1989, Cell 59, 313-323).

6.2.3. NOTCH-DELTA-MEDIATED AGGREGATION IS CALCIUM DEPENDENT

Previous studies have suggested that EGF-like repeats that contain a particular consensus sequence may serve as calcium (Ca²⁺) binding domains (Morita et al., 1984, J. Biol. Chem. 259, 5698-5704; Sugo et al., 1984, J. Biol. Chem. 259, 5705-5710; Rees et al., 1988, EMBO J. 7, 2053-2061; Handford et al., 1990, EMBO J. 9, 475-480). For at least two of these proteins, C and C1, Ca²⁺ binding has further been shown to be a necessary component of their interactions with other proteins (Villiers et al., 1980, FEBS Lett. 117, 289-294; Esmon et al., 1983, J. Biol. Chem. 258, 5548-5553; Johnson, et al., 1983, J. Biol. Chem. 258, 5554-

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5560). Many of the EGF-homologous repeats within Notch and most of those within Delta contain the necessary consensus sequence for Ca^{2+} binding (Rees et al., 1988, EMBO J. 7, 2053-2061; Stenflo et al., 1987, 5 Proc. Natl. Acad. Sci. USA 84, 368-372; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735; Handford et al., 1990, EMBO J. 9, 475-480), although it has not yet been determined whether or not these proteins do bind calcium. We therefore tested the ability of 10 expressing cells to aggregate in the presence or absence of Ca^{2+} ions to determine whether there is a Ca^{2+} ion requirement for Notch-Delta aggregation. To minimize possible nonspecific effects due to metabolic responses to the removal of Ca^{2+} , these experiments 15 were performed at 4°C. Control mixtures of Notch⁺ and Delta⁺ cells incubated under aggregation conditions in Ca^{2+} -containing medium at 4°C readily formed aggregates (an average of $34\% \pm 13\%$, mean $\pm$ SD, n = 3; Table II). In contrast, cells mixed in medium that 20 lacked Ca^{2+} ions and contained EGTA formed few aggregates ($5\% \pm 5\%$). These results clearly demonstrate a dependence of Notch-Delta-mediated aggregation on exogenous Ca^{2+} and are in marked contrast to those recently published for the 25 *Drosophila* fasciclin III and fasciclin I proteins in S2 cells (Snow et al., 1989, Cell 59, 313-323; Elkins et al., 1990, J. Cell Biol. 110, 1825-1832), which detected no effect of Ca^{2+} ion removal on aggregation mediated by either protein.

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TABLE II
EFFECT OF EXOGENOUS Ca²⁺ ON NOTCH⁺-DELTA⁺ AGGREGATION^a

	Without Ca ²⁺ Ions		With Ca ²⁺ Ions	
	Over- all ^b	N Cells ^c	Over- all ^b	N Cells ^c
Experiment 1	4	2	28	27
Experiment 2	12	0	53	50
Experiment 3	0	0	22	17

^a Data presented as percentage of expressing cells found in aggregates (as in Table I).
^b Combined aggregation data for both Notch⁺ and Delta⁺ cells.
^c Aggregation data for Notch⁺ cells in Notch⁺-Delta⁺ aggregates.
^d Aggregation data for Delta⁺ cells in Notch⁺-Delta⁺ aggregates.

6.2.4. NOTCH AND DELTA INTERACT WITHIN A SINGLE CELL

We asked whether Notch and Delta are associated within the membrane of one cell that expresses both proteins by examining the distributions of Notch and Delta in cotransfected cells. As shown in Figures 4A and 4B, these two proteins often show very similar distributions at the surface of cotransfected cells. To test whether the observed colocalization was coincidental or represented a stable interaction between Notch and Delta, we treated live cells with an excess of polyclonal anti-Notch antiserum. This treatment resulted in "patching" of Notch on the surface of expressing cells into discrete patches as detected by immunofluorescence. There was a distinct correlation between the distributions of Notch and Delta on the surfaces of these cells after this treatment (Figures 4C and 4D), indicating that these proteins are associated within the membrane. It is important to note that these experiments do not address the question of whether this association is direct or mediated by other components, such as the cytoskeleton. To control for the possibility that Delta is nonspecifically patched in this experiment, we cotransfected cells with Notch and with the previously mentioned neuroglial construct (A. Bieber and C. Goodman, unpublished data) and patched with anti-Notch antisera. In this case there was no apparent correlation between Notch and neuroglial.

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6.2.5. INTERACTIONS WITH DELTA DO NOT REQUIRE THE INTRACELLULAR DOMAIN OF NOTCH

In addition to a large extracellular domain that contains EGF-like repeats, Notch has a sizeable intracellular (IC) domain of ~940 amino acids. The IC domain includes a phosphorylation site (Kidd et al.,

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1989, Genes Dev. 3, 1113-1129), a putative nucleotide binding domain, a polyglutamine stretch (Wharton et al., 1985, Cell 43, 567-581; Kidd, et al., 1986, Mol. Cell. Biol. 6, 3094-3108), and sequences homologous to
5 the yeast cdc10 gene, which is involved in cell cycle control in yeast (Breedon and Nasmyth, 1987, Nature 329, 651-654). Given the size and structural complexity of this domain, we wondered whether it is required for Notch-Delta interactions. We therefore
10 used a variant Notch construct from which coding sequences for ~835 amino acids of the IC domain, including all of the structural features noted above, had been deleted (leaving 25 membrane-proximal amino acids and a novel 59 amino acid carboxyl terminus; see
15 Experimental Procedures and Figure 1 for details). This construct, designated ECN1, was expressed constitutively under control of the normal Notch promoter in transfected cells at a level lower than that observed for the metallothionein promoter
20 constructs, but still readily detectable by immunofluorescence.

In aggregation assays, cells that expressed the ECN1 construct consistently formed aggregates with Delta⁺ cells (31% of ECN1-expressing cells were in
25 aggregates in one of three experiments; see also Figure 3I), but not with themselves (only 4% in aggregates), just as we observed for cells that expressed intact Notch. We also observed sharp bands of ECN1 staining within regions of contact with Delta⁺
30 cells, again indicating a localization of ECN1 within regions of contact between cells. To test for interactions within the membrane, we repeated the surface antigen co-patching experiments using cells cotransfected with the ECN1 and Delta constructs. As
35 observed for intact Notch, we found that when ECN1 was

patched using polyclonal antisera against the extracellular domain of Notch, ECN1 and Delta colocalized at the cell surface (Figures 4E and 4F). These results demonstrate that the observed
5 interactions between Notch and Delta within the membrane do not require the deleted portion of the IC domain of Notch and are therefore probably mediated by the extracellular domain. However, it is possible that the remaining transmembrane or IC domain
10 sequences in ECN1 are sufficient to mediate interactions within a single cell.

6.2.6. NOTCH AND DELTA FORM DETERGENT-SOLUBLE INTERMOLECULAR COMPLEXES

15 Together, we take the preceding results to indicate molecular interactions between Notch and Delta present within the same membrane and between these proteins expressed on different cells. As a further test for such interactions, we asked whether
20 these proteins would coprecipitate from nondenaturing detergent extracts of cells that express Notch and Delta. If Notch and Delta form a stable intermolecular complex either between or within cells, then it should be possible to precipitate both
25 proteins from cell extracts using specific antisera directed against one of these proteins. We performed this analysis by immunoprecipitating Delta with polyclonal antisera from NP-40/deoxycholate lysates (see Experimental Procedures) of cells cotransfected
30 with the Notch and Delta constructs that had been allowed to aggregate overnight or of 0-24 hr wild-type embryos. We were unable to perform the converse immunoprecipitates because it was not possible to discern unambiguously a faint Delta band among
35 background Staph A bands. It is important to note that we tested this polyclonal anti-Delta antiserum

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for cross-reactivity against Notch in cell lysates (Figure 5A, lane 1) and by immunofluorescence (e.g., compare Figures 3D and 3E) and found none. After repeated washing to remove nonspecifically adhering proteins, we assayed for coprecipitation of Notch using a monoclonal antibody (MAb C17.9C6) against Notch on Western blots.

As Figure 5 shows, we did detect coprecipitation of Notch in Delta immunoprecipitates from cotransfected cells and embryos. However, coprecipitating Notch appeared to be present in much smaller quantities than Delta and was therefore difficult to detect. This disparity is most likely due to the disruption of Notch-Delta complexes during the lysis and washing steps of the procedure. However, it is also possible that this disparity reflects a nonequimolar interaction between Notch and Delta or greatly different affinities of the antisera used to detect these proteins. The fact that immunoprecipitation of Delta results in the coprecipitation of Notch constitutes direct evidence that these two proteins form stable intermolecular complexes in transfected S2 cells and in embryonic cells.

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6.3. DISCUSSION

We have studied interactions between the protein products of two of the neurogenic loci, Notch and Delta, in order to understand their cellular functions better. Using an in vitro aggregation assay that employs normally nonadhesive S2 cells, we showed that cells that express Notch and Delta adhere specifically to one another. The specificity of this interaction is apparent from the observation that Notch⁺-Delta⁺ cell aggregates rarely contained

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nonexpressing cells, even though nonexpressing cells composed the vast majority of the total cell population in these experiments. We propose that this aggregation is mediated by heterotypic binding between the extracellular domains of Notch and Delta present on the surfaces of expressing cells. Consistent with this proposal, we find that antisera directed against the extracellular domain of Notch inhibit Notch-Delta-mediated aggregation, and that the ECN1 Notch variant, which lacks almost all of the Notch intracellular domain, can mediate aggregation with cells that express Delta. We also found that cells that express only Delta aggregate with one another, while those that express only Notch do not. These findings suggest that Delta can participate in a homotypic interaction when present on apposed cell surfaces but that Notch cannot under our assay conditions.

The proposal that Notch and Delta interact at the cell surface is further supported by three lines of evidence. First, we find an intense localization of both proteins within regions of contact which Notch⁺ and Delta⁺ cells, implying that Notch and Delta interact directly, even when expressed in different cells. Second, Notch and Delta colocalize on the surface of cells that express both proteins, suggesting that these proteins can interact within the cell membrane. Third, Notch and Delta can be coprecipitated from nondenaturing detergent extracts of cultured cells that express both proteins as well as from extracts of embryonic cells. Together, these results strongly support the hypothesis that Notch and Delta can interact heterotypically when expressed on the surfaces of either the same or different cells.

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The underlying basis for the observed genetic interactions between Notch and Delta and between Notch and mam (Xu et al., 1990, Genes Dev. 4, 464-475) may be a dose-sensitive interaction between
5 the proteins encoded by these genes.

Two lines of evidence suggest that the Notch and Delta proteins function similarly in vitro and in vivo. First, the genetic analyses have indicated that the stoichiometry of Notch and Delta is crucial for
10 their function in development. Our observations that both Notch-Delta and Delta-Delta associations may occur in vitro imply that Notch and Delta may compete for binding to Delta. Thus, dose-sensitive genetic interactions between Notch and Delta may be the result
15 of competitive binding interactions between their protein products. Second, we were able to detect Notch-Delta association in lysates of cultured cells and in lysates of Drosophila embryos using immunoprecipitation. Taken together, these genetic
20 and biochemical analyses suggest that Notch and Delta do associate in vivo in a manner similar to that which we propose on the basis of our aggregation assays.

Genetic and molecular analyses of Notch have also raised the possibility that there may be
25 interactions between individual Notch proteins (Portin, 1975, Genetics 81, 121-133; Kelley et al., 1987, Cell 51, 539-548; Artavanis-Tsakonas, 1988, Trends Genet. 4, 95-100). Indeed, Kidd et al. (1989, Genes Dev. 3, 1113-1129) have proposed that this
30 protein forms disulfide cross-linked dimers, although this point has not yet been rigorously proven. With or without the formation of covalent cross-links, such interactions could presumably occur either within a single cell or between cells. However, our find that
35 Notch⁺ cells do not aggregate homotypically suggests

that Notch-Notch associations are likely to occur within a single cell and not between cells.

Alternatively, it is possible that homotypic Notch interactions require gene products that are not
5 expressed in S2 cells.

The Notch-Delta interactions indicated by our analysis are probably mediated by the extracellular domains of these proteins. Aggregation experiments using the ECN1 construct, from which
10 almost the entire intracellular domain of Notch has been removed or altered by in vitro mutagenesis, confirmed this conclusion. Further experiments that demonstrate ECN1-Delta associations within the membrane on the basis of their ability to co-patch
15 indicated that these interactions are also likely to be mediated by the extracellular domains of Notch and Delta, although in this case we cannot exclude possible involvement of the transmembrane domain or the remaining portion of the Notch intracellular
20 domain. These results are especially interesting in light of the fact that both Notch and Delta have EGF-like repeats within their extracellular domains (Wharton et al., 1985, Cell 43, 567-581; Kidd et al.,
1986, Mol. Cell Biol. 6, 3094-3108; Vassin et al.,
25 1987, EMBO J. 6, 3431-3440; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735).

A second issue of interest regarding EGF domains is the proposal that they can serve as Ca^{2+} binding domains when they contain a consensus sequence
30 consisting of Asp, Asp/Asn, Asp/Asn, and Tyr/Phe residues at conserved positions within EGF-like repeats (Rees et al., 1988, EMBO J. 7, 2053-2061; Handford et al., 1990, EMBO J. 9, 475-480).

Comparisons with a proposed consensus sequence for Ca^{2+}
35 binding have revealed that similar sequences are found

within many of the EGF-like repeats of Notch (Rees et al., 1988, EMBO J. 7, 2053-2061) and within most of the EGF-like repeats of Delta (Kopczynski et al., 1988, Genes Dev. 2, 1723-1735). Furthermore, sequence analyses of Notch mutations have shown that certain Ax alleles are associated with changes in amino acids within this putative Ca^{2+} binding domain (Kelley et al., 1987, Cell 51, 539-548; Hartley et al., 1987, EMBO J. 6, 3407-3417; Rees et al., 1988, EMBO J. 7, 2053-2061). For example, the Ax^{E2} mutation, which correlates with a His to Tyr change in the 29th EGF-like repeat, appears to change this repeat toward the consensus for Ca^{2+} binding. Conversely, the Ax^{9B2} mutation appears to change the 24th EGF-like repeat away from this consensus as a result of an Asp to Val change. Thus, the genetic interactions between Ax alleles and Delta mutations (Xu et al., 1990, Genes Dev., 4, 464-475) raise the possibility that Ca^{2+} ions play a role in Notch-Delta interactions. Our finding that exogenous Ca^{2+} is necessary for Notch-Delta-mediated aggregation of transfected S2 cells supports this contention.

As we have argued (Johansen et al., 1989, J. Cell Biol. 109, 2427-2440; Alton et al., 1989, Dev. Genet. 10, 261-272), on the basis of previous molecular and genetic analyses one could not predict with any certainty the cellular function of either Notch or Delta beyond their involvement in cell-cell interactions. However, given the results presented here, it now seems reasonable to suggest that Notch and Delta may function in vivo to mediate adhesive interactions between cells. At the same time, it is quite possible that the observed Notch-Delta interactions may not reflect a solely adhesive function and may in addition reflect receptor-ligand

binding interactions that occur in vivo. Indeed, the presence of a structurally complex 1000 amino acid intracellular domain within Notch may be more consistent with a role in signal transduction than
5 with purely adhesive interactions. Given that Notch may have an adhesive function in concert with Delta, axonal expression of Notch may play some role in axon guidance.

10 7. EGF REPEATS 11 AND 12 OF NOTCH ARE REQUIRED AND SUFFICIENT FOR NOTCH-DELTA-MEDIATED AGGREGATION

In this study, we use the same aggregation assay as described in Section 6, together with deletion mutants of Notch to identify regions within
15 the extracellular domain of Notch necessary for interactions with Delta. We present evidence that the EGF repeats of Notch are directly involved in this interaction and that only two of the 36 EGF repeats appear necessary. We demonstrate that these two EGF
20 repeats are sufficient for binding to Delta and that the calcium dependence of Notch-Delta mediated aggregation also associates with these two repeats. Finally, the two corresponding EGF repeats from the Xenopus homolog of Notch also mediate aggregation with
25 Delta, implying that not only has the structure of Notch been evolutionarily conserved, but also its function. These results suggest that the extracellular domain of Notch is surprisingly modular, and could potentially bind a variety of proteins in
30 addition to Delta.

7.1. EXPERIMENTAL PROCEDURES

7.1.1. EXPRESSION CONSTRUCTS

The constructs described are all derivatives
35 of the full length Notch expression construct #1 pMtNMg (see Section 6, supra). All ligations were

performed using DNA fragments cut from low melting temperature agarose gels (Sea Plaque, FMC BioProducts). The 6 kb EcoRI-XhoI fragment from pMtNMg containing the entire extracellular domain of Notch was ligated into the EcoRI-XhoI sites of the BluescriptTM vector (Stratagene), and named RI/XBS. All subsequent deletions and insertions of EGF repeats were performed in this subclone. The Notch sequence containing the EcoRI-XhoI fragment of these RI/XBS derivatives was then mixed with the 5.5 kb XhoI-XbaI fragment from pMtNMg containing the intracellular domain and 3' sequences needed for polyadenylation, and then inserted into the EcoRI-XbaI site of pRMHa-3 (Bunch et al., 1988, Nucl. Acids Res. 16, 1043-1061) in a three piece ligation. All subsequent numbers refer to nucleotide coordinates of the Notch sequence according to Wharton et al. (1985, Cell 43, 567-581).

For construct #2 DSph, RI/XBS was digested to completion with SphI and then recircularized, resulting in a 3.5 kb in-frame deletion from SphI(996) to SphI(4545).

For construct #3 ΔCla, RI/XBS was digested to completion with ClaI and then religated, producing a 2.7 kb in-frame deletion from ClaI(1668) to ClaI(4407). The ligation junction was checked by double strand sequencing (as described by Xu et al., 1990, Genes Dev. 4, 464-475) using the SequenaseTM Kit (U.S. Biochemical Corp., Cleveland). We found that although the ClaI site at position 4566 exists according to the sequence, it was not recognized under our conditions by the ClaI restriction enzyme.

For constructs #4-12, RI/XBS was partially digested with ClaI and then religated to produce all possible combinations of in-frame deletions:
construct #4 ΔEGF7-17 removed the sequence between

ClaI(1668) and ClaI(2820); Construct #5 ΔEGF9-26 removed the sequence between ClaI(1905) and ClaI(3855); construct #6 ΔEGF17-31 removed the sequence between ClaI(2820) and ClaI(4407); construct
5 #7 ΔEGF7-9 removed the sequence between ClaI(1668) and ClaI(1905); construct #8 ΔEGF9-17 removed the sequence between ClaI(1905) and ClaI(2820); construct #9 ΔEGF17-26 removed the sequence between ClaI(2820) and ClaI(3855); construct #10 ΔEGF 26-30 removed the
10 sequence between ClaI(3855) and ClaI(4407); construct #11 ΔEGF9-30 removed the sequence between ClaI(1905) and ClaI(4407); construct #12 ΔEGF 7-26 removed the sequence between ClaI(1668) and ClaI(3855).

For constructs #13 ΔCla+EGF9-17 and #14
15 ΔCla+EGF17-26, the ~0.9 kb fragment between ClaI(1905) and ClaI(2820), and the ~1.0 kb fragment between ClaI(2820) and ClaI(3855), respectively, were inserted into the unique ClaI site of construct #3 ΔCla.

For construct #16 split, the 11 kb KpnI/XbaI
20 fragment of pMtNMg was replaced with the corresponding KpnI/XbaI fragment from a Notch minigene construct containing the split mutation in EGF repeat 14.

For constructs #17-25, synthetic primers for
polymerase chain reaction (PCR) were designed to
25 amplify stretches of EGF repeats while breaking the EGF repeats at the ends of the amplified piece in the same place as the common ClaI sites just after the third cysteine of the repeat (see Figure 7). The PCR products were gel purified as usual and ligated into
30 the ClaI site of construct #3 ΔCla which was made blunt by filling with the Klenow fragment of DNA Polymerase I (Maniatis et al., 1990, Molecular Cloning, A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York). The
35 correct orientation of the inserts was determined by

PCR using a sense strand primer within the insert together with an antisense strand primer in EGF repeat 35. All primers were 20-mers, and were named with the number of the nucleotide at their 5' end, according to the nucleotide coordinates of the Notch sequence in Wharton et al. (1985, Cell 43, 567-581), and S refers to a sense strand primer while A refers to an antisense strand primer. Construct #16 Δ Cla+EGF(9-13) used primers S1917 and A2367. Construct #17 Δ Cla+EGF(11-15) used primers S2141 and A2591. Construct #18 Δ Cla+EGF(13-17) used primers S2375 and A2819. Construct #19 Δ Cla+EGF(10-13) used primers S2018 and A2367. Construct #20 Δ Cla+EGF(11-13) used primers S2141 and A2367. Construct #21 Δ Cla+EGF(10-12) used primers S2018 and A2015. Construct #22 Δ Cla+EGF(10-11) used primers S2018 and A2322. Construct #23 Δ Cla+EGF(10-12) used primers S2018 and A2322. Construct #24 Δ Cla+EGF(11-12) used primers S2081 and A2322.

For construct #25 Δ EGF, construct R1/XBS was digested to completion with SphI(996) and partially digested with BamHI(5135). The resulting incompatible ends were joined using a synthetic linker designed to create a unique ClaI site. This produced an in frame deletion which removed all 36 EGF repeats with the exception of the first half of repeat 1. For constructs #26-29, the EGF fragments were inserted into this ClaI site as previously described for the corresponding constructs #13, 16, 19, and 23.

For construct #30 Δ ECN, construct R1/XBS was digested to completion with BglI, EcoRI and XhoI. The ~0.2 kb EcoRI-BglI fragment (722-948) and the ~0.7 kb BglI-XhoI (5873-6627) fragments were ligated with EcoRI-XhoI cut Bluescript vector and a synthetic linker designed to create a unique ClaI site,

resulting in an in-frame deletion from BglI(941) to BglI(5873) that removed all 36 EGF repeats except for the first third of repeat 1 as well as the 3 Notch/lin-12 repeats. For constructs #31 and 32, the
 5 EGF fragments were inserted into the unique ClaI site as previously described for constructs #19 and 23.

For constructs #33 and 34, PCR primers S1508 and A1859 based on the Xenopus Notch sequence (Coffman et al., 1990, Science 249, 1438-1441; numbers refer to
 10 nucleotide coordinates used in this paper), were used to amplify EGF repeats 11 and 12 out of a Xenopus stage 17 cDNA library (library was made by D. Melton and kindly provided by M. Danilchek). The fragment was ligated into construct #3 DCl a and sequenced.

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7.1.2. CELL CULTURE AND TRANSFECTION

The Drosophila S2 cell line was grown and transfected as described in Section 6, supra. The Delta-expressing stably transformed S2 cell line L-49-
 20 6-7 (kindly established by L. Cherbas) was grown in M3 medium (prepared by Hazleton Co.) supplemented with 11% heat inactivated fetal calf serum (FCS) (Hyclone), 100 U/ml penicillin-100 µg/ml streptomycin-0.25 µg/ml fungizoneTM (Hazleton), 2×10^{-7} M methotrexate, 0.1 mM
 25 hypoxanthine, and 0.016 mM thymidine.

7.1.3. AGGREGATION ASSAYS AND IMMUNOFLUORESCENCE

Aggregation assays and Ca⁺⁺ dependence experiments were as described supra, Section 6. Cells
 30 were stained with the anti-Notch monoclonal antibody 9C6.C17 and anti-Delta rat polyclonal antisera (details described in Section 6, supra). Surface expression of Notch constructs in unpermeabilized cells was assayed using rat polyclonal antisera raised
 35 against the 0.8 kb (amino acids 237-501; Wharton et

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al., 1985, Cell 43, 567-581) BstYI fragment from the extracellular domain of Notch. Cells were viewed under epifluorescence on a Leitz Orthoplan 2 microscope.

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7.2. RESULTS

7.2.1. EGF REPEATS 11 AND 12 OF NOTCH ARE REQUIRED FOR NOTCH-DELTA MEDIATED AGGREGATION

We have undertaken an extensive deletion analysis of the extracellular domain of the Notch protein, which we have shown (supra, Section 6) to be involved in Notch-Delta interactions, to identify the precise domain of Notch mediating these interactions. We tested the ability of cells transfected with the various deletion constructs to interact with Delta using the aggregation assay described in Section 6. Briefly, Notch deletion constructs were transiently transfected into Drosophila S2 cells, induced with CuSO₄, and then aggregated overnight at room temperature with a small amount of cells from the stably transformed Delta expressing cell line L49-6-7(Cherbas), yielding a population typically composed of ~1% Notch expressing cells and ~5% Delta expressing cells, with the remaining cells expressing neither protein. To assay the degree of aggregation, cells were stained with antisera specific to each gene product and examined with immunofluorescent microscopy (see experimental procedures for details). Aggregates were defined as clusters of four or more cells containing both Notch and Delta expressing cells, and the values shown in Figure 6 represent the percentage of all Notch expressing cells found in such clusters. All numbers reflect the average result from at least two separate transfection experiments in which at least 100 Notch expressing cell units (either single cells or clusters) were scored.

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Schematic drawings of the constructs tested and results of the aggregation experiments are shown in Figure 6 (see Experimental Procedures for details). All expression constructs were derivatives of the full
5 length Notch expression construct #1 pMtNMg (described in Section 6, supra).

The initial constructs (#2 DSph and #3 ΔCla) deleted large portions of the EGF repeats. Their inability to promote Notch-Delta aggregation suggested
10 that the EGF repeats of Notch were involved in the interaction with Delta. We took advantage of a series of six in-frame ClaI restriction sites to further dissect the region between EGF repeats 7 and 30. Due to sequence homology between repeats, five of the ClaI
15 sites occur in the same relative place within the EGF repeat, just after the third cysteine, while the sixth site occurs just before the first cysteine of EGF repeat 31 (Figure 7). Thus, by performing a partial ClaI digestion and then religating, we obtained
20 deletions that not only preserved the open reading frame of the Notch protein but in addition frequently maintained the structural integrity and conserved spacing, at least theoretically, of the three disulfide bonds in the chimeric EGF repeats produced
25 by the religation (Figure 6, constructs #4-14). Unfortunately, the most 3' ClaI site was resistant to digestion while the next most 3' ClaI site broke between EGF repeats 30 and 31. Therefore, when various ClaI digestion fragments were reinserted into
30 the framework of the complete ClaI digest (construct #3 ΔCla), the overall structure of the EGF repeats was apparently interrupted at the 3' junction.

Several points about this series of constructs are worth noting. First, removal of the
35 ClaI restriction fragment breaking in EGF repeats 9

and 17 (construct #8 Δ EGF9-17) abolished aggregation with Delta, while reinsertion of this piece into construct #3 Δ Cla, which lacks EGF repeats 7-30, restored aggregation to roughly wild type levels (construct #13 Δ Cla+EGF9-17), suggesting that EGF repeats 9 through 17 contain sequences important for binding to Delta. Second, all constructs in this series (#4-14) were consistent with the binding site mapping to EGF repeats 9 through 17. Expression constructs containing these repeats (#6, 7, 9, 10, 13) promoted Notch-Delta interactions while constructs lacking these repeats (#4, 5, 8, 11, 12, 14) did not. To confirm that inability to aggregate with Delta cells was not simply due to failure of the mutagenized Notch protein to reach the cell surface, but actually reflected the deletion of the necessary binding site, we tested for cell surface expression of all constructs by immunofluorescently staining live transfected cells with antibodies specific to the extracellular domain of Notch. All constructs failing to mediate Notch-Delta interactions produced a protein that appeared to be expressed normally at the cell surface. Third, although the aggregation assay is not quantitative, two constructs which contained EGF repeats 9-17, #9 Δ EGF17-26 or most noticeably #10 Δ EGF26-30, aggregated at a seemingly lower level. Cells transfected with constructs #9 Δ EGF17-26 and #10 Δ EGF26-30 showed considerably less surface staining than normal, although fixed and permeabilized cells reacted with the same antibody stained normally, indicating we had not simply deleted the epitopes recognized by the antisera. By comparing the percentage of transfected cells in either permeabilized or live cell populations, we found that roughly 50% of transfected cells for construct #9

ΔEGF17-26 and 10% for construct #10 ΔEGF26-30 produced detectable protein at the cell surface. Thus these two constructs produced proteins which often failed to reach the cell surface, perhaps because of misfolding, thereby reducing, but not abolishing, the ability of transfected cells to aggregate with Delta-expressing cells.

Having mapped the binding site to EGF repeats 9 through 17, we checked whether any Notch mutations whose molecular lesion has been determined mapped to this region. The only such mutation was split, a semidominant Notch allele that correlates with a point mutation in EGF repeat 14 (Hartley et al., 1987, EMBO J. 6, 3407-3417; Kelley et al., 1987, Mol. Cell. Biol. 6, 3094-3108). In fact, a genetic screen for second site modifiers of split revealed several alleles of Delta, suggesting a special relationship between the split allele of Notch, and Delta (Brand and Campus-Ortega, 1990, Roux's Arch. Dev. Biol. 198(5), 275-285). To test for possible effects of the split mutation on Notch-Delta mediated aggregation, an 11 kb fragment containing the missense mutation associated with split was cloned into the Notch expression construct (#15 split). However, aggregation with Delta-expressing cells was unaffected in this construct suggesting, as was confirmed by subsequent constructs, that EGF repeat 14 of Notch was not involved in the interactions with Delta modelled by our tissue culture assay.

Thus, to further map the Delta binding domain within EGF repeats 9-17, we used specific oligonucleotide primers and the PCR technique to generate several subfragments of this region. To be consistent with constructs #4-14 which produced proteins that were able to interact with Delta, we

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designed the primers to splice the EGF repeats just after the third cysteine, in the same place as the common ClaI site (Figure 7). The resulting PCR products were ligated into the ClaI site of construct #3 ΔCla. Three overlapping constructs, #16, 17 and 18 were produced, only one of which, #16 ΔCla+EGF9-13, when transfected into S2 cells, allowed aggregation with Delta cells. Construct #19 ΔCla+EGF(10-13), which lacks EGF repeat 9, further defined EGF repeats 10-13 as the region necessary for Notch-Delta interactions.

Constructs #20-24 represented attempts to break this domain down even further using the same PCR strategy (see Figure 7). We asked first whether both EGF repeats 11 and 12 were necessary, and second, whether the flanking sequences from EGF repeats 10 and 13 were directly involved in binding to Delta. Construct #20 ΔCla+EGF(11-13), in which EGF repeat 12 is the only entire repeat added, and #21 ΔCla+EGF(10-12), in which EGF repeat 11 is the only entire repeat added, failed to mediate aggregation, suggesting that the presence of either EGF repeat 11 or 12 alone was not sufficient for Notch-Delta interactions. However, since the 3' ligation juncture of these constructs interrupted the overall structure of the EGF repeats, it was possible that a short "buffer" zone was needed to allow the crucial repeat to function normally. Thus for example in construct #19 ΔCla+EGF(10-13), EGF repeat 12 might not be directly involved in binding to Delta but instead might contribute the minimum amount of buffer sequence needed to protect the structure of EGF repeat 11, thereby allowing interactions with Delta. Constructs #22-24 addressed this issue. We designed PCR primers that broke at the end of the EGF repeat and therefore were less likely to disrupt the

EGF disulfide formation at the 3' ligation juncture. Constructs #22 Δ Cla+EGF(10-11), which did not mediate aggregation, and #23 Δ Cla+EGF(10-12), which did, again suggested that both repeats 11 and 12 are required while the flanking sequence from repeat 13 clearly is not. Finally, construct #24 Δ Cla+EGF(11-12), although now potentially structurally disrupted at the 5' junction, convincingly demonstrated that the sequences from EGF repeat 10 are not crucial. Thus based on entirely consistent data from 24 constructs, we propose that EGF repeats 11 and 12 of Notch together define the smallest functional unit obtainable from this analysis that contains the necessary sites for binding to Delta in transfected S2 cells.

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7.2.2. EGF REPEATS 11 AND 12 OF NOTCH ARE SUFFICIENT
FOR NOTCH-DELTA MEDIATED AGGREGATION

The large ClaI deletion into which PCR fragments were inserted (#3 Δ Cla) retains roughly 1/3 of the original 36 EGF repeats as well as the three Notch/lin-12 repeats. While these are clearly not sufficient to promote aggregation, it is possible that they form a necessary framework within which specific EGF repeats can interact with Delta. To test whether only a few EGF repeats were in fact sufficient to promote aggregation, we designed two constructs, #25 Δ EGF which deleted all 36 EGF repeats except for the first two-thirds of repeat 1, and #30 Δ ECN which deleted the entire extracellular portion of Notch except for the first third of EGF repeat 1 and ~35 amino acids just before the transmembrane domain. Fragments which had mediated Notch-Delta aggregation in the background of construct #3 Δ Cla, when inserted into construct #25 Δ EGF, were again able to promote interactions with Delta (constructs #26-30). Analogous constructs (#31,32) in which the Notch/lin-

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12 repeats were also absent, again successfully mediated Notch-Delta aggregation. Thus EGF repeats 11 and 12 appear to function as independent modular units which are sufficient to mediate Notch-Delta interactions in S2 cells, even in the absence of most of the extracellular domain of Notch.

7.2.3. EGF REPEATS 11 AND 12 OF NOTCH MAINTAIN THE
CALCIUM DEPENDENCE OF NOTCH-DELTA
MEDIATED AGGREGATION

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As described in Section 6, supra (Fehon et al., 1990, Cell 61, 523-534), we showed that Notch-Delta-mediated S2 cell aggregation is calcium dependent. We therefore examined the ability of cells expressing certain deletion constructs to aggregate with Delta expressing cells in the presence or absence of Ca^{++} ions. We tested constructs #1 pMtNMg as a control, and #13, 16, 19, 23, 24, 26, 27 and 28, and found that cells mixed in Ca^{++} containing medium at 4°C readily formed aggregates while cells mixed in Ca^{++} free medium containing EGTA failed to aggregate (Table III).

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TABLE IIIEFFECT OF EXOGENOUS Ca^{++} ON NOTCH - DELTA AGGREGATION^a

		<u>Without Ca^{++} Ions</u>	<u>With Ca^{++} Ions</u>
5	1. pMtNMg	0	37
	13. $\Delta\text{Cla}+\text{EGF}(9-17)$	0	31
	16. $\Delta\text{Cla}+\text{EGF}(9-13)$	0	38
	19. $\Delta\text{Cla}+\text{EGF}(10-13)$	0	42
	23. $\Delta\text{Cla}+\text{EGF}(10-12)$	0	48
10	29. $\Delta\text{EGF}+\text{EGF}(10-12)$	0	44
	32. $\Delta\text{ECN}+\text{EGF}(10-12)$	0	39
	33. $\Delta\text{Cla}+\text{XEGF}(10-13)$	0	34

^aData presented as percentage of Notch-expressing cells
 15 found in aggregates (as in Figure 6).

Clearly, the calcium dependence of the interaction has
 been preserved in even the smallest construct,
 consistent with the notion that the minimal constructs
 20 containing EGF repeats 11 and 12 bind to Delta in a
 manner similar to that of full length Notch. This
 result is also interesting in light of recent studies
 suggesting EGF-like repeats with a particular
 consensus sequence may act as Ca^{++} binding domains
 25 (Morita et al., 1984, J. Biol. Chem. 259, 5698-5704;
 Sugo et al., 1984, J. Biol. Chem. 259, 5705-5710; Rees
 et al., 1988, EMBO J. 7, 2053-2061; Handford et al.,
 1990, EMBO J. 9, 475-480). Over half of the EGF
 repeats in Notch, including repeats 11 and 12, conform
 30 to this consensus, further strengthening the argument
 that EGF repeats 11 and 12 are responsible for
 promoting Notch-Delta interactions.

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7.2.4. THE DELTA BINDING FUNCTION OF EGF REPEATS 11
AND 12 OF NOTCH IS CONSERVED IN THE XENOPUS
HOMOLOG OF NOTCH

5 Having mapped the Delta binding site to EGF
repeats 11 and 12 of Notch, we were interested in
asking whether this function was conserved in the
Notch homolog that has been identified in Xenopus
(Coffman et al., 1990, Science 249, 1438-1441). This
10 protein shows a striking similarity to Drosophila
Notch in overall structure and organization. For
example, within the EGF repeat region both the number
and linear organization of the repeats has been
preserved, suggesting a possible functional
15 conservation as well. To test this, we made PCR
primers based on the Xenopus Notch sequence (Coffman
et al., 1990, Science 249, 1438-1441) and used these
to obtain an ~350 bp fragment from a Xenopus Stage 17
cDNA library that includes EGF repeats 11 and 12
20 flanked by half of repeats 10 and 13 on either side.
This fragment was cloned into construct #3 ΔCla, and
three independent clones were tested for ability to
interact with Delta in the cell culture aggregation
assay. Two of the clones, #33a&bΔCla+XEGF(10-13),
25 when transfected into S2 cells were able to mediate
Notch-Delta interactions at a level roughly equivalent
to the analogous Drosophila Notch construct
#19ΔCla+EGF(10-13), and again in a calcium dependent
manner (Table III). However, the third clone
30 #33cΔCla+XEGF(10-13) failed to mediate Notch-Delta
interactions although the protein was expressed
normally at the cell surface as judged by staining
live unpermeabilized cells. Sequence comparison of
the Xenopus PCR product in constructs #33a and 33c
35 revealed a missense mutation resulting in a leucine to

proline change (amino acid #453, Coffman, et al., 1990, Science 249, 1438-1441) in EGF repeat 11 of construct #33c. Although this residue is not conserved between Drosophila and Xenopus Notch (Figure 8), the introduction of a proline residue might easily disrupt the structure of the EGF repeat, and thus prevent it from interacting properly with Delta.

Comparison of the amino acid sequence of EGF repeats 11 and 12 of Drosophila and Xenopus Notch reveals a high degree of amino acid identity, including the calcium binding consensus sequence (Figure 8, SEQ ID NO:1 and NO:2). However the level of homology is not strikingly different from that shared between most of the other EGF repeats, which overall exhibit about 50% identity at the amino acid level. This one to one correspondence between individual EGF repeats suggests that perhaps they too may comprise conserved functional units. Delta interactions, again in a calcium ion-dependent manner.

20

7.3. DISCUSSION

We have continued our study of interactions between the protein products of the genes Notch and Delta, using the in vitro S2 cell aggregation assay described in Section 6, supra. Based on an extensive deletion analysis of the extracellular domain of Notch, we show that the regions of Notch containing EGF-homologous repeats 11 and 12 are both necessary and sufficient for Notch-Delta-mediated aggregation, and that this Delta binding capability has been conserved in the same two EGF repeats of Xenopus Notch. Our finding that the aggregation mapped to EGF repeats 11 and 12 of Notch demonstrates that the EGF repeats of Notch also function as specific protein binding domains.

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Recent studies have demonstrated that EGF domains containing a specific consensus sequence can bind Ca^{++} ions (Morita et al., 1984, J. Biol. Chem. 259, 5698-5704; Sugo et al., 1984, J. Biol. Chem. 259, 5705-5710; Rees et al., 1988, EMBO J. 7, 2053-2061; Handford et al., 1990, EMBO J. 9, 475-480). In fact, about one half of the EGF repeats in Notch, including repeats 11 and 12, conform to this consensus. We have shown that exogenous Ca^{++} was necessary for Notch-Delta mediated aggregation of transfected S2 cells (see Section 6; Fehon et al., 1990, Cell 61, 523-534). We tested a subset of our deletion constructs and found that EGF repeats 11 and 12 alone (#32 Δ ECN+EGF(11-12)) were sufficient to maintain the Ca^{++} dependence of Notch-Delta interactions.

A number of studies have suggested that the genetic interactions between Notch and Delta may reflect a dose sensitive interaction between their protein products. Genetic studies have indicated that the relative gene dosages of Notch and Delta are crucial for normal development. For example, Xu et al. (1990, Genes Dev. 4, 464-475) found that null mutations at Delta could suppress lethal interactions between heterozygous combinations of Abruptex (Ax) alleles, a class of Notch mutations that correlate with missense mutations within the EGF repeats (Hartley et al., 1987, EMBO J. 6, 3407-3417; Kelley et al., 1987, Mol. Cell Biol. 6, 3094-3108). The in vitro interactions we have described in which we observe both Notch-Delta and Delta-Delta associations (see Section 6) imply that a competitive interaction between Notch and Delta for binding to Delta may reflect the underlying basis for the observed genetic interactions. Furthermore, we were able to coimmunoprecipitate Notch and Delta from both tissue

culture and embryonic cell extracts (see Section 6), indicating a possible in vivo association of the two proteins. In addition, mRNA in situ analyses of Notch and Delta expression patterns in the embryo suggest
5 that expression of the two is overlapping but not identical (Kopczynski and Muskavitch, 1989, Development 107, 623-636; Hartley et al., 1987, EMBO J. 6, 3407-3417). Detailed antibody analysis of Notch protein expression during development have recently
10 revealed Notch expression to be more restricted at the tissue and subcellular levels than previous studies had indicated (Johansen et al., 1989, J. Cell Biol. 109, 2427-2440; Kidd et al., 1989, Genes Dev. 3, 1113-1129).

15 Our finding that the same two EGF repeats from the Xenopus Notch homolog are also able to mediate interactions with Delta in tissue culture cells argues strongly that a similar function will have been conserved in vivo. Although these two EGF
20 repeats are sufficient in vitro, it is of course possible that in vivo more of the Notch molecule may be necessary to facilitate Notch-Delta interactions. In fact, we were somewhat surprised for two reasons to find that the Delta binding site did not map to EGF
25 repeats where several of the Ax mutations have been shown to fall, first, because of the genetic screen (Xu et al., 1990, Genes Dev. 4, 464-475) demonstrating interactions between Ax alleles and Delta mutations, and second, because of sequence analyses that have
30 shown certain Ax alleles are associated with single amino acid changes within the putative Ca⁺⁺ binding consensus of the EGF repeats. For example, the AX^{E2} mutation changes EGF repeat 29 toward the Ca⁺⁺ binding consensus sequence while the AX^{9B2} mutation moves EGF
35 repeat 24 away from the consensus. It is possible

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that in vivo these regions of the Notch protein may be involved in interactions, either with Delta and/or other proteins, that may not be accurately modelled by our cell culture assay.

5 Our in vitro mapping of the Delta binding domain to EGF repeats 11 and 12 of Notch represents the first assignment of function to a structural domain of Notch. In fact, the various deletion constructs suggest that these two EGF repeats function
10 as a modular unit, independent of the immediate context into which they are placed. Thus, neither the remaining 34 EGF repeats nor the three Notch/lin-12 repeats appear necessary to establish a structural framework required for EGF repeats 11 and 12 to
15 function. Interestingly, almost the opposite effect was observed: although our aggregation assay does not measure the strength of the interaction, as we narrowed down the binding site to smaller and smaller fragments, we observed an increase in the ability of
20 the transfected cells to aggregate with Delta expressing cells, suggesting that the normal flanking EGF sequences actually impede association between the proteins. For two separate series of constructs, either in the background of construct #3 Δ Cla (compare
25 #9, 16, 19, 23) or in the background of construct #25 Δ EGF (compare #26, 27, 28), we observed an increase in ability to aggregate such that the smallest constructs (#19, 23, 28, 29) consistently aggregated above wild type levels (#1 pMtNMg). These results imply that the
30 surrounding EGF repeats may serve to limit the ability of EGF repeats 11 and 12 to access Delta, thereby perhaps modulating Notch-Delta interactions in vivo.

Notch encodes a structurally complex transmembrane protein that has been proposed to play a
35 pleiotropic role throughout Drosophila development.

The fact that EGF repeats 11 and 12 appear to function as an independent modular unit that is sufficient, at least in cell culture, for interactions with Delta, immediately presents the question of the role of the hypothesis is that these may also form modular binding domains for other proteins interacting with Notch at various times during development.

In addition to Xenopus Notch, lin-12 and glp-1, two genes thought to function in cell-cell interactions involved in the specification of certain cell fates during C. elegans development, encode EGF homologous transmembrane proteins which are structurally quite similar to Drosophila and Xenopus Notch. All four proteins contain EGF homologous repeats followed by three other cysteine rich repeats (Notch/lin-12 repeats) in the extracellular domain, a single transmembrane domain, and six cdc10/ankyrin repeats in the intracellular region. Unlike Xenopus Notch, which, based on both sequence comparison as well as the results of our Delta binding assay, seems likely to encode the direct functional counterpart of Drosophila Notch, lin-12 and glp-1 probably encode distinct members of the same gene family. Comparison of the predicted protein products of lin-12 and glp-1 with Notch reveal specific differences despite an overall similar organization of structural motifs. The most obvious difference is that lin-12 and glp-1 proteins contain only 13 and 10 EGF repeats, respectively, as compared to the 36 for both Xenopus and Drosophila Notch. In addition, in the nematode genes the array of EGF repeats is interrupted after the first EGF repeat by a distinct stretch of sequence absent from Notch. Furthermore, with respect to the Delta binding domain we have defined as EGF repeats 11 and 12 of Notch, there are no two contiguous EGF

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repeats in the lin-12 or glp-1 proteins exhibiting the Ca⁺⁺ binding consensus sequence, nor any two contiguous repeats exhibiting striking similarity to EGF repeats 11 and 12 of Notch, again suggesting that
5 the lin-12 and glp-1 gene products are probably functionally distinct from Notch.

Our finding that EGF repeats 11 and 12 of Notch form a discrete Delta binding unit represents the first concrete evidence supporting the idea that
10 each EGF repeat or small subset of repeats may play a unique role during development, possibly through direct interactions with other proteins. The homologies seen between the adhesive domain of Delta and Serrate (see Section 8.3.4, infra) suggest that
15 the homologous portion of Serrate is "adhesive" in that it mediates binding to other toporythmic proteins. In addition, the gene scabrous, which encodes a secreted protein with similarity to fibrinogen, may interact with Notch.

20 In addition to the EGF repeat, multiple copies of other structural motifs commonly occur in a variety of proteins. One relevant example is the cdc10/ankyrin motif, six copies of which are found in the intracellular domain of Notch. Ankyrin contains
25 22 of these repeats. Perhaps repeated arrays of structural motifs may in general represent a linear assembly of a series of modular protein binding units. Given these results together with the known structural, genetic and developmental complexity of
30 Notch, Notch may interact with a number of different ligands in a precisely regulated temporal and spacial pattern throughout development. Such context specific interactions with extracellular proteins could be mediated by the EGF and Notch/lin-12 repeats, while
35 interactions with cytoskeletal and cytoplasmic

proteins could be mediated by the intracellular cdc10/ankyrin motifs.

5 8. THE AMINO-TERMINUS OF DELTA IS AN EGF-BINDING
DOMAIN THAT INTERACTS WITH NOTCH AND DELTA

Aggregation of cultured cells programmed to express wild type and variant Delta proteins has been employed to delineate Delta sequences required for heterotypic interaction with Notch and homotypic Delta
10 interaction. We have found that the amino terminus of the Delta extracellular domain is necessary and sufficient for the participation of Delta in heterotypic (Delta-Notch) and homotypic (Delta-Delta) interactions. We infer that the amino terminus of
15 Delta is an EGF motif-binding domain (EBD), given that Notch EGF-like sequences are sufficient to mediate heterotypic interaction with Delta. The Delta EBD apparently possesses two activities: the ability to bind EGF-related sequences and the ability to self-
20 associate. We also find that Delta is taken up by cultured cells that express Notch, which may be a reflection of a mechanism by which these proteins interact in vivo.

25 8.1. MATERIALS AND METHODS

8.1.1. CELL LINES

The S2 Drosophila cell line (Schneider, 1972, J. Embryol. Exp. Morph. 27, 353-365) used in these experiments was grown as described in Section 6.

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8.1.2. IMMUNOLOGICAL PROBES

Immunohistochemistry was performed as described in Section 6, supra, or sometimes with minor modifications of this procedure. Antisera and
35 antibodies employed included mouse polyclonal anti-

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Delta sera raised against a Delta ELR array segment that extends from the fourth through ninth ELRs (see Section 6); rat polyclonal anti-Delta sera raised against the same Delta segment (see Section 6); rat
5 polyclonal anti-Notch sera raised against a Notch ELR array segment that extends from the fifth through thirteenth ELRs; mouse monoclonal antibody C17.9C6 (see Section 6), which recognizes the Notch intracellular domain; and mouse monoclonal antibody
10 BP-104 (Hortsch et al., 1990, Neuron 4, 697-709), which recognizes the long form of Drosophila neuroglial.

8.1.3. EXPRESSION VECTOR CONSTRUCTS

15 Constructs employed to program expression of wild type Delta (pMTD11) and wild type Notch (pMTNMg) are described in Section 6, supra. Constructs that direct expression of variant Delta proteins were generated using pMTD11, the D11 cDNA cloned into
20 Bluescript+ (pBSD11; Kopczynski et al., 1988, Genes Dev. 2, 1723-1735), and pRmHa3-104 (A.J. Bieber, pers. comm.), which consists of the insertion of the 1B7A-250 cDNA into the metallothionein promoter vector
pRmHa-3 (Bunch et al., 1988, Nucl. Acids Res. 16,
25 1043-1061) and supports inducible expression of the long form of Drosophila neuroglial (Hortsch et al., 1990, Neuron 4, 697-709).

Briefly, constructs were made as follows:

Del(Sca-Nae) - Cut pBSD11 with SalI
30 (complete digest) and ScaI (partial), isolate vector-containing fragment. Cut pBSD11 with NaeI (partial) and SalI (complete), isolate Delta carboxyl-terminal coding fragment. Ligate fragments, transform, and isolate clones. Transfer EcoRI insert into pRmHa-3.

Del(Bam-Bgl) - Cut pBSD11 with BglII (complete) and BamHI (partial), fill ends with Klenow DNA polymerase, ligate, transform, and isolate clones. Transfer EcoRI insert into pRmHa-3.

5 Del(ELR1-ELR3) - PCR-amplify basepairs 236-830 of the D11 cDNA using 5-ACTTCAGCAACGATCACGGG-3' (SEQ ID NO:26) and 5'-TTGGGTATGTGACAGTAATCG-3' (SEQ ID NO:27), treat with T4 DNA polymerase, ligate into pBSD11 cut with ScaI (partial) and BglII (complete)
10 and end-filled with Klenow DNA polymerase, transform, and isolate clones. Transfer BamHI-SalI Delta carboxyl-terminal coding fragment into pRmHa-3.

Del(ELR4-ELR5) - pBSD11 was digested to completion with BglII and partially with PstI. The
15 5.6 kb vector-containing fragment was isolated, circularized using T4 DNA ligase in the presence of a 100X molar excess of the oligonucleotide 5'-GATCTGCA-3', and transformed and clones were isolated. The resulting EcoRI insert was then transferred into
20 pRmHa-3.

Ter(Dde) - Cut pBSD11 with DdeI (partial), end-fill with Klenow DNA polymerase, ligate with 100X molar excess of 5'-TTAAGTTAACTTAA-3' (SEQ ID NO:28), transform, and isolate clones. Transfer EcoRI insert
25 into pRmHa-3.

Ins(Nae)A - Cut pMTD11 with NaeI (partial), isolate vector-containing fragment, ligate with 100X molar excess of 5'-GGAAGATCTTCC-3' (SEQ ID NO:29), transform, and isolate clones.

30 NAE B - pMTD11 was digested partially with NaeI, and the population of tentatively linearized circles approximately 5.8 kb in length was isolated. The fragments were recircularized using T4 DNA ligase in the presence of a 100X molar excess of the
35 oligonucleotide 5'-GGAAGATCTTCC-3' (SEQ ID NO:29) and

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transformed, and a clone (NAE A) that contained multiple inserts of the linker was isolated. NAE A was digested to completion with BglII, and the resulting 0.4 kb and 5.4 kb fragments were isolated, ligated and transformed, and clones were isolated.

Ins(Stu) - Cut pMTD11 with StuI (complete), isolate vector-containing fragment, ligate with 100X molar excess of 5'-GGAAGATCTTCC-3' (SEQ ID NO:29), transform and isolate clones.

STU B - pMTD11 was digested completely with StuI, and the resulting 5.8 kb fragment was isolated. The fragment was recircularized using T4 DNA ligase in the presence of a 100X molar excess of the oligonucleotide 5'-GGAAGATCTTCC-3' (SEQ ID NO:29) and transformed, and a clone (STU A) that contained multiple inserts of the linker was isolated. STU B was digested to completion with BglII, and the resulting 0.6 kb and 5.2 kb fragments were isolated, ligated and transformed, and clones were isolated.

NG1 - Cut pRmHa3-104 with BglII (complete) and EcoRI (complete), isolate vector-containing fragment. Cut Ins(Nae)A with EcoRI (complete) and BglII (complete), isolate Delta amino-terminal coding fragment. Ligate fragments, transform and isolate clones.

NG2 - Cut pRmHa3-104 with BglII (complete) and EcoRI (complete), isolate vector-containing fragment. Cut Del(ELR1-ELR3) with EcoRI (complete) and BglII (complete), isolate Delta amino-terminal coding fragment. Ligate fragments, transform and isolate clones.

NG3 - Cut pRmHa3-104 with BglII (complete) and EcoRI (complete), isolate vector-containing fragment. Cut pMTD11 with EcoRI (complete) and BglII (complete), isolate Delta amino-terminal coding

fragment. Ligate fragments, transform and isolate clones.

NG4 - Cut pRmHa3-104 with BglII (complete) and EcoRI (complete), isolate vector containing
5 fragment. Cut Del(Sca-Nae) with EcoRI (complete) and BglII (complete), isolate Delta amino-terminal coding fragment. Ligate fragments, transform and isolate clones.

NG5 - Generate Del(Sca-Stu) as follows: cut
10 pMTD11 with ScaI (complete) and StuI (complete), isolate ScaI-ScaI amino-terminal coding fragment and StuI-ScaI carboxyl-terminal coding fragment, ligate, transform and isolate clones. Cut Del(Sca-Stu) with
15 EcoRI (complete) and BglII (complete), isolate Delta amino terminal coding fragment. Cut pRmHa3-104 with BglII (complete) and EcoRI (complete), isolate vector-containing fragment. Ligate fragments, transform and isolate clones.

The sequence contents of the various Delta
20 variants are shown in Table IV. Schematic diagrams of the Delta variants defined in Table IV are shown in Figure 9.

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TABLE IV
SEQUENCE CONTENTS OF DELTA VARIANTS
EMPLOYED IN THIS STUDY

		<u>Nucleotides</u>	<u>Amino Acids</u>
5	Wild type	1-2892 ^A	1-833
	Del(Sca-Nae)	1-235/734-2892	1-31/W/199-833
	Del(Bam-Bgl)	1-713/1134-2892	1-191/332-833
10	Del(ELR1-ELR3)	1-830/1134-2892	1-230/332-833
	Del(ELR4-ELR5)	1-1137/1405-2892	1-332/422-833
	Ter(Dde)	1-2021/TTAAGTTAACTTAA ^E / 2227-2892	1-626/H
15	Ins(Nae)A	1-733/(GGAAGATCTTCC) _n ^F / 734-2892 ^B	1-197/(RKIF) _n 198-833
	NAE B	1-733/GGAAGATCTTCC ^F / 734-2892	1-197/RKIF 198-833
	Ins(Stu)	1-535/(GGAAGATCTTCC) _n ^F / 536-2892 ^B	1-131/ G(KIFR) _{n-1} KIFP/133-833
20	STU B	1-535/GGAAGATCTTCC ^F / 536-2892	1-131/GKIFP 133-833
	NG1	1-733/GGAA/2889-3955(NG) ^C	1-198/K/952- 1302 ^D
25	NG2	1-830/2889-3955(NG)	1-230/952- 1302
	NG3	1-1133/2889-3955(NG)	1-331/952- 1302
30	NG4	1-235/734-1133/ 2889-3955(NG)	1-31/199-331/ 952-1302
	NG5	1-235/536-1133/ 2889-3955(NG)	1-31/S/133- 952-1302

35 A Coordinates for Delta sequences correspond to the sequence of the D11 cDNA (Figure 12).

- B The exact number of linkers inserted has not been determined for this construct.
- C Coordinates for neuroglial (Bieber et al., 1989, Cell 59, 447-460; Hortsch et al., 1990, Neuron 4, 697-709) nucleotide sequences present in Delta-neuroglial chimeras correspond to the sequence of the 1B7A-250 cDNA (Figure 13, SEQ ID NO:5) and are indicated in bold face type.
- 5 D Neuroglial amino acid sequences are derived from conceptual translation of the 1B7A-250 cDNA nucleotide sequence (Figure 13, SEQ ID NO:5) and are indicated in bold face type.
- E SEQ ID NO:28
- 10 F SEQ ID NO:29

8.1.4. AGGREGATION PROTOCOLS

Cell transfection and aggregation were performed as described in Section 6, supra, or with

15 minor modifications thereof.

8.2. RESULTS

8.2.1. AMINO-TERMINAL SEQUENCES WITHIN THE DELTA EXTRACELLULAR DOMAIN ARE NECESSARY AND SUFFICIENT FOR THE HETEROTYPIC INTERACTION WITH NOTCH

Because we anticipated that some Delta variants might not be efficiently localized on the cell surface, we investigated the relationship between the level of expression of wild type Delta and the

25 extent of aggregation with Notch-expressing cells by varying the input amount of Delta expression construct in different transfections. We found that the heterotypic Delta-Notch interaction exhibits only slight dependence on the Delta input level over a 10-

30 fold range in this assay (Figure 9A). Given the robustness of the heterotypic interaction over the range tested and our observations that each of the Delta variants we employed exhibited substantial surface accumulation in transfected cells, we infer

35 that the inability of a given Delta variant to support

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heterotypic aggregation most probably reflects a functional deficit exhibited by that variant, as opposed to the impact of reduced levels of surface expression on heterotypic aggregation.

- 5 The results of the heterotypic aggregation experiments mediated by Delta variants and wild-type Notch are shown in Table V.

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TABLE V

HETEROTYPIC AGGREGATION MEDIATED BY
DELTA VARIANTS AND WILD TYPE NOTCH

<u>Construct</u>	<u>Aggregated Total^A</u>	<u>Unaggregated Total</u>	<u>Expt.#</u>	<u>Aggregated Notch⁺ Delta^{+B}</u>	<u>Unaggregated Notch⁺ Delta⁺</u>
Wild type					
	33(H) ^c	179	1	15	18
					67
					112
	58(H)	247	2	37	21
					218
					29
	38(H)	209	3	21	17
					148
					61
	29(H)	174	4	18	11
					95
					79
	175(B)	68	5	84	91
					37
					31
Del(Sca-Nae)	0(H)	207	1	0	0
					125
					82
	0(H)	226	2	0	0
					215
					11
	0(H)	287	3	0	0
					215
					72
	0(H)	200	4	ND ^D	ND
					ND
Del(Bam-Bgl)	4(H)	245	1	3	1
					171
					74
	0(H)	200	2	0	0
					110
					90
	0(H)	200	3	ND	ND
					ND
Del(ELR1-ELR3)	28(B)	296	1	11	17
					139
					157
	20(B)	90	2	9	11
					53
					37
	22(B)	227	3	19	13
					114
					113
	127(B)	97	4	19	78
					66
					61
Del(ELR4-ELR5)	38(H)	188	1	26	12
					141
					47
	36(H)	204	2	20	16
					90
					114
Ter(Dde)	53(H)	236	1	24	29
					144
					92
	51(H)	214	2	30	21
					126
					88

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Ins(Nae)A	52(H)	190	3	30	22	110	80
	0(B)	205	1	0	0	111	94
	0(B)	254	2	0	0	161	93
	0(B)	201	3	0	0	121	80
NG1	0(B)	208	1	0	0	140	68
	0(B)	114	2	0	0	38	76
	0(B)	218	3	0	0	76	142
	14(B)	106	1	7	7	54	52
NG2	50(B)	216	2	35	15	94	122
	36(B)	168	3	12	24	29	139
	71(B)	175	1	43	28	84	91
	0(B)	254	1	0	0	150	104
NG4	0(B)	215	2	0	0	35	180
	0(B)	200	3	0	0	93	107

A Total number of expressing cells in aggregates that contain four or more cells.

B Cells that express neuroglial-based constructs (NGn) were detected using a monoclonal antibody that recognizes the intracellular domain of neuroglial (see Materials and Methods).

C (H) indicates that cells were aggregated in a 25 ml Erlenmeyer flask, (B) indicates that cells were aggregated in a 12-well microtiter plate (see Materials and Methods).

D Data for individual cell types (i.e., Delta⁺ and Notch⁺) in aggregates and unaggregated were not recorded.

Delta amino acids (AA) 1-230 is the current minimum sequence interval defined as being sufficient for interaction with Notch. This is based on the success of NG2-Notch aggregation. Within this interval, Delta
5 AA198-230 are critical because their deletion in the NG1 construct inactivated the Notch-binding activity observed for the NG2 construct. Also within this interval, Delta AA32-198 are critical because their deletion in the NG4 construct also inactivated the
10 Notch-binding activity observed for the NG3 construct. The importance of Delta AA192-230 is also supported by the observation that the Del(ELR1-ELR3) variant, which contains all Delta amino acids except AA231-331, possessed Notch-binding activity, while the Del(Bam-
15 Bgl) variant, which contains all Delta amino acids except AA192-331, was apparently inactivated for Notch-binding activity.

Conformation and/or primary sequence in the vicinity of Delta AA197/198 is apparently critical
20 because a multimeric insertion of the tetrapeptide - Arg-Lys-Ile-Phe [in one letter code (see e.g. Lehninger et al., 1975, Biochemistry, 2d ed., p. 72), RKIF] (SEQ ID NO:30) - between these two residues, as in the Ins(Nae)A construct, inactivated the Notch-
25 binding activity observed with wild type Delta.

In addition, the observation that the Del(ELR1-ELR3) construct supported aggregation implies that ELR1-ELR3 are not required for Delta-Notch interaction; the observation that the Del(ELR4-ELR5)
30 construct supported aggregation implies that ELR4 and ELR5 are not required for Delta-Notch interaction, and the observation that the Ter(Dde) construct supported aggregation implies that the Delta intracellular domain is not required for Delta-Notch interaction.

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8.2.2. AMINO-TERMINAL SEQUENCES WITHIN THE DELTA
EXTRACELLULAR DOMAIN ARE NECESSARY AND
SUFFICIENT FOR HOMOTYPIC INTERACTION

The results of the homotypic aggregation
experiments mediated by Delta variants is shown in
5 Table VI.

TABLE VI
HOMOTYPIC AGGREGATION MEDIATED BY DELTA VARIANTS

10	<u>Construct</u>	<u>Aggregated</u>	<u>Unaggregated</u>	<u>Expt. #</u>
	Wild type	38 (H) ^A	175	1
		48 (H)	171	2
		13 (H)	95	3
		33 (H)	173	4
15		134 (B)	72	5
	Del (Sca-Nae)	0 (H)	200	1
		0 (H)	200	2
		0 (H)	200	3
20	Del (Bam-Bgl)	0 (H)	200	1
		0 (H)	200	2
		0 (H)	200	3
	Del (ELR1-ELR3)	160 (B)	62	1
		55 (B)	80	2
25		0 (B)	200	3
		4 (B)	203	4
		41 (B)	234	5
		4 (B)	366	6 ^B
		23 (B)	325 (1:20)	
30		0 (B)	400	7 ^B
		5 (B)	347 (1:5)	
		10 (B)	228 (1:20)	
		0 (B)	400	8 ^B
		16 (B)	346 (1:5)	
35		4 (B)	268 (1:20)	

		4 (B)	500	9 ^c
		18 (B)	500 (1:5)	
		12 (B)	271 (1:20)	
		7 (B)	128 (1:50)	
5		0 (B)	500	10 ^c
		0 (B)	500 (1:5)	
		0 (B)	500 (1:20)	
		21 (B)	246 (1:50)	
		0 (B)	500	11 ^c
10		5 (B)	500 (1:5)	
		8 (B)	177 (1:20)	
		4 (B)	69 (1:50)	
	Del (ELR4-ELR5)	21 (H)	175	1
		29 (H)	243	2
15		35 (H)	179	3
	Ter (Dde)	53 (H)	164	1
		33 (H)	178	2
		36 (H)	203	3
	Ins (Nae) A	0 (B)	200	1
20		0 (B)	200	2
		0 (B)	200	3

-
- 25 A (H) indicates that cells were aggregated in a 25 ml Erlenmeyer flask; (B) indicates that cells were aggregated in a 12-well microtiter plate (see Materials and Methods).
- 30 B Transfected cells were incubated under aggregation conditions overnight, then diluted into the appropriate volume of log-phase S2 cells in the presence of inducer and incubated under aggregation conditions for an additional four to six hours.
- 35 C Transfected cells to which inducer had been added were diluted into the appropriate volume of log-phase S2 cells to which inducer had been added,

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and the cell mixture was incubated under aggregation conditions overnight.

Deletion of Delta AA32-198 [Del(Sca-Nae)] or Delta
5 AA192-331 [Del(Bam-Bgl)] from the full-length Delta protein eliminated the Delta-Delta interaction. Deletion of Delta AA231-331 [Del(ELR1-ELR3)] did not eliminate the Delta-Delta interaction. Therefore, sequences within the Delta AA32-230 are required for
10 the Delta-Delta interaction.

Conformation and/or primary sequence in the vicinity of Delta AA197/198 is apparently critical for the Delta-Delta interaction because a multimeric insertion of the tetrapeptide -Arg-Lys-Ile-Phe- (SEQ
15 ID NO:30) between these two residues, as in the Ins(Nae)A construct, inactivated Delta-Delta interaction.

In addition, the observation that the Del(ELR1-ELR3) construct could support aggregation
20 implies that ELR1-ELR3 are not required for Delta-Delta interaction; the observation that the Del(ELR-ELR5) construct supported aggregation implies that ELR4 and ELR5 are not required for Delta-Delta interaction, and the observation that the Ter(Dde)
25 construct supported aggregation implies that the Delta intracellular domain is not required for Delta-Delta interaction.

A summary of the results of assays for heterotypic and homotypic aggregation with various
30 constructs are shown in Table VI A.

TABLE VI A

AGGREGATION MEDIATED BY WILD TYPE AND VARIANT DELTA PROTEINS				
5	CONSTRUCT	HETEROTYPIC AGGREGATION ^a		HOMOTYPIC AGGREGATION ^b DELTA
		DELTA	NOTCH	
	Wild Type	33 ± 12 ^c	26 ± 11 ^c	27 ± 10 ^c
	Del(Sca-Nae)	0	0	0
	Del(Bam-Bgl)	0.4 ± 0.4	0.6 ± 0.6	0
10	Del(ELR1-ELR3)	25 ± 11 ^d	15 ± 3 ^d	32 ±15 ^d
	Del(ELR4-ELR5)	17 ± 2	18 ± 2	13 ± 2
	Ter(Dde)	22 ± 1	18 ± 2	18 ± 3
	NAE B	25 ± 5	0	27 ± 7
15	STU B	0	0	0
	NG1	0	0	0
	NG2	13 ± 1	23 ± 6	4 ± 1 ^d
	NG3	16 ± 1	13 ± 1	27 ± 17
	NG4	0	0	0.5 ± 0.3

- 20 a: Mean fraction (%) of Delta or Notch cells in aggregates of four or more cells ($\pm$ standard error). N=3 replicates, unless otherwise noted.
- b: Mean fraction (%) of Delta cells in aggregates of four or more cells ($\pm$ standard error). N= 3 replicates, unless otherwise noted.
- c: N = 5 replicates.
- 25 d: N = 4 replicates.

8.2.3. DELTA SEQUENCES INVOLVED IN HETEROTYPIC AND HOMOTYPIC INTERACTIONS ARE QUALITATIVELY DISTINCT

The respective characteristics of Delta sequences repaired for heterotypic and homotypic interaction were further defined using Delta variants in which short, in-frame, translatable linker insertions were introduced into the Delta amino terminus (i.e., NAE B and STU B; Figure 9, Table VI

35 A). Replacement of Delta residue 132 (A) with the

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pentapeptide GKIFP (STU B variant) leads to the inactivation of heterotypic and homotypic interaction activities of the Delta amino terminus. This suggests that some Delta sequences required for these two distinct interactions are coincident and reside in proximity to residue 132. On the other hand, insertion of the tetrapeptide RKIF between Delta residues 198 and 199 (NAE B variant) eliminates the ability of the Delta amino terminus to mediate heterotypic interaction with Notch, but has no apparent effect on the ability of the altered amino terminus to mediate homotypic interaction. The finding that the NAE B insertion affects only one of the two activities of the Delta amino terminus implies that the Delta sequences that mediate heterotypic and homotypic interactions, while coincident, are qualitatively distinct.

8.2.4. DELTA IS TAKEN UP BY CELLS THAT EXPRESS NOTCH

During the course of many heterotypic aggregation experiments, we have noted that Delta protein can sometimes be found within cells that have been programmed to express Notch, but not Delta. We conduct heterotypic aggregation assays by mixing initially separate populations of S2 cells that have been independently transfected with expression constructs that program expression of either Delta or Notch. Yet, we often detect punctate staining of Delta within Notch-expressing cells found in heterotypic aggregates using Delta-specific antisera. Our observations are consistent with Delta binding directly to Notch at the cell surface and subsequent clearance of this Delta-Notch complex from the cell surface via endocytosis.

8.3. DISCUSSION

8.3.1. AMINO-TERMINAL SEQUENCES UNRELATED TO EGF ARE INVOLVED IN THE INTERACTION BETWEEN DELTA AND NOTCH

5 We have employed cell aggregation assays to
define a region within the amino-proximal region of
the Delta extracellular domain that is necessary and
sufficient to mediate the Delta-Notch interaction.
Functional analyses of a combination of deletion and
sufficiency constructs revealed that this region
10 extends, maximally, from AA1 through AA230. It is
striking that this region does not include any of the
EGF-like sequences that reside within the Delta
extracellular domain. It is probable that the
particular Delta sequences within the sufficient
15 interval required for interaction with Notch include
AA198-230 because deletion of these residues
eliminates Notch-binding activity. The fact that
deletion of AA32-198 also inactivates Notch-binding
activity suggests that sequences amino-proximal to
20 AA198 are also required, although the deleterious
impact of this deletion could result from the removal
of additional amino acids in the immediate vicinity of
AA198.

25 Sequences within Delta sufficient for
interaction with Notch can be grouped into three
subdomains - N1, N2, and N3 - that differ in their
respective contents of cysteine residues (Figure 10,
SEQ ID NO:3). The N1 and N3 domains each contain six
cysteine residues, while the N2 domain contains none.
30 The even number of cysteines present in N1 and N3,
respectively, allows for the possibility that the
respective structures of these subdomains are
dictated, in part, by the formation of particular
disulfide bonds. The broad organizational pattern of
35 the Delta amino-terminus is also generally analogous

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to that of the extracellular domain of the vertebrate EGF receptor (Lax et al., 1988, Mol. Cell. Biol. 8, 1970-1978), in which sequences believed to interact with EGF are bounded by two cysteine-rich subdomains.

5

8.3.2. DELTA SEQUENCES REQUIRED FOR HOMOTYPIC
AND FOR HOMOTYPIC HETEROTYPIC
INTERACTIONS APPEAR TO BE COINCIDENT

Our results also indicate that sequences essential for homotypic Delta interaction reside
10 within the interval AA32-230. Deletion of sequences or insertion of additional amino acids within this amino-proximal domain eliminate the ability of such Delta variants to singly promote cell aggregation. Thus, sequences required for Delta-Delta interaction
15 map within the same domain of the protein as those required for Delta-Notch interaction.

8.3.3. THE DELTA AMINO TERMINUS CONSTITUTES
AN EGF-BINDING MOTIF

20 The work described in examples supra has revealed that Notch sequences required for Delta-Notch interaction in the cell aggregation assay map within the EGF-like repeat array of the Notch extracellular domain. This finding implies that Delta and Notch
25 interact by virtue of the binding of the Delta amino-terminus to EGF-like sequences within Notch and, therefore, that the amino-terminus of the Delta extracellular domain constitutes an EGF-binding domain (Figure 11).

30 These results also raise the possibility that homotypic Delta interaction involves the binding of the Delta amino-terminus to EGF-like sequences within the Delta extracellular domain (Figure 12). However, none of the EGF-like repeats within the Delta
35 extracellular domain are identical to any of the EGF-

like repeats within the Notch extracellular domain (Figure 13, SEQ ID NO:6; Wharton et al., 1985, Cell 43, 567-581). Given this fact, if Delta homotypic interactions are indeed mediated by interaction
5 between the Delta amino-terminus and Delta EGF-like repeats, then the Delta EGF-binding domain has the capacity to interact with at least two distinct EGF-like sequences.

10 8.3.4. DELTA SEQUENCES INVOLVED IN THE
DELTA-NOTCH INTERACTION ARE CONSERVED
IN THE SERRATE PROTEIN

Alignment of amino acid sequences from the amino termini of the Delta (Figure 13, SEQ ID NO:6, and Figure 15, SEQ ID NO:9) and Serrate (Fleming et
15 al., 1990, Genes & Dev. 4, 2188-2201; Thomas et al., 1991, Devel. 111, 749-761) reveals a striking conservation of structural character and sequence composition. The general N1-N2-N3 subdomain structure of the Delta amino terminus is also observed within
20 the Serrate amino terminus, as is the specific occurrence of six cysteine residues within the Delta N1- and Delta N3-homologous domains of the Serrate protein. Two notable blocks of conservation
25 correspond to Delta AA63-73 (8/11 residues identical) and Delta AA195-206 (10/11 residues identical). The latter block is of particular interest because insertion of additional amino acids in this interval can eliminate the ability of Delta to bind to Notch or
30 Delta.

8.3.5. CIS AND TRANS INTERACTIONS BETWEEN
DELTA AND NOTCH MAY INVOLVE DIFFERENT
SEQUENCES WITHIN NOTCH

Inspection of the overall structures of
35 Delta and Notch suggests that Delta-Notch interaction could involve contacts between the Delta EGF-binding

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domain with either of two regions within Notch, depending on whether the interaction were between molecules that reside on opposing membranes or within the same membrane (Figure 11). The cell aggregation assays, which presumably detect the interaction of molecules in opposing membranes, imply that the Delta EGF-binding domain interacts with Notch EGF-like repeats 11 and 12 (see examples supra). If tandem arrays of EGF-like motifs do form rod-like structures (Engel, 1989, FEBS Lett. 251, 1-7) within the Delta and Notch proteins, then the estimated displacement of the Delta EGF-binding domain from the cell surface would presumably be sufficient to accommodate the rigid array of Notch EGF-like repeats 1-10. It is also intriguing to note that the displacement of the Delta EGF-binding domain from the cell surface could place this domain in the vicinity of the Notch EGF-like repeats (25-29) that are affected by Abruptex mutations (Hartley et al., 1987, EMBO J. 6, 3407-3417; Kelley et al., 1987, Mol. Cell. Biol. 6, 3094-3108) and could allow for interaction of Delta and Notch proteins present within the same membrane.

8.3.6. INTERACTIONS ANALOGOUS TO THE DELTA-NOTCH INTERACTION IN VERTEBRATES

Given the interaction between Delta and Notch in *Drosophila*, it is quite probable that a Delta homologue (Helta?) exists in vertebrates and that the qualitative and molecular aspects of the Delta-Notch and Delta-Delta interactions that we have defined in *Drosophila* will be highly conserved in vertebrates, including humans. Such homologs can be cloned and sequenced as described supra, Section 5.2.

9. SEQUENCES WHICH MEDIATE NOTCH-SERRATE INTERACTIONS

We report a novel molecular interaction between Notch and Serrate, and show that the two EGF repeats of Notch which mediate interactions with Delta, namely EGF repeats 11 and 12, also constitute a Serrate binding domain.

To test whether Notch and Serrate directly interact, S2 cells were transfected with a Serrate expression construct and mixed with Notch expressing cells in our aggregation assay. For the Serrate expression construct, a synthetic primer containing an artificial BamHI site immediately 5' to the initiator AUG at position 442 (all sequence numbers are according to Fleming et al., 1990, Genes & Dev. 4:2188-2201) and homologous through position 464, was used in conjunction with a second primer from position 681-698 to generate a DNA fragment of ~260 base pairs. This fragment was cut with BamHI and KpnI (position 571) and ligated into Bluescript KS+ (Stratagene). This construct, BTSer5'PCR, was checked by sequencing, then cut with KpnI. The Serrate KpnI fragment (571 - 2981) was inserted and the proper orientation selected, to generate BTSer5'PCR-Kpn. The 5' SacII fragment of BTSer5'PCR-Kpn (SacII sites in Bluescript polylinker and in Serrate (1199)) was isolated and used to replace the 5' SacII fragment of cDNA C1 (Fleming et al., 1990, Genes & Dev. 4:2188-2201), thus regenerating the full length Serrate cDNA minus the 5' untranslated regions. This insert was isolated by a SalI and partial BamHI digestion and shuttled into the BamHI and SalI sites of pRmHa-3 to generate the final expression construct, Ser-mtn.

We found that Serrate expressing cells adhere to Notch expressing cells in a calcium dependent manner (Figure 6 and Table VII). However, unlike Delta, under the experimental conditions

tested, Serrate does not appear to interact homotypically. In addition, we detect no interactions between Serrate and Delta.

5 TABLE VII

Effect of Exogenous Ca ⁺⁺ on Notch - Serrate Aggregation ^a		
10	<u>Notch-Serrate</u>	
	<u>Without Ca⁺⁺</u>	<u>With Ca⁺⁺</u>
1. pMtNMg	0	15
32. ΔECN+EGF(10-12)	0	13
15 33. ΔCla+XEGF(10-13)	0	15

^a Data presented as percentage of Notch expressing cells found in aggregates (as in Figure 6). All numbers are from single transfection experiments (rather than an average of values from several separate experiments as in Figure 6).

We have tested a subset of our Notch deletion constructs to map the Serrate-binding domain and have found that EGF repeats 11 and 12, in addition to binding to Delta, also mediate interactions with Serrate (Figure 6; Constructs #1, 7-10, 13, 16, 17, 19, 28, and 32). In addition, the Serrate-binding function of these repeats also appears to have been conserved in the corresponding two EGF repeats of Xenopus Notch (#33ΔCla+XEGF(10-13)). These results unambiguously show that Notch interacts with both Delta and Serrate, and that the same two EGF repeats of Notch mediate both interactions. We were also able to define the Serrate region which is essential for

the Notch/Serrate aggregation. Deleting nucleotides 676-1287 (i.e. amino acids 79-282) (See Figure 15) eliminates the ability of the Serrate protein to aggregate with Notch.

5 Notch and Serrate appear to aggregate less efficiently than Notch and Delta, perhaps because the Notch-Serrate interaction is weaker. For example, when scoring Notch-Delta aggregates, we detect ~40% of all Notch expressing cells in clusters with Delta
10 expressing cells (Figure 6, #1 pMtNMg) and ~40% of all Delta expressing cells in contact with Notch expressing cells. For Notch-Serrate, we find only ~20% of all Notch expressing cells (Figure 6; pMtNMg) and ~15% of all Serrate expressing cells in
15 aggregates. For the various Notch deletion constructs tested, we consistently detect a reduction in the amount of aggregation between Notch and Serrate as compared to the corresponding Notch-Delta levels (Figure 6), with the possible exception of constructs
20 #9 and 10 which exhibit severely reduced levels of aggregation even with Delta. One trivial explanation for this reduced amount of aggregation could be that our Serrate construct simply does not express as much
25 protein at the cell surface as the Delta construct, thereby diminishing the strength of the interaction. Alternatively, the difference in strength of interaction may indicate a fundamental functional difference between Notch-Delta and Notch-Serrate interactions that may be significant in vivo.

30

10. THE CLONING, SEQUENCING, AND EXPRESSION OF HUMAN NOTCH

10.1. ISOLATION AND SEQUENCING OF HUMAN NOTCH

35

Clones for the human Notch sequence were originally obtained using the polymerase chain

reaction (PCR) to amplify DNA from a 17-18 week human fetal brain cDNA library in the Lambda Zap IITM vector (Stratagene). Degenerate primers to be used in this reaction were designed by comparing the amino acid
5 sequences of the Xenopus homolog of Notch with Drosophila Notch. Three primers (cdc1 (SEQ ID NO:10), cdc2 (SEQ ID NO:11), and cdc3 (SEQ ID NO:12); Figure 16) were designed to amplify either a 200 bp or a 400 bp fragment as primer pairs cdc1/cdc2 or cdc1/cdc3,
10 respectively.

The 400 bp fragment obtained in this manner was then used as a probe with which to screen the same library for human Notch clones. The original screen yielded three unique clones, hN3k, hN2K, and hN5k, all
15 of which were shown by subsequent sequence analysis to fall in the 3' end of human Notch (Figure 17). A second screen using the 5' end of hN3k as probe was undertaken to search for clones encompassing the 5' end of human Notch. One unique clone, hN4k, was
20 obtained from this screen, and preliminary sequencing data indicate that it contains most of the 5' end of the gene (Figure 17). Together, clones hN4k, hN3k and hN5k encompass about 10 kb of the human Notch homolog, beginning early in the EGF-repeats and extending into
25 the 3' untranslated region of the gene. All three clones are cDNA inserts in the EcoRI site of pBluescript SK⁺ (Stratagene). The host E. coli strain is XL1-Blue (see Maniatis, T., 1990, Molecular Cloning, A Laboratory Manual, 2d ed., Cold Spring
30 Harbor Laboratory, Cold Spring Harbor, New York, p. A12).

The sequence of various portions of Notch contained in the cDNA clones was determined (by use of Sequenase®, U.S. Biochemical Corp.) and is shown in
35 Figures 19-22 (SEQ ID NO:13 through NO:25).

The complete nucleotide sequences of the human Notch cDNA contained in hN3k and hN5k was determined by the dideoxy chain termination method using the Sequenase® kit (U.S. Biochemical Corp.).

5 Those nucleotide sequences encoding human Notch, in the appropriate reading frame, were readily identified since translation in only one out of the three possible reading frames yields a sequence which, upon comparison with the published Drosophila Notch deduced
10 amino acid sequence, yields a sequence with a substantial degree of homology to the Drosophila Notch sequence. Since there are no introns, translation of all three possible reading frames and comparison with Drosophila Notch was easily accomplished, leading to
15 the ready identification of the coding region. The DNA and deduced protein sequences of the human Notch cDNA in hN3k and hN5k are presented in Figures 23 and 24, respectively. Clone hN3k encodes a portion of a Notch polypeptide starting at approximately the third
20 Notch/lin-12 repeat to several amino acids short of the carboxy-terminal amino acid. Clone hN5k encodes a portion of a Notch polypeptide starting approximately before the cdc10 region through the end of the polypeptide, and also contains a 3' untranslated
25 region.

Comparing the DNA and protein sequences presented in Figure 23 (SEQ ID NO:31 and NO:32) with those in Figure 24 (SEQ ID NO:33 and NO:34) reveals significant differences between the sequences,
30 suggesting that hN3k and hN5k represent part of two distinct Notch-homologous genes. Our data thus suggest that the human genome harbors more than one Notch-homologous gene. This is unlike Drosophila, where Notch appears to be a single-copy gene.

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Comparison of the DNA and amino acid sequences of the human Notch homologs contained in hN3k and hN5k with the corresponding Drosophila Notch sequences (as published in Wharton et al., 1985, Cell 43:567-581) and with the corresponding Xenopus Notch sequences (as published in Coffman et al., 1990, Science 249:1438-1441 or available from Genbank® (accession number M33874)) also revealed differences.

The amino acid sequence shown in Figure 23 (hN3k) was compared with the predicted sequence of the TAN-1 polypeptide shown in Figure 2 of Ellisen et al., August 1991, Cell 66:649-661. Some differences were found between the deduced amino acid sequences; however, overall the hN3k Notch polypeptide sequence is 99% identical to the corresponding TAN-1 region (TAN-1 amino acids 1455 to 2506). Four differences were noted: in the region between the third Notch/lin-12 repeat and the first cdc10 motif, there is an arginine (hN3k) instead of an X (TAN-1 amino acid 1763); (2) there is a proline (hN3k) instead of an X (TAN-1, amino acid 1787); (3) there is a conservative change of an aspartic acid residue (hN3k) instead of a glutamic acid residue (TAN-1, amino acid 2495); and (4) the carboxyl-terminal region differs substantially between TAN-1 amino acids 2507 and 2535.

The amino acid sequence shown in Figure 24 (hN5k) was compared with the predicted sequence of the TAN-1 polypeptide shown in Figure 2 of Ellisen et al., August 1991, Cell 66:649-661. Differences were found between the deduced amino acid sequences. The deduced Notch polypeptide of hN5k is 79% identical to the TAN-1 polypeptide (64% identical to Drosophila Notch) in the cdc10 region that encompasses both the cc10 motif (TAN-1 amino acids 1860 to 2217) and the well-conserved flanking regions (Fig. 25). The cdc10

region covers amino acids 1860 through 2217 of the TAN-1 sequence. In addition, the hN5k encoded polypeptide is 65% identical to the TAN-1 polypeptide (44% identical to Drosophila Notch) at the carboxy-terminal end of the molecule containing a PEST (proline, glutamic acid, serine, threonine)-rich region (TAN-1 amino acids 2482 to 2551) (Fig. 25B). The stretch of 215 amino acids lying between the

10 of the Notch-homologous clones represented by hN3k, hN5k, and TAN-1. Neither the hN5k polypeptide nor Drosophila Notch shows significant levels of amino acid identity to the other proteins in this region (e.g., hN5k/TAN-1 = 24% identity; hN5k/Drosophila

15 Notch = 11% identity; TAN-1/Drosophila Notch = 17% identity). In contrast, Xenopus Notch (Xotch) (SEQ ID NO:35), rat Notch (SEQ ID NO:36), and TAN-1 (SEQ ID NO:37) continue to share significant levels of sequence identity with one another (e.g., TAN-1/rat

20 Notch = 75% identity, TAN-1/Xenopus Notch = 45% identity, rat Notch/Xenopus Notch = 50% identity).

Finally, examination of the sequence of the intracellular domains of the vertebrate Notch homologs, shown in Figure 25B revealed an unexpected finding:

25 all of these proteins, including hN5k, contain a putative CcN motif, associated with nuclear targeting function, in the conserved region following the last of the six cdc10 repeats (Fig. 25B). Although Drosophila Notch lacks such a defined motif, closer

30 inspection of its sequence revealed the presence of a possible bipartite nuclear localization sequence (Robbins et al., 1991, Cell 64:615-623), as well as of possible CK II and cdc2 phosphorylation sites, all in relative proximity to one another, thus possibly

35 defining an alternative type of CcN motif (Fig. 25B).

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10.2. EXPRESSION OF HUMAN NOTCH

Expression constructs were made using the human Notch cDNA clones discussed in Section 10.1 above. In the cases of hN3k and hN2k, the entire
5 clone was excised from its vector as an EcoRI restriction fragment and subcloned into the EcoRI restriction site of each of the three pGEX vectors (Glutathione S-Transferase expression vectors; Smith and Johnson, 1988, Gene 7, 31-40). This allows for
10 the expression of the Notch protein product from the subclone in the correct reading frame. In the case of hN5k, the clone contains two internal EcoRI restriction sites, producing 2.6, 1.5 and 0.6 kb fragments. Both the 2.6 and the 1.5 kb fragments have
15 also been subcloned into each of the pGEX vectors.

The pGEX vector system was used to obtain expression of human Notch fusion (chimeric) proteins from the constructs described below. The cloned Notch DNA in each case was inserted, in phase, into the
20 appropriate pGEX vector. Each construct was then electroporated into bacteria (E. coli), and was expressed as a fusion protein containing the Notch protein sequences fused to the carboxyl terminus of
25 glutathione S-transferase protein. Expression of the fusion proteins was confirmed by analysis of bacterial protein extracts by polyacrylamide gel electrophoresis, comparing protein extracts obtained from bacteria containing the pGEX plasmids with and without the inserted Notch DNA. The fusion proteins
30 were soluble in aqueous solution, and were purified from bacterial lysates by affinity chromatography using glutathione-coated agarose (since the carboxyl terminus of glutathione S-transferase binds to glutathionine). The expressed fusion proteins were

bound by an antibody to Drosophila Notch, as assayed by Western blotting.

The constructs used to make human Notch-glutathione S-transferase fusion proteins were as follows:

hNFP#2 - PCR was used to obtain a fragment starting just before the cdc10 repeats at nucleotide 192 of the hN5k insert to just before the PEST-rich region at nucleotide 1694. The DNA was then digested with BamHI and SmaI and the resulting fragment was ligated into pGEX-3. After expression, the fusion protein was purified by binding to glutathione agarose. The purified polypeptide was quantitated on a 4-15% gradient polyacrylamide gel. The resulting fusion protein had an approximate molecular weight of 83 kD.

hN3FP#1 - The entire hN3k DNA insert (nucleotide 1 to 3235) was excised from the Bluescript (SK) vector by digesting with EcoRI. The DNA was ligated into pGEX-3.

hN3FP#2 - A 3' segment of hN3k DNA (nucleotide 1847 to 3235) plus some of the polylinker was cut out of the Bluescript (SK) vector by digesting with XmaI. The fragment was ligated into pGEX-1.

Following purification, these fusion proteins are used to make either polyclonal and/or monoclonal antibodies to human Notch.

30 11. DEPOSIT OF MICROORGANISMS

The following recombinant bacteria, each carrying a plasmid encoding a portion of human Notch, were deposited on May 2, 1991 with the American Type Culture Collection, 1201 Parklawn Drive, Rockville, Maryland 20852, under the provisions of the Budapest

WO 92/19734

PCT/US92/03651

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Treaty on the International Recognition of the Deposit
of Microorganisms for the Purposes of Patent
Procedures.

5	<u>Bacteria</u>	carrying	<u>Plasmid</u>	<u>ATCC Accession No.</u>
	<u>E. coli</u> XL1-Blue		hN4k	68610
	<u>E. coli</u> XL1-Blue		hN3k	68609
	<u>E. coli</u> XL1-Blue		hN5k	68611

10 The present invention is not to be limited
in scope by the microorganisms deposited or the
specific embodiments described herein. Indeed,
various modifications of the invention in addition to
those described herein will become apparent to those
15 skilled in the art from the foregoing description and
accompanying figures. Such modifications are intended
to fall within the scope of the appended claims.

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SEQUENCE LISTING

(1) GENERAL INFORMATION:

- (i) APPLICANT: Artavanis-Tsakonas, Spyridon et al.
- (ii) TITLE OF INVENTION: Human Notch And Delta, Binding Domains
In Toporythmic Proteins, And Methods Based Thereon
- (iii) NUMBER OF SEQUENCES: 37
- (iv) CORRESPONDENCE ADDRESS:
 - (A) ADDRESSEE: Pennie & Edmonds
 - (B) STREET: 1155 Avenue of the Americas
 - (C) CITY: New York
 - (D) STATE: New York
 - (E) COUNTRY: U.S.A.
 - (F) ZIP: 10036
- (v) COMPUTER READABLE FORM:
 - (A) MEDIUM TYPE: Floppy disk
 - (B) COMPUTER: IBM PC compatible
 - (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.25
- (vi) CURRENT APPLICATION DATA:
 - (A) APPLICATION NUMBER:
 - (B) FILING DATE:
 - (C) CLASSIFICATION:
- (viii) ATTORNEY/AGENT INFORMATION:
 - (A) NAME: Misrock, S. Leslie
 - (B) REGISTRATION NUMBER: 18,872
 - (C) REFERENCE/DOCKET NUMBER: 7326-009
- (ix) TELECOMMUNICATION INFORMATION:
 - (A) TELEPHONE: 212 790-9090
 - (B) TELEFAX: 212 8698864/9741
 - (C) TELEX: 66141 PENNIE

(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 77 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: unknown
- (ii) MOLECULE TYPE: peptide
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

Glu	Asp	Ile	Asp	Glu	Cys	Asp	Gln	Gly	Ser	Pro	Cys	Glu	His	Asn	Gly
1				5					10					15	
Ile	Cys	Val	Asn	Thr	Pro	Gly	Ser	Tyr	Arg	Cys	Asn	Cys	Ser	Gln	Gly
			20				25						30		
Phe	Thr	Gly	Pro	Arg	Cys	Glu	Thr	Asn	Ile	Asn	Glu	Cys	Glu	Ser	His
		35				40						45			
Pro	Cys	Gln	Asn	Glu	Gly	Ser	Cys	Leu	Asp	Asp	Pro	Gly	Thr	Phe	Arg
	50					55					60				
Cys	Val	Cys	Met	Pro	Gly	Phe	Thr	Gly	Thr	Gln	Cys	Glu			
65					70							75			

(2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 78 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Asn	Asp	Val	Asp	Glu	Cys	Ser	Leu	Gly	Ala	Asn	Pro	Cys	Glu	His	Gly
1				5				10					15		
Gly	Arg	Cys	Thr	Asn	Thr	Leu	Gly	Ser	Phe	Gln	Cys	Asn	Cys	Pro	Gln
			20				25						30		
Gly	Tyr	Ala	Gly	Pro	Arg	Cys	Glu	Ile	Asp	Val	Asn	Glu	Cys	Leu	Ser
		35					40					45			
Asn	Pro	Cys	Gln	Asn	Asp	Ser	Thr	Cys	Leu	Asp	Gln	Ile	Gly	Glu	Phe
	50					55					60				
Gln	Cys	Ile	Cys	Met	Pro	Gly	Tyr	Glu	Gly	Leu	Tyr	Cys	Glu		
65					70					75					

(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 203 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

Gly	Ser	Phe	Glu	Leu	Arg	Leu	Lys	Tyr	Phe	Ser	Asn	Asp	His	Gly	Arg
1				5				10					15		
Asp	Asn	Glu	Gly	Arg	Cys	Cys	Ser	Gly	Glu	Ser	Asp	Gly	Ala	Thr	Gly
			20					25					30		
Lys	Cys	Leu	Gly	Ser	Cys	Lys	Thr	Arg	Phe	Arg	Val	Cys	Leu	Lys	His
		35					40					45			
Tyr	Gln	Ala	Thr	Ile	Asp	Thr	Thr	Ser	Gln	Cys	Thr	Tyr	Gly	Asp	Val
	50					55					60				
Ile	Thr	Pro	Ile	Leu	Gly	Glu	Asn	Ser	Val	Asn	Leu	Thr	Asp	Ala	Gln
65					70					75					80
Arg	Phe	Gln	Asn	Lys	Gly	Phe	Thr	Asn	Pro	Ile	Gln	Phe	Pro	Phe	Ser
			85					90						95	
Phe	Ser	Trp	Pro	Gly	Thr	Phe	Ser	Leu	Ile	Val	Glu	Ala	Trp	His	Asp
			100					105					110		
Thr	Asn	Asn	Ser	Gly	Asn	Ala	Arg	Thr	Asn	Lys	Leu	Leu	Ile	Gln	Arg
			115				120					125			
Leu	Leu	Val	Gln	Gln	Val	Leu	Glu	Val	Ser	Ser	Glu	Trp	Lys	Thr	Asn
			130			135					140				

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Lys Ser Glu Ser Gln Tyr Thr Ser Leu Glu Tyr Asp Phe Arg Val Thr
 145 150 155 160

Cys Asp Leu Asn Tyr Tyr Gly Ser Gly Cys Ala Lys Phe Cys Arg Pro
 165 170 175

Arg Asp Asp Ser Phe Gly His Ser Thr Cys Ser Glu Thr Gly Glu Ile
 180 185 190

Ile Cys Leu Thr Gly Trp Gln Gly Asp Tyr Cys
 195 200

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 199 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

Gly Asn Phe Glu Leu Glu Ile Leu Glu Ile Ser Asn Thr Asn Ser His
 1 5 10 15

Leu Leu Asn Gly Tyr Cys Cys Gly Met Pro Ala Glu Leu Arg Ala Thr
 20 25 30

Lys Thr Ile Gly Cys Ser Pro Cys Thr Thr Ala Phe Arg Leu Cys Leu
 35 40 45

Lys Glu Tyr Gln Thr Thr Glu Gln Gly Ala Ser Ile Ser Thr Gly Cys
 50 55 60

Ser Phe Gly Asn Ala Thr Thr Lys Ile Leu Gly Gly Ser Ser Phe Val
 65 70 75 80

Leu Ser Asp Pro Gly Val Gly Ala Ile Val Leu Pro Phe Thr Phe Arg
 85 90 95

Trp Thr Lys Ser Phe Thr Leu Ile Leu Gln Ala Leu Asp Met Tyr Asn
 100 105 110

Thr Ser Tyr Pro Asp Ala Glu Arg Leu Ile Glu Glu Thr Ser Tyr Ser
 115 120 125

Gly Val Ile Leu Pro Ser Pro Glu Trp Lys Thr Leu Asp His Ile Gly
 130 135 140

Arg Asn Ala Arg Ile Thr Tyr Arg Val Arg Val Gln Cys Ala Val Thr
 145 150 155 160

Tyr Tyr Asn Thr Thr Cys Thr Thr Phe Cys Arg Pro Arg Asp Asp Gln
 165 170 175

Phe Gly His Tyr Ala Cys Gly Ser Glu Gly Gln Lys Leu Cys Leu Asn
 180 185 190

Gly Trp Gln Gly Val Asn Cys
 195

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2892 base pairs
 (B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

(A) NAME/KEY: CDS

(B) LOCATION: 142..2640

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GAATTCGGAG GAATTATTCA AAACATAAAC ACAATAAACA ATTTGAGTAG TTGCCGCACA	60
CACACACACA CACAGCCCGT GGATTATTAC ACTAAAAGCG ACACTCAATC CAAAAAATCA	120
GCAACAAAAA CATCAATAAA C ATG CAT TGG ATT AAA TGT TTA TTA ACA GCA	171
Met His Trp Ile Lys Cys Leu Leu Thr Ala	
1 5 10	
TTC ATT TGC TTC ACA GTC ATC GTG CAG GTT CAC AGT TCC GGC AGC TTT	219
Phe Ile Cys Phe Thr Val Ile Val Gln Val His Ser Ser Gly Ser Phe	
15 20 25	
GAG TTG CGC CTG AAG TAC TTC AGC AAC GAT CAC GGG CGG GAC AAC GAG	267
Glu Leu Arg Leu Lys Tyr Phe Ser Asn Asp His Gly Arg Asp Asn Glu	
30 35 40	
GGT CGC TGC TGC AGC GGG GAG TCG GAC GGA GCG ACG GGC AAG TGC CTG	315
Gly Arg Cys Cys Ser Gly Glu Ser Asp Gly Ala Thr Gly Lys Cys Leu	
45 50 55	
GGC AGC TGC AAG ACG CGG TTT CGC GTC TGC CTA AAG CAC TAC CAG GCC	363
Gly Ser Cys Lys Thr Arg Phe Arg Val Cys Leu Lys His Tyr Gln Ala	
60 65 70	
ACC ATC GAC ACC ACC TCC CAG TGC ACC TAC GGG GAC GTG ATC ACG CCC	411
Thr Ile Asp Thr Thr Ser Gln Cys Thr Tyr Gly Asp Val Ile Thr Pro	
75 80 85 90	
ATT CTC GGC GAG AAC TCG GTC AAT CTG ACC GAC GCC CAG CGC TTC CAG	459
Ile Leu Gly Glu Asn Ser Val Asn Leu Thr Asp Ala Gln Arg Phe Gln	
95 100 105	
AAC AAG GGC TTC ACG AAT CCC ATC CAG TTC CCC TTC TCG TTC TCA TGG	507
Asn Lys Gly Phe Thr Asn Pro Ile Gln Phe Pro Phe Ser Phe Ser Trp	
110 115 120	
CCG GGT ACC TTC TCG CTG ATC GTC GAG GCC TGG CAT GAT ACG AAC AAT	555
Pro Gly Thr Phe Ser Leu Ile Val Glu Ala Trp His Asp Thr Asn Asn	
125 130 135	
AGC GGC AAT GCG CGA ACC AAC AAG CTC CTC ATC CAG CGA CTC TTG GTG	603
Ser Gly Asn Ala Arg Thr Asn Lys Leu Leu Ile Gln Arg Leu Leu Val	
140 145 150	
CAG CAG GTA CTG GAG GTG TCC TCC GAA TGG AAG ACG AAC AAG TCG GAA	651
Gln Gln Val Leu Glu Val Ser Ser Glu Trp Lys Thr Asn Lys Ser Glu	
155 160 165 170	
TCG CAG TAC ACG TCG CTG GAG TAC GAT TTC CGT GTC ACC TGC GAT CTC	699
Ser Gln Tyr Thr Ser Leu Glu Tyr Asp Phe Arg Val Thr Cys Asp Leu	
175 180 185	
AAC TAC TAC GGA TCC GGC TGT GCC AAG TTC TGC CGG CCC CGC GAC GAT	747
Asn Tyr Tyr Gly Ser Gly Cys Ala Lys Phe Cys Arg Pro Arg Asp Asp	
190 195 200	
TCA TTT GGA CAC TCG ACT TGC TCG GAG ACG GGC GAA ATT ATC TGT TTG	795

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Ser	Phe	Gly	His	Ser	Thr	Cys	Ser	Glu	Thr	Gly	Glu	Ile	Ile	Cys	Leu	
		205					210					215				
ACC	GGA	TGG	CAG	GGC	GAT	TAC	TGT	CAC	ATA	CCC	AAA	TGC	GCC	AAA	GGC	843
Thr	Gly	Trp	Gln	Gly	Asp	Tyr	Cys	His	Ile	Pro	Lys	Cys	Ala	Lys	Gly	
	220					225					230					
TGT	GAA	CAT	GGA	CAT	TGC	GAC	AAA	CCC	AAT	CAA	TGC	GTT	TGC	CAA	CTG	891
Cys	Glu	His	Gly	His	Cys	Asp	Lys	Pro	Asn	Gln	Cys	Val	Cys	Gln	Leu	
235					240					245					250	
GGC	TGG	AAG	GGA	GCC	TTG	TGC	AAC	GAG	TGC	GTT	CTG	GAA	CCG	AAC	TGC	939
Gly	Trp	Lys	Gly	Ala	Leu	Cys	Asn	Glu	Cys	Val	Leu	Glu	Pro	Asn	Cys	
				255				260						265		
ATC	CAT	GGC	ACC	TGC	AAC	AAA	CCC	TGG	ACT	TGC	ATC	TGC	AAC	GAG	GGT	987
Ile	His	Gly	Thr	Cys	Asn	Lys	Pro	Trp	Thr	Cys	Ile	Cys	Asn	Glu	Gly	
			270					275						280		
TGG	GGA	GGC	TTG	TAC	TGC	AAC	CAG	GAT	CTG	AAC	TAC	TGC	ACC	AAC	CAC	1035
Trp	Gly	Gly	Leu	Tyr	Cys	Asn	Gln	Asp	Leu	Asn	Tyr	Cys	Thr	Asn	His	
		285					290					295				
AGA	CCC	TGC	AAG	AAT	GGC	GGA	ACC	TGC	TTC	AAC	ACC	GGC	GAG	GGA	TTG	1083
Arg	Pro	Cys	Lys	Asn	Gly	Gly	Thr	Cys	Phe	Asn	Thr	Gly	Glu	Gly	Leu	
	300					305					310					
TAC	ACA	TGC	AAA	TGC	GCT	CCA	GGA	TAC	AGT	GGT	GAT	GAT	TGC	GAA	AAT	1131
Tyr	Thr	Cys	Lys	Cys	Ala	Pro	Gly	Tyr	Ser	Gly	Asp	Asp	Cys	Glu	Asn	
315					320					325					330	
GAG	ATC	TAC	TCC	TGC	GAT	GCC	GAT	GTC	AAT	CCC	TGC	CAG	AAT	GGT	GGT	1179
Glu	Ile	Tyr	Ser	Cys	Asp	Ala	Asp	Val	Asn	Pro	Cys	Gln	Asn	Gly	Gly	
				335				340						345		
ACC	TGC	ATC	GAT	GAG	CCG	CAC	ACA	AAA	ACC	GGC	TAC	AAG	TGT	CAT	TGC	1227
Thr	Cys	Ile	Asp	Glu	Pro	His	Thr	Lys	Thr	Gly	Tyr	Lys	Cys	His	Cys	
			350					355						360		
GCC	AAC	GGC	TGG	AGC	GGA	AAG	ATG	TGC	GAG	GAG	AAA	GTG	CTC	ACG	TGT	1275
Ala	Asn	Gly	Trp	Ser	Gly	Lys	Met	Cys	Glu	Glu	Lys	Val	Leu	Thr	Cys	
		365					370					375				
TCG	GAC	AAA	CCC	TGT	CAT	CAG	GGA	ATC	TGC	CGC	AAC	GTT	CGT	CCT	GGC	1323
Ser	Asp	Lys	Pro	Cys	His	Gln	Gly	Ile	Cys	Arg	Asn	Val	Arg	Pro	Gly	
	380					385					390					
TTG	GGA	AGC	AAG	GGT	CAG	GGC	TAC	CAG	TGC	GAA	TGT	CCC	ATT	GGC	TAC	1371
Leu	Gly	Ser	Lys	Gly	Gln	Gly	Tyr	Gln	Cys	Glu	Cys	Pro	Ile	Gly	Tyr	
395					400					405					410	
AGC	GGA	CCC	AAC	TGC	GAT	CTC	CAG	CTG	GAC	AAC	TGC	AGT	CCG	AAT	CCA	1419
Ser	Gly	Pro	Asn	Cys	Asp	Leu	Gln	Leu	Asp	Asn	Cys	Ser	Pro	Asn	Pro	
				415				420						425		
TGC	ATA	AAC	GGT	GGA	AGC	TGT	CAG	CCG	AGC	GGA	AAG	TGT	ATT	TGC	CCA	1467
Cys	Ile	Asn	Gly	Gly	Ser	Cys	Gln	Pro	Ser	Gly	Lys	Cys	Ile	Cys	Pro	
			430					435						440		
GCG	GGA	TTT	TCG	GGA	ACG	AGA	TGC	GAG	ACC	AAC	ATT	GAC	GAT	TGT	CTT	1515
Ala	Gly	Phe	Ser	Gly	Thr	Arg	Cys	Glu	Thr	Asn	Ile	Asp	Asp	Cys	Leu	
		445					450					455				
GGC	CAC	CAG	TGC	GAG	AAC	GGA	GGC	ACC	TGC	ATA	GAT	ATG	GTC	AAC	CAA	1563
Gly	His	Gln	Cys	Glu	Asn	Gly	Gly	Thr	Cys	Ile	Asp	Met	Val	Asn	Gln	
		460				465					470					
TAT	CGC	TGC	CAA	TGC	GTT	CCC	GGT	TTC	CAT	GGC	ACC	CAC	TGT	AGT	AGC	1611
Tyr	Arg	Cys	Gln	Cys	Val	Pro	Gly	Phe	His	Gly	Thr	His	Cys	Ser	Ser	
475					480					485					490	

AAA GTT GAC TTG TGC CTC ATC AGA CCG TGT GCC AAT GGA GGA ACC TGC Lys Val Asp Leu Cys Leu Ile Arg Pro Cys Ala Asn Gly Gly Thr Cys 495 500 505	1659
TTG AAT CTC AAC AAC GAT TAC CAG TGC ACC TGT CGT GCG GGA TTT ACT Leu Asn Leu Asn Asn Asp Tyr Gln Cys Thr Cys Arg Ala Gly Phe Thr 510 515 520	1707
GGC AAG GAT TGC TCT GTG GAC ATC GAT GAG TGC AGC AGT GGA CCC TGT Gly Lys Asp Cys Ser Val Asp Ile Asp Glu Cys Ser Ser Gly Pro Cys 525 530 535	1755
CAT AAC GGC GGC ACT TGC ATG AAC CGC GTC AAT TCG TTC GAA TGC GTG His Asn Gly Gly Thr Cys Met Asn Arg Val Asn Ser Phe Glu Cys Val 540 545 550	1803
TGT GCC AAT GGT TTC AGG GGC AAG CAG TGC GAT GAG GAG TCC TAC GAT Cys Ala Asn Gly Phe Arg Gly Lys Gln Cys Asp Glu Glu Ser Tyr Asp 555 560 565 570	1851
TCG GTG ACC TTC GAT GCC CAC CAA TAT GGA GCG ACC ACA CAA GCG AGA Ser Val Thr Phe Asp Ala His Gln Tyr Gly Ala Thr Thr Gln Ala Arg 575 580 585	1899
GCC GAT GGT TTG ACC AAT GCC CAG GTA GTC CTA ATT GCT GTT TTC TCC Ala Asp Gly Leu Thr Asn Ala Gln Val Val Leu Ile Ala Val Phe Ser 590 595 600	1947
GTT GCG ATG CCT TTG GTG GCG GTT ATT GCG GCG TGC GTG GTC TTC TGC Val Ala Met Pro Leu Val Ala Val Ile Ala Ala Cys Val Val Phe Cys 605 610 615	1995
ATG AAG CGC AAG CGT AAG CGT GCT CAG GAA AAG GAC GAC GCG GAG GCC Met Lys Arg Lys Arg Lys Arg Ala Gln Glu Lys Asp Asp Ala Glu Ala 620 625 630	2043
AGG AAG CAG AAC GAA CAG AAT GCG GTG GCC ACA ATG CAT CAC AAT GGC Arg Lys Gln Asn Glu Gln Asn Ala Val Ala Thr Met His His Asn Gly 635 640 645 650	2091
AGT GGG GTG GGT GTA GCT TTG GCT TCA GCC TCT CTG GGC GGC AAA ACT Ser Gly Val Gly Val Ala Leu Ala Ser Ala Ser Leu Gly Gly Lys Thr 655 660 665	2139
GGC AGC AAC AGC GGT CTC ACC TTC GAT GGC GGC AAC CCG AAT ATC ATC Gly Ser Asn Ser Gly Leu Thr Phe Asp Gly Gly Asn Pro Asn Ile Ile 670 675 680	2187
AAA AAC ACC TGG GAC AAG TCG GTC AAC AAC ATT TGT GCC TCA GCA GCA Lys Asn Thr Trp Asp Lys Ser Val Asn Asn Ile Cys Ala Ser Ala Ala 685 690 695	2235
GCA GCG GCG GCG GCG GCA GCA GCG GCG GAC GAG TGT CTC ATG TAC GGC Ala Ala Ala Ala Ala Ala Ala Ala Ala Asp Glu Cys Leu Met Tyr Gly 700 705 710	2283
GGA TAT GTG GCC TCG GTG GCG GAT AAC AAC AAT GCC AAC TCA GAC TTT Gly Tyr Val Ala Ser Val Ala Asp Asn Asn Ala Asn Ser Asp Phe 715 720 725 730	2331
TGT GTG GCT CCG CTA CAA AGA GCC AAG TCG CAA AAG CAA CTC AAC ACC Cys Val Ala Pro Leu Gln Arg Ala Lys Ser Gln Lys Gln Leu Asn Thr 735 740 745	2379
GAT CCC ACG CTC ATG CAC CGC GGT TCG CCG GCA GGC AGC TCA GCC AAG Asp Pro Thr Leu Met His Arg Gly Ser Pro Ala Gly Ser Ser Ala Lys 750 755 760	2427
GGA GCG TCT GGC GGA GGA CCG GGA GCG GCG GAG GGC AAG AGG ATC TCT Gly Ala Ser Gly Gly Gly Pro Gly Ala Ala Glu Gly Lys Arg Ile Ser	2475

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765	770	775	
GTT TTA GGC GAG GGT TCC TAC TGT AGC CAG CGT TGG CCC TCG TTG GCG			2523
Val Leu Gly Glu Gly Ser Tyr Cys Ser Gln Arg Trp Pro Ser Leu Ala			
780	785	790	
GCG GCG GGA GTG GCC GGA GCC TGT TCA TCC CAG CTA ATG GCT GCA GCT			2571
Ala Ala Gly Val Ala Gly Ala Cys Ser Ser Gln Leu Met Ala Ala Ala			
795	800	805	810
TCG GCA GCG GGC AGC GGA GCG GGG ACG GCG CAA CAG CAG CGA TCC GTG			2619
Ser Ala Ala Gly Ser Gly Ala Gly Thr Ala Gln Gln Gln Arg Ser Val			
815	820	825	
GTC TGC GGC ACT CCG CAT ATG TAACTCCAAA AATCCGGAAG GGCTCCTGGT			2670
Val Cys Gly Thr Pro His Met			
830			
AAATCCGGAG AAATCCGCAT GGAGGAGCTG ACAGCACATA CACAAAGAAA AGACTGGGTT			2730
GGGTTCAAAA TGTGAGAGAG ACGCCAAAAT GTTGTGTGTTG ATTGAAGCAG TTTAGTCGTC			2790
ACGAAAAATG AAAAATCTGT AACAGGCATA ACTCGTAAAC TCCCTAAAAA ATTTGTATAG			2850
TAATTAGCAA AGCTGTGACC CAGCCGTTTC GATCCCGAAT TC			2892

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 833 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Met	His	Trp	Ile	Lys	Cys	Leu	Leu	Thr	Ala	Phe	Ile	Cys	Phe	Thr	Val
1				5					10					15	
Ile	Val	Gln	Val	His	Ser	Ser	Gly	Ser	Phe	Glu	Leu	Arg	Leu	Lys	Tyr
			20					25					30		
Phe	Ser	Asn	Asp	His	Gly	Arg	Asp	Asn	Glu	Gly	Arg	Cys	Cys	Ser	Gly
		35					40					45			
Glu	Ser	Asp	Gly	Ala	Thr	Gly	Lys	Cys	Leu	Gly	Ser	Cys	Lys	Thr	Arg
	50					55					60				
Phe	Arg	Val	Cys	Leu	Lys	His	Tyr	Gln	Ala	Thr	Ile	Asp	Thr	Thr	Ser
	65				70				75						80
Gln	Cys	Thr	Tyr	Gly	Asp	Val	Ile	Thr	Pro	Ile	Leu	Gly	Glu	Asn	Ser
			85						90					95	
Val	Asn	Leu	Thr	Asp	Ala	Gln	Arg	Phe	Gln	Asn	Lys	Gly	Phe	Thr	Asn
		100						105					110		
Pro	Ile	Gln	Phe	Pro	Phe	Ser	Phe	Ser	Trp	Pro	Gly	Thr	Phe	Ser	Leu
		115					120					125			
Ile	Val	Glu	Ala	Trp	His	Asp	Thr	Asn	Asn	Ser	Gly	Asn	Ala	Arg	Thr
		130				135					140				
Asn	Lys	Leu	Leu	Ile	Gln	Arg	Leu	Leu	Val	Gln	Gln	Val	Leu	Glu	Val
	145				150					155					160
Ser	Ser	Glu	Trp	Lys	Thr	Asn	Lys	Ser	Glu	Ser	Gln	Tyr	Thr	Ser	Leu
			165					170						175	

Glu	Tyr	Asp	Phe	Arg	Val	Thr	Cys	Asp	Leu	Asn	Tyr	Tyr	Gly	Ser	Gly	180	185	190	
Cys	Ala	Lys	Phe	Cys	Arg	Pro	Arg	Asp	Asp	Ser	Phe	Gly	His	Ser	Thr	195	200	205	
Cys	Ser	Glu	Thr	Gly	Glu	Ile	Ile	Cys	Leu	Thr	Gly	Trp	Gln	Gly	Asp	210	215	220	
Tyr	Cys	His	Ile	Pro	Lys	Cys	Ala	Lys	Gly	Cys	Glu	His	Gly	His	Cys	225	230	235	240
Asp	Lys	Pro	Asn	Gln	Cys	Val	Cys	Gln	Leu	Gly	Trp	Lys	Gly	Ala	Leu	245	250	255	
Cys	Asn	Glu	Cys	Val	Leu	Glu	Pro	Asn	Cys	Ile	His	Gly	Thr	Cys	Asn	260	265	270	
Lys	Pro	Trp	Thr	Cys	Ile	Cys	Asn	Glu	Gly	Trp	Gly	Gly	Leu	Tyr	Cys	275	280	285	
Asn	Gln	Asp	Leu	Asn	Tyr	Cys	Thr	Asn	His	Arg	Pro	Cys	Lys	Asn	Gly	290	295	300	
Gly	Thr	Cys	Phe	Asn	Thr	Gly	Glu	Gly	Leu	Tyr	Thr	Cys	Lys	Cys	Ala	305	310	315	320
Pro	Gly	Tyr	Ser	Gly	Asp	Asp	Cys	Glu	Asn	Glu	Ile	Tyr	Ser	Cys	Asp	325	330	335	
Ala	Asp	Val	Asn	Pro	Cys	Gln	Asn	Gly	Gly	Thr	Cys	Ile	Asp	Glu	Pro	340	345	350	
His	Thr	Lys	Thr	Gly	Tyr	Lys	Cys	His	Cys	Ala	Asn	Gly	Trp	Ser	Gly	355	360	365	
Lys	Met	Cys	Glu	Glu	Lys	Val	Leu	Thr	Cys	Ser	Asp	Lys	Pro	Cys	His	370	375	380	
Gln	Gly	Ile	Cys	Arg	Asn	Val	Arg	Pro	Gly	Leu	Gly	Ser	Lys	Gly	Gln	385	390	395	400
Gly	Tyr	Gln	Cys	Glu	Cys	Pro	Ile	Gly	Tyr	Ser	Gly	Pro	Asn	Cys	Asp	405	410	415	
Leu	Gln	Leu	Asp	Asn	Cys	Ser	Pro	Asn	Pro	Cys	Ile	Asn	Gly	Gly	Ser	420	425	430	
Cys	Gln	Pro	Ser	Gly	Lys	Cys	Ile	Cys	Pro	Ala	Gly	Phe	Ser	Gly	Thr	435	440	445	
Arg	Cys	Glu	Thr	Asn	Ile	Asp	Asp	Cys	Leu	Gly	His	Gln	Cys	Glu	Asn	450	455	460	
Gly	Gly	Thr	Cys	Ile	Asp	Met	Val	Asn	Gln	Tyr	Arg	Cys	Gln	Cys	Val	465	470	475	480
Pro	Gly	Phe	His	Gly	Thr	His	Cys	Ser	Ser	Lys	Val	Asp	Leu	Cys	Leu	485	490	495	
Ile	Arg	Pro	Cys	Ala	Asn	Gly	Gly	Thr	Cys	Leu	Asn	Leu	Asn	Asn	Asp	500	505	510	
Tyr	Gln	Cys	Thr	Cys	Arg	Ala	Gly	Phe	Thr	Gly	Lys	Asp	Cys	Ser	Val	515	520	525	
Asp	Ile	Asp	Glu	Cys	Ser	Ser	Gly	Pro	Cys	His	Asn	Gly	Gly	Thr	Cys	530	535	540	
Met	Asn	Arg	Val	Asn	Ser	Phe	Glu	Cys	Val	Cys	Ala	Asn	Gly	Phe	Arg				

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545		550		555		560									
Gly	Lys	Gln	Cys	Asp	Glu	Glu	Ser	Tyr	Asp	Ser	Val	Thr	Phe	Asp	Ala
				565					570					575	
His	Gln	Tyr	Gly	Ala	Thr	Thr	Gln	Ala	Arg	Ala	Asp	Gly	Leu	Thr	Asn
			580					585					590		
Ala	Gln	Val	Val	Leu	Ile	Ala	Val	Phe	Ser	Val	Ala	Met	Pro	Leu	Val
		595					600					605			
Ala	Val	Ile	Ala	Ala	Cys	Val	Val	Phe	Cys	Met	Lys	Arg	Lys	Arg	Lys
	610					615					620				
Arg	Ala	Gln	Glu	Lys	Asp	Asp	Ala	Glu	Ala	Arg	Lys	Gln	Asn	Glu	Gln
625					630					635					640
Asn	Ala	Val	Ala	Thr	Met	His	His	Asn	Gly	Ser	Gly	Val	Gly	Val	Ala
				645					650					655	
Leu	Ala	Ser	Ala	Ser	Leu	Gly	Gly	Lys	Thr	Gly	Ser	Asn	Ser	Gly	Leu
			660					665					670		
Thr	Phe	Asp	Gly	Gly	Asn	Pro	Asn	Ile	Ile	Lys	Asn	Thr	Trp	Asp	Lys
		675					680					685			
Ser	Val	Asn	Asn	Ile	Cys	Ala	Ser	Ala	Ala	Ala	Ala	Ala	Ala	Ala	Ala
	690					695					700				
Ala	Ala	Ala	Asp	Glu	Cys	Leu	Met	Tyr	Gly	Gly	Tyr	Val	Ala	Ser	Val
705					710					715					720
Ala	Asp	Asn	Asn	Asn	Ala	Asn	Ser	Asp	Phe	Cys	Val	Ala	Pro	Leu	Gln
				725					730					735	
Arg	Ala	Lys	Ser	Gln	Lys	Gln	Leu	Asn	Thr	Asp	Pro	Thr	Leu	Met	His
			740					745					750		
Arg	Gly	Ser	Pro	Ala	Gly	Ser	Ser	Ala	Lys	Gly	Ala	Ser	Gly	Gly	Gly
		755					760					765			
Pro	Gly	Ala	Ala	Glu	Gly	Lys	Arg	Ile	Ser	Val	Leu	Gly	Glu	Gly	Ser
	770					775					780				
Tyr	Cys	Ser	Gln	Arg	Trp	Pro	Ser	Leu	Ala	Ala	Ala	Gly	Val	Ala	Gly
785					790					795					800
Ala	Cys	Ser	Ser	Gln	Leu	Met	Ala	Ala	Ala	Ser	Ala	Ala	Gly	Ser	Gly
				805					810					815	
Ala	Gly	Thr	Ala	Gln	Gln	Gln	Arg	Ser	Val	Val	Cys	Gly	Thr	Pro	His
			820				825						830		

Met

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1067 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

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GATCTACTAC	GAGGAGGTTA	AGGAGAGCTA	TGTGGGCGAG	CGACGCGAAT	ACGATCCCCA	60
CATCACCGAT	CCCAGGGTCA	CACGCATGAA	GATGGCCGGC	CTGAAGCCCA	ACTCCAAATA	120
CCGCATCTCC	ATCACTGCCA	CCACGAAAAT	GGGCGAGGGA	TCTGAACACT	ATATCGAAAA	180
GACCACGCTC	AAGGATGCCG	TCAATGTGGC	CCCTGCCACG	CCATCTTTCT	CCTGGGAGCA	240
ACTGCCATCC	GACAATGGAC	TAGCCAAGTT	CCGCATCAAC	TGGCTGCCAA	GTACCGAGGG	300
TCATCCAGGC	ACTCACTTCT	TTACGATGCA	CAGGATCAAG	GGCGAAACCC	AATGGATACG	360
CGAGAATGAG	GAAAAGAACT	CCGATTACCA	GGAGGTCGGT	GGCTTAGATC	CGGAGACCGC	420
CTACGAGTTC	CGCGTGGTGT	CCGTGGATGG	CCACTTTAAC	ACGGAGAGTG	CCACGCAGGA	480
GATCGACACG	AACACCGTTG	AGGGACCAAT	AATGGTGGCC	AACGAGACGG	TGGCCAATGC	540
CGGATGGTTC	ATTGGCATGA	TGCTGGCCCT	GGCCTTCATC	ATCATCCTCT	TCATCATCAT	600
CTGCATTATC	CGACGCAATC	GGGGCGGAAA	GTACGATGTC	CACGATCGGG	AGCTGGCCAA	660
CGGCCGGCGG	GATTATCCCG	AAGAGGGCGG	ATTCCACGAG	TACTCGCAAC	CGTTGGATAA	720
CAAGAGCGCT	GGTCGCCAAT	CCGTGAGTTC	AGCGAACAAA	CCGGGCGTGG	AAAGCGATAC	780
TGATTCGATG	GCCGAATACG	GTGATGGCGA	TACAGGACAA	TTTACCGAGG	ATGGCTCCTT	840
CATTGGCCAA	TATGTTCTTG	GAAAGCTCCA	ACCGCCGGTT	AGCCCACAGC	CACTGAACAA	900
TTCCGCTGCG	GCGCATCAGG	CGGCGCCAAC	TGCCGGAGGA	TCGGGAGCAG	CCGGATCGGC	960
AGCAGCAGCC	GGAGCATCGG	GTGGAGCATC	GTCCGCCGGA	GGAGCAGCTG	CCAGCAATGG	1020
AGGAGCTGCA	GCCGGAGCCG	TGGCCACCTA	CGTCTAAGCT	TGGTACC		1067

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1320 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 442..1320

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

CCGAGTCGAG	CGCCGTGCTT	CGAGCGGTGA	TGAGCCCCTT	TTCTGTCAAC	GCTAAAGATC	60
TACAAAACAT	CAGCGCCTAT	CAAGTGGAAG	TGTCAAGTGT	GAACAAAACA	AAAACGAGAG	120
AAGCACATAC	TAAGGTCCAT	ATAAATAATA	AATAATAATT	GTGTGTGATA	ACAACATTAT	180
CCAAACAAAA	CCAAACAAAA	CGAAGGCAAA	GTGGAGAAAA	TGATACAGCA	TCCAGAGTAC	240
GGCCGTTATT	CAGCTATCCA	GAGCAAGTGT	AGTGTGGCAA	AATAGAAACA	AACAAAGGCA	300
CCAAAATCTG	CATACATGGG	CTAATTAAGG	CTGCCCAGCG	AATTTACATT	TGTGTGGTGC	360
CAATCCAGAG	TGAATCCGAA	ACAAACTCCA	TCTAGATCGC	CAACCAGCAT	CACGCTCGCA	420
AACGCCCCCA	GAATGTACAA	A ATG TTT AGG AAA CAT	TTT CGG CGA AAA CCA			471
		Met Phe Arg Lys His	Phe Arg Arg Lys Pro			

					1						5						10	
GCT	ACG	TCG	TCG	TCG	TTG	GAG	TCA	ACA	ATA	GAA	TCA	GCA	GAC	AGC	CTG	519		
Ala	Thr	Ser	Ser	Ser	Leu	Glu	Ser	Thr	Ile	Glu	Ser	Ala	Asp	Ser	Leu			
					15						20						25	
GGA	ATG	TCC	AAG	AAG	ACG	GCG	ACA	AAA	AGG	CAG	CGT	CCG	AGG	CAT	CGG	567		
Gly	Met	Ser	Lys	Lys	Thr	Ala	Thr	Lys	Arg	Gln	Arg	Pro	Arg	His	Arg			
					30						35						40	
GTA	CCC	AAA	ATC	GCG	ACC	CTG	CCA	TCG	ACG	ATC	CGC	GAT	TGT	CGA	TCA	615		
Val	Pro	Lys	Ile	Ala	Thr	Leu	Pro	Ser	Thr	Ile	Arg	Asp	Cys	Arg	Ser			
					45						50						55	
TTA	AAG	TCT	GCC	TGC	AAC	TTA	ATT	GCT	TTA	ATT	TTA	ATA	CTG	TTA	GTC	663		
Leu	Lys	Ser	Ala	Cys	Asn	Leu	Ile	Ala	Leu	Ile	Leu	Ile	Leu	Leu	Val			
					60						65						70	
CAT	AAG	ATA	TCC	GCA	GCT	GGT	AAC	TTC	GAG	CTG	GAA	ATA	TTA	GAA	ATC	711		
His	Lys	Ile	Ser	Ala	Ala	Gly	Asn	Phe	Glu	Leu	Glu	Ile	Leu	Glu	Ile			
					75						80						85	90
TCA	AAT	ACC	AAC	AGC	CAT	CTA	CTC	AAC	GGC	TAT	TGC	TGC	GGC	ATG	CCA	759		
Ser	Asn	Thr	Asn	Ser	His	Leu	Leu	Asn	Gly	Tyr	Cys	Cys	Gly	Met	Pro			
					95						100						105	
GCG	GAA	CTT	AGG	GCC	ACC	AAG	ACG	ATA	GGC	TGC	TCG	CCA	TGC	ACG	ACG	807		
Ala	Glu	Leu	Arg	Ala	Thr	Lys	Thr	Ile	Gly	Cys	Ser	Pro	Cys	Thr	Thr			
					110						115						120	
GCA	TTC	CGG	CTG	TGC	CTG	AAG	GAG	TAC	CAG	ACC	ACG	GAG	CAG	GGT	GCC	855		
Ala	Phe	Arg	Leu	Cys	Leu	Lys	Glu	Tyr	Gln	Thr	Thr	Glu	Gln	Gly	Ala			
					125						130						135	
AGC	ATA	TCC	ACG	GGC	TGT	TCG	TTT	GGC	AAC	GCC	ACC	ACC	AAG	ATA	CTG	903		
Ser	Ile	Ser	Thr	Gly	Cys	Ser	Phe	Gly	Asn	Ala	Thr	Thr	Lys	Ile	Leu			
					140						145						150	
GGT	GGC	TCC	AGC	TTT	GTG	CTC	AGC	GAT	CCG	GGT	GTG	GGA	GCC	ATT	GTG	951		
Gly	Gly	Ser	Ser	Phe	Val	Leu	Ser	Asp	Pro	Gly	Val	Gly	Ala	Ile	Val			
					155						160						165	170
CTG	CCC	TTT	ACG	TTT	CGT	TGG	ACG	AAG	TCG	TTT	ACG	CTG	ATA	CTG	CAG	999		
Leu	Pro	Phe	Thr	Phe	Arg	Trp	Thr	Lys	Ser	Phe	Thr	Leu	Ile	Leu	Gln			
					175						180						185	
GCG	TTG	GAT	ATG	TAC	AAC	ACA	TCC	TAT	CCA	GAT	GCG	GAG	AGG	TTA	ATT	1047		
Ala	Leu	Asp	Met	Tyr	Asn	Thr	Ser	Tyr	Pro	Asp	Ala	Glu	Arg	Leu	Ile			
					190						195						200	
GAG	GAA	ACA	TCA	TAC	TCG	GGC	GTG	ATA	CTG	CCG	TCG	CCG	GAG	TGG	AAG	1095		
Glu	Glu	Thr	Ser	Tyr	Ser	Gly	Val	Ile	Leu	Pro	Ser	Pro	Glu	Trp	Lys			
					205						210						215	
ACG	CTG	GAC	CAC	ATC	GGG	CGG	AAC	GCG	CGG	ATC	ACC	TAC	CGT	GTC	CGG	1143		
Thr	Leu	Asp	His	Ile	Gly	Arg	Asn	Ala	Arg	Ile	Thr	Tyr	Arg	Val	Arg			
					220						225						230	
GTG	CAA	TGC	GCC	GTT	ACC	TAC	TAC	AAC	ACG	ACC	TGC	ACG	ACC	TTC	TGC	1191		
Val	Gln	Cys	Ala	Val	Thr	Tyr	Tyr	Asn	Thr	Thr	Cys	Thr	Thr	Phe	Cys			
					235						240						245	250
CGT	CCG	CGG	GAC	GAT	CAG	TTC	GGT	CAC	TAC	GCC	TGC	GGC	TCC	GAG	GGT	1239		
Arg	Pro	Arg	Asp	Asp	Gln	Phe	Gly	His	Tyr	Ala	Cys	Gly	Ser	Glu	Gly			
					255						260						265	
CAG	AAG	CTC	TGC	CTG	AAT	GGC	TGG	CAG	GGC	GTC	AAC	TGC	GAG	GAG	GCC	1287		
Gln	Lys	Leu	Cys	Leu	Asn	Gly	Trp	Gln	Gly	Val	Asn	Cys	Glu	Glu	Ala			
					270						275						280	

ATA TGC AAG GCG GGC TGC GAC CCC GTC CAC GGC
 Ile Cys Lys Ala Gly Cys Asp Pro Val His Gly
 285 290

1320

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 293 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

Met Phe Arg Lys His Phe Arg Arg Lys Pro Ala Thr Ser Ser Ser Leu
 1 5 10 15
 Glu Ser Thr Ile Glu Ser Ala Asp Ser Leu Gly Met Ser Lys Lys Thr
 20 25 30
 Ala Thr Lys Arg Gln Arg Pro Arg His Arg Val Pro Lys Ile Ala Thr
 35 40 45
 Leu Pro Ser Thr Ile Arg Asp Cys Arg Ser Leu Lys Ser Ala Cys Asn
 50 55 60
 Leu Ile Ala Leu Ile Leu Ile Leu Leu Val His Lys Ile Ser Ala Ala
 65 70 75 80
 Gly Asn Phe Glu Leu Glu Ile Leu Glu Ile Ser Asn Thr Asn Ser His
 85 90 95
 Leu Leu Asn Gly Tyr Cys Cys Gly Met Pro Ala Glu Leu Arg Ala Thr
 100 105 110
 Lys Thr Ile Gly Cys Ser Pro Cys Thr Thr Ala Phe Arg Leu Cys Leu
 115 120 125
 Lys Glu Tyr Gln Thr Thr Glu Gln Gly Ala Ser Ile Ser Thr Gly Cys
 130 135 140
 Ser Phe Gly Asn Ala Thr Thr Lys Ile Leu Gly Gly Ser Ser Phe Val
 145 150 155 160
 Leu Ser Asp Pro Gly Val Gly Ala Ile Val Leu Pro Phe Thr Phe Arg
 165 170 175
 Trp Thr Lys Ser Phe Thr Leu Ile Leu Gln Ala Leu Asp Met Tyr Asn
 180 185 190
 Thr Ser Tyr Pro Asp Ala Glu Arg Leu Ile Glu Glu Thr Ser Tyr Ser
 195 200 205
 Gly Val Ile Leu Pro Ser Pro Glu Trp Lys Thr Leu Asp His Ile Gly
 210 215 220
 Arg Asn Ala Arg Ile Thr Tyr Arg Val Arg Val Gln Cys Ala Val Thr
 225 230 235 240
 Tyr Tyr Asn Thr Thr Cys Thr Thr Phe Cys Arg Pro Arg Asp Asp Gln
 245 250 255
 Phe Gly His Tyr Ala Cys Gly Ser Glu Gly Gln Lys Leu Cys Leu Asn
 260 265 270
 Gly Trp Gln Gly Val Asn Cys Glu Glu Ala Ile Cys Lys Ala Gly Cys
 275 280 285

Asp Pro Val His Gly
290

(2) INFORMATION FOR SEQ ID NO:10:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 26 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

- (ix) FEATURE:
(A) NAME/KEY: modified_base
(B) LOCATION: 6
(D) OTHER INFORMATION: /mod_base= i
/label= N

- (ix) FEATURE:
(A) NAME/KEY: modified_base
(B) LOCATION: 12
(D) OTHER INFORMATION: /mod_base= i
/label= N

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

GAYGCNAAYG TNCARGAYAA YATGGG

26

(2) INFORMATION FOR SEQ ID NO:11:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 25 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

- (ix) FEATURE:
(A) NAME/KEY: modified_base
(B) LOCATION: 3
(D) OTHER INFORMATION: /mod_base= i
/label= N

- (ix) FEATURE:
(A) NAME/KEY: modified_base
(B) LOCATION: 12
(D) OTHER INFORMATION: /mod_base= i
/label= N

- (ix) FEATURE:
(A) NAME/KEY: modified_base
(B) LOCATION: 18
(D) OTHER INFORMATION: /mod_base= i
/label= N

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

ATNARRTCYT CNACCATNCC YTCDA

25

(2) INFORMATION FOR SEQ ID NO:12:

- (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 26 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: modified_base
- (B) LOCATION: 12
- (D) OTHER INFORMATION: /mod_base= i
/label= N

(ix) FEATURE:

- (A) NAME/KEY: modified_base
- (B) LOCATION: 18
- (D) OTHER INFORMATION: /mod_base= i
/label= N

(ix) FEATURE:

- (A) NAME/KEY: modified_base
- (B) LOCATION: 21
- (D) OTHER INFORMATION: /mod_base= i
/label= N

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

TCCATRTGRT CNGTDATNTC NCKRTT

26

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 267 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

GAATTCCGCT GGGAGAATGG TCTGAGCTAC CTGCCCCGTCC TGCTGGGGCA TCAATGGCAA	60
GTGGGGAAAG CCACACTGGG CAAACGGGCC AGGCCATTTC TGAATGTGG TACATGGTGG	120
GCAGGGGGCC CGCAACAGCT GGAGGGCAGG TGGACTGAGG CTGGGGATCC CCCGCTGGTT	180
GGGCAATACT GCCTTTACCC ATGAGCTGGA AAGTCACAAT GGGGGGCAAG GGCTCCCGAG	240
GGTGGTTATG TGCTTCCTTC AGGTGGC	267

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 574 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

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GAATTCCTTC CATTATACGT GACTTTTCTG AACTGTAGC CACCCTAGTG TCTCTAACTC	60
CCTCTGGAGT TTGTCAGCTT TGGTCTTTTC AAAGAGCAGG CTCTCTTCAA GCTCCTTAAT	120
GCGGGCATGC TCCAGTTTGG TCTGCGTCTC AAGATCACCT TTGGTAATTG ATTCTTCTTC	180
AACCCGGAAC TGAAGGCTGG CTCTCACCCT CTAGGCAGAG CAGGAATTCC GAGGTGGATG	240
TGTTAGATGT GAATGTCCGT GGCCAGATG GCTGCACCCC ATTGATGTTG GCTTCTCTCC	300
GAGGAGGCAG CTCAGATTTG AGTGATGAAG ATGAAGATGC AGAGGACTGT TCTGCTAACA	360
TCATCACAGA CTTGGTCTAC CAGGGTGCCA GCCTCCAGNC CAGACAGACC GGACTGGTGA	420
GATGGCCCTG CACCTTGCAG CCCGCTACTC ACGGGCTGAT GCTGCCAAGC GTCTCCTGGA	480
TGCAGGTGCA GATGCCAATG CCCAGGACAA CATGGGCCGC TGTCCACTCC ATGCTGCAGT	540
GGCACGTGAT GCCAAGGTGT ATTCAGATCT GTTA	574

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 295 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

TCCAGATTCT GATTCGCAAC CGAGTAACTG ATCTAGATGC CAGGATGAAT GATGGTACTA	60
CACCCCTGAT CCTGGCTGCC CGCCTGGCTG TGGAGGGAAT GGTGGCAGAA CTGATCAACT	120
GCCAAGCGGA TGTGAATGCA GTGGATGACC ATGGAAAATC TGCTCTTCAC TGGGCAGCTG	180
CTGTCAATAA TGTGGAGGCA ACTCTTTTGT TGTTGAAAAA TGGGGCCAAC CGAGACATGC	240
AGGACAACAA GGAAGAGACA CCTCTGTTTC TTGCTGCCCCG GGAGGAGCTA TAAGC	295

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 333 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

GAATTCCCAT GAGTCGGGAG CTTGATCAA AATTGATGAG CCTTTAGAAG GATCCGAAGA	60
TCGGATCATT ACCATTACAG GAACAGGCAC CTGTAGCTGG TGGCTGGGGG TGTGTCCAC	120
AGGCGAGGAG TAGCTGTGCT GCGAGGGGGG CGTCAGGAAC TGGGCTGCGG TCACGGGTGG	180
GACCAGCGAG GATGGCAGCG ACGTGGGCAG GCGGGGGCTC TCCTGGGGCA GAATAGTGTG	240
CACCGCCAGG CTGCTGGGGC CCAGTACTGC ACGTCTGCCT GGCTCGGCTC TCCACTCAGG	300
AAGCTCCGGC CCAGGTGGCC GCTGGCTGCT GAG	333

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 582 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

GAATTCCTGC CAGGAGGACG CGGGCAACAA GGTCTGCAGC CTGCAGTGCA ACAACCACGC	60
GTGCGGCTGG GACGGCGGTG ACTGCTCCCT CAACTTCACA ATGACCCCTG GAAGAACTGC	120
ACGCAGTCTC TGCAGTGCTG GAAGTACTTC AGTGACGGCC ACTGTGACAG CCAGTGCAAC	180
TCAGCCGGCT GCCTCTTCGA CGGCTTTGAC TGCCAGCGGC GGAAGGCCAG TTGCAACCCC	240
CTGTACGACC AGTACTGCAA GGACCACTTC AGCGACGGGC ACTGCGACCA GGGCTGCAAC	300
AGCGCGGAGT NCAGNTGGGA CGGGCTGGAC TGTGCGGCAG TGTACCCGAG AGCTGGCGGC	360
GCACGCTGGT GGTGGTGGTG CTGATGCCGC CGGAGCAGCT GCGCAACAGC TCCTTCCACT	420
TCCTGCGGGA CGTCAGCCGC GTGCTGCACA CCAACGTGTC TTCAAGCGTG ACGCACACGG	480
CCAGCAGATG ATGTTCCCCT ACTACGGCCG CGAGGAGGAG CTGCGCAAGC CCCATCAAGC	540
GTGCCGCCGA GGGCTGGGCC GCACCTGACG CCTGCTGGGC CA	582

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 150 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

TCAGCCGAGT GCTGCACACC AACGTGTCTT CAAGCGTGAC GCACACGGCC AGCAGATGAT	60
GTTCCCCTAC TACGGCCGCG AGGAGGAGCT GCGCAAGCCC CATCAAGCGT GCCGCCGAGG	120
GCTGGGCCGC ACCTGACGCC TGCTGGGCCA	150

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 247 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

TTACCATTAC AGGAACAGGC ACCTGTAGCT GGTGGCTGGG GGTGTTGTCC ACAGGCGAGG	60
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AGTAGCTGTG CTGCGAGGGG GCGGTCAGGA ACTGGGCTGC GGTCACGGGT GGGACCAGCG 120
 AGGATGGCAG CGACGTGGGC AGGGCGGGGC TCTCCTGGGG CAGAATAGTG TGCACCGCCA 180
 GCTGCTGGGG CCCAGTGCTG CACGTCTGCC TGGCTCGGCT CTCCACTCAG GAAGCTCCGG 240
 CCCAGGT 247

(2) INFORMATION FOR SEQ ID NO:20:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 248 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

GAATTCCATT CAGGAGGAAA GGGTGGGGAG AGAAGCAGGC ACCCACTTTC CCGTGGCTGG 60
 ACTCGTTCCC AGGTGGCTCC ACCGGCAGCT GTGACCGCCG CAGGTGGGGG CGGAGTGCCA 120
 TTCAGAAAAT TCCAGAAAAG CCCTACCCCA ACTCGGACGG CAACGTCACA CCCGTGGGTA 180
 GCAACTGGCA CACAAACAGC CAGCGTGTCT GGGGCACGGG GGGATGGCAC CCCCTGCAGG 240
 CAGAGCTG 248

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 323 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

CTAAAGGGAA CAAAGCNGG AGCTCCACCG CGGGCGGCNC NGCTCTAGAA CTAGTGGANN 60
 NCCCGGGCTG CAGGAATTCC GGCGGACTGG GCTCGGGCTC AGAGCGGCGC TGTGGAAGAG 120
 ATTCTAGACC GGGAGAACAA GCGAATGGCT GACAGCTGGC CTCCAAAGTC ACCAGGCTCA 180
 AATCGCTCGC CCTGGACATC GAGGGATGCA GAGGATCAGA ACCGGTACCT GGATGGCATG 240
 ACTCGGATTT ACAAGCATGA CCAGCCTGCT TACAGGGAGC GTGANNTTTT CACATGCAGT 300
 CGACAGACAC GAGCTCTATG CAT 323

(2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 330 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

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(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

GAATTCGAG GTGGATGTGT TAGATGTGAA TGTCCGTGGC CCAGATGGCT GCACCCCAT	60
GATGTTGGCT TCTCTCCGAG GAGGCAGCTC AGATTGAGT GATGAAGATG AAGATGCAGA	120
GGACTCTTCT GCTAACATCA TCACAGACTT GGTCTTACCA GGGTGCCAGC CTTCCAGGCC	180
CAAGAACAGA CCGGACTTGG TGAGATGGCC CTGCACCTTG CAGCCCGCTA CTACGGGCTG	240
ATGCTGCCAA GGTTCCTGGAT GCAGGTGCAG ATGCCAATGC CCAGGACAAC ATGGGCCGCT	300
GTCCACTCCA TGCTGCAGTG GCACTGATGC	330

(2) INFORMATION FOR SEQ ID NO:23:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 167 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

CAGAGGATGG TGAGGGTCCA TGCAGATAGG TTCTCCCAT CCTGTGAATA ATAAATGGGT	60
GCAAGGGCAG AGAGTCACCA TTTAGAATGA TAAATGTTT GCACACTATG AAAGAGGCTG	120
ACAGAATGTT GCCACATGGA GAGATAAAGC AGAGAATGAA CAACTT	167

(2) INFORMATION FOR SEQ ID NO:24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 225 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

AGGATGAATG ATGGTACTAC ACCCCTGATC CTGGCTGCCC GCCTGGCTGT GGAGGGAATG	60
GTGGCAGAAC TGATCAACTG CCAAGCGGAT GTGAATGCAG TGGATGACCA TGGAAAATCT	120
GCTCTTCACT GGGCAGCTGC TGTCAATAAT GTGGAGGCAA CTCTTTTGTT GTTGAAAAT	180
GGGGCCAACC GAGACATGCA GGACAACAAG GAAGAGACAC CTCTG	225

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 121 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

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AATAATAAAT GGGTGCAAGG GCAGAGAGTC ACCATTTAGA ATGATAAAAT GTTTGCACAC 60
TATGAAAGAG GCTGACAGAA TGTGCCACA TGGAGAGATA AAGCAGAGAA TGAACAAACT 120
T 121

(2) INFORMATION FOR SEQ ID NO:26:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 20 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

ACTTCAGCAA CGATCACGGG 20

(2) INFORMATION FOR SEQ ID NO:27:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27:

TTGGGTATGT GACAGTAATC G 21

(2) INFORMATION FOR SEQ ID NO:28:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 14 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:28:

TTAAGTTAAC TTAA 14

(2) INFORMATION FOR SEQ ID NO:29:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 12 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:29:

GGAAGATCTT CC 12

(2) INFORMATION FOR SEQ ID NO:30:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 4 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:30:

Arg Lys Ile Phe
 1

(2) INFORMATION FOR SEQ ID NO:31:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 3234 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
 (B) LOCATION: 1..3234

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:31:

TGC CAG GAG GAC GCG GGC AAC AAG GTC TGC AGC CTG CAG TGC AAC AAC	48
Cys Gln Glu Asp Ala Gly Asn Lys Val Cys Ser Leu Gln Cys Asn Asn	
1 5 10 15	
CAC GCG TGC GGC TGG GAC GGC GGT GAC TGC TCC CTC AAC TTC AAT GAC	96
His Ala Cys Gly Trp Asp Gly Gly Asp Cys Ser Leu Asn Phe Asn Asp	
20 25 30	
CCC TGG AAG AAC TGC ACG CAG TCT CTG CAG TGC TGG AAG TAC TTC AGT	144
Pro Trp Lys Asn Cys Thr Gln Ser Leu Gln Cys Trp Lys Tyr Phe Ser	
35 40 45	
GAC GGC CAC TGT GAC AGC CAG TGC AAC TCA GCC GGC TGC CTC TTC GAC	192
Asp Gly His Cys Asp Ser Gln Cys Asn Ser Ala Gly Cys Leu Phe Asp	
50 55 60	
GGC TTT GAC TGC CAG CGT GCG GAA GGC CAG TGC AAC CCC CTG TAC GAC	240
Gly Phe Asp Cys Gln Arg Ala Glu Gly Gln Cys Asn Pro Leu Tyr Asp	
65 70 75 80	
CAG TAC TGC AAG GAC CAC TTC AGC GAC GGG CAC TGC GAC CAG GGC TGC	288
Gln Tyr Cys Lys Asp His Phe Ser Asp Gly His Cys Asp Gln Gly Cys	
85 90 95	
AAC AGC GCG GAG TGC GAG TGG GAC GGC CTG GAC TGT GCG GAG CAT GTA	336
Asn Ser Ala Glu Cys Glu Trp Asp Gly Leu Asp Cys Ala Glu His Val	
100 105 110	
CCC GAG AGG CTG GCG GCC GGC ACG CTG GTG GTG GTG GTG CTG ATG CCG	384
Pro Glu Arg Leu Ala Ala Gly Thr Leu Val Val Val Val Leu Met Pro	
115 120 125	
CCG GAG CAG CTG CGC AAC AGC TCC TTC CAC TTC CTG CGG GAG CTC AGC	432
Pro Glu Gln Leu Arg Asn Ser Ser Phe His Phe Leu Arg Glu Leu Ser	
130 135 140	

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CGC GTG CTG CAC ACC AAC GTG GTC TTC AAG CGT GAC GCA CAC GGC CAG Arg Val Leu His Thr Asn Val Val Phe Lys Arg Asp Ala His Gly Gln 145 150 155 160	480
CAG ATG ATC TTC CCC TAC TAC GGC CGC GAG GAG GAG CTG CGC AAG CAC Gln Met Ile Phe Pro Tyr Tyr Gly Arg Glu Glu Glu Leu Arg Lys His 165 170 175	528
CCC ATC AAG CGT GCC GCC GAG GGC TGG GCC GCA CCT GAC GCC CTG CTG Pro Ile Lys Arg Ala Ala Glu Gly Trp Ala Ala Pro Asp Ala Leu Leu 180 185 190	576
GGC CAG GTG AAG GCC TCG CTG CTC CCT GGT GGC AGC GAG GGT GGG CGG Gly Gln Val Lys Ala Ser Leu Leu Pro Gly Gly Ser Glu Gly Gly Arg 195 200 205	624
CGG CGG AGG GAG CTG GAC CCC ATG GAC GTC CGC GGC TCC ATC GTC TAC Arg Arg Arg Glu Leu Asp Pro Met Asp Val Arg Gly Ser Ile Val Tyr 210 215 220	672
CTG GAG ATT GAC AAC CGG CAG TGT GTG CAG GCC TCC TCG CAG TGC TTC Leu Glu Ile Asp Asn Arg Gln Cys Val Gln Ala Ser Ser Gln Cys Phe 225 230 235 240	720
CAG AGT GCC ACC GAC GTG GCC GCA TTC CTG GGA GCG CTC GCC TCG CTG Gln Ser Ala Thr Asp Val Ala Ala Phe Leu Gly Ala Leu Ala Ser Leu 245 250 255	768
GGC AGC CTC AAC ATC CCC TAC AAG ATC GAG GCC GTG CAG AGT GAG ACC Gly Ser Leu Asn Ile Pro Tyr Lys Ile Glu Ala Val Gln Ser Glu Thr 260 265 270	816
GTG GAG CCG CCC CCG CCG GCG CAG CTG CAC TTC ATG TAC GTG GCG GCG Val Glu Pro Pro Pro Ala Gln Leu His Phe Met Tyr Val Ala Ala 275 280 285	864
GCC GCC TTT GTG CTT CTG TTC TTC GTG GGC TGC GGG GTG CTG CTG TCC Ala Ala Phe Val Leu Leu Phe Phe Val Gly Cys Gly Val Leu Leu Ser 290 295 300	912
CGC AAG CGC CGG CGG CAG CAT GGC CAG CTC TGG TTC CCT GAG GGC TTC Arg Lys Arg Arg Arg Gln His Gly Gln Leu Trp Phe Pro Glu Gly Phe 305 310 315 320	960
AAA GTG TCT GAG GCC AGC AAG AAG AAG CGG CGG GAG CCC CTC GGC GAG Lys Val Ser Glu Ala Ser Lys Lys Lys Arg Arg Glu Pro Leu Gly Glu 325 330 335	1008
GAC TCC GTG GGC CTC AAG CCC CTG AAG AAC GCT TCA GAC GGT GCC CTC Asp Ser Val Gly Leu Lys Pro Leu Lys Asn Ala Ser Asp Gly Ala Leu 340 345 350	1056
ATG GAC GAC AAC CAG AAT GAG TGG GGG GAC GAG GAC CTG GAG ACC AAG Met Asp Asp Asn Gln Asn Glu Trp Gly Asp Glu Asp Leu Glu Thr Lys 355 360 365	1104
AAG TTC CGG TTC GAG GAG CCC GTG GTT CTG CCT GAC CTG GAC GAC CAG Lys Phe Arg Phe Glu Glu Pro Val Val Leu Pro Asp Leu Asp Asp Gln 370 375 380	1152
ACA GAC CAC CGG CAG TGG ACT CAG CAG CAC CTG GAT GCC GCT GAC CTG Thr Asp His Arg Gln Trp Thr Gln Gln His Leu Asp Ala Ala Asp Leu 385 390 395 400	1200
CGC ATG TCT GCC ATG GCC CCC ACA CCG CCC CAG GGT GAG GTT GAC GCC Arg Met Ser Ala Met Ala Pro Thr Pro Pro Gln Gly Glu Val Asp Ala 405 410 415	1248
GAC TGC ATG GAC GTC AAT GTC CGC GGG CCT GAT GGC TTC ACC CCG CTC Asp Cys Met Asp Val Asn Val Arg Gly Pro Asp Gly Phe Thr Pro Leu 1296	

2102208

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420				425				430								
ATG	ATC	GCC	TCC	TGC	AGC	GGG	GGC	GGC	CTG	GAG	ACG	GGC	AAC	AGC	GAG	1344
Met	Ile	Ala	Ser	Cys	Ser	Gly	Gly	Gly	Leu	Glu	Thr	Gly	Asn	Ser	Glu	
		435					440					445				
GAA	GAG	GAG	GAC	GCG	CCG	GCC	GTC	ATC	TCC	GAC	TTC	ATC	TAC	CAG	GGC	1392
Glu	Glu	Glu	Asp	Ala	Pro	Ala	Val	Ile	Ser	Asp	Phe	Ile	Tyr	Gln	Gly	
	450					455					460					
GCC	AGC	CTG	CAC	AAC	CAG	ACA	GAC	CGC	ACG	GGC	GAG	ACC	GCC	TTG	CAC	1440
Ala	Ser	Leu	His	Asn	Gln	Thr	Asp	Arg	Thr	Gly	Glu	Thr	Ala	Leu	His	
465					470					475					480	
CTG	GCC	GCC	CGC	TAC	TCA	CGC	TCT	GAT	GCC	GCC	AAG	CGC	CTG	CTG	GAG	1488
Leu	Ala	Ala	Arg	Tyr	Ser	Arg	Ser	Asp	Ala	Ala	Lys	Arg	Leu	Leu	Glu	
				485					490					495		
GCC	AGC	GCA	GAT	GCC	AAC	ATC	CAG	GAC	AAC	ATG	GGC	CGC	ACC	CCG	CTG	1536
Ala	Ser	Ala	Asp	Ala	Asn	Ile	Gln	Asp	Asn	Met	Gly	Arg	Thr	Pro	Leu	
			500					505					510			
CAT	GCG	GCT	GTG	TCT	GCC	GAC	GCA	CAA	GGT	GTC	TTC	CAG	ATC	CTG	ATC	1584
His	Ala	Ala	Val	Ser	Ala	Asp	Ala	Gln	Gly	Val	Phe	Gln	Ile	Leu	Ile	
		515					520					525				
CGG	AAC	CGA	GCC	ACA	GAC	CTG	GAT	GCC	CGC	ATG	CAT	GAT	GGC	ACG	ACG	1632
Arg	Asn	Arg	Ala	Thr	Asp	Leu	Asp	Ala	Arg	Met	His	Asp	Gly	Thr	Thr	
	530					535					540					
CCA	CTG	ATC	CTG	GCT	GCC	CGC	CTG	GCC	GTG	GAG	GGC	ATG	CTG	GAG	GAC	1680
Pro	Leu	Ile	Leu	Ala	Ala	Arg	Leu	Ala	Val	Glu	Gly	Met	Leu	Glu	Asp	
545					550					555					560	
CTC	ATC	AAC	TCA	CAC	GCC	GAC	GTC	AAC	GCC	GTA	GAT	GAC	CTG	GGC	AAG	1728
Leu	Ile	Asn	Ser	His	Ala	Asp	Val	Asn	Ala	Val	Asp	Asp	Leu	Gly	Lys	
				565				570						575		
TCC	GCC	CTG	CAC	TGG	GCC	GCC	GCC	GTG	AAC	AAT	GTG	GAT	GCC	GCA	GTT	1776
Ser	Ala	Leu	His	Trp	Ala	Ala	Ala	Val	Asn	Asn	Val	Asp	Ala	Ala	Val	
			580					585					590			
GTG	CTC	CTG	AAG	AAC	GGG	GCT	AAC	AAA	GAT	ATG	CAG	AAC	AAC	AGG	GAG	1824
Val	Leu	Leu	Lys	Asn	Gly	Ala	Asn	Lys	Asp	Met	Gln	Asn	Asn	Arg	Glu	
		595					600					605				
GAG	ACA	CCC	CTG	TTT	CTG	GCC	GCC	CGG	GAG	GGC	AGC	TAC	GAG	ACC	GCC	1872
Glu	Thr	Pro	Leu	Phe	Leu	Ala	Ala	Arg	Glu	Gly	Ser	Tyr	Glu	Thr	Ala	
	610					615					620					
AAG	GTG	CTG	CTG	GAC	CAC	TTT	GCC	AAC	CGG	GAC	ATC	ACG	GAT	CAT	ATG	1920
Lys	Val	Leu	Leu	Asp	His	Phe	Ala	Asn	Arg	Asp	Ile	Thr	Asp	His	Met	
625					630				635						640	
GAC	CGC	CTG	CCG	CGC	GAC	ATC	GCA	CAG	GAG	CGC	ATG	CAT	CAC	GAC	ATC	1968
Asp	Arg	Leu	Pro	Arg	Asp	Ile	Ala	Gln	Glu	Arg	Met	His	His	Asp	Ile	
				645					650					655		
GTG	AGG	CTG	CTG	GAC	GAG	TAC	AAC	CTG	GTG	CGC	AGC	CCG	CAG	CTG	CAC	2016
Val	Arg	Leu	Leu	Asp	Glu	Tyr	Asn	Leu	Val	Arg	Ser	Pro	Gln	Leu	His	
			660					665					670			
GGA	GCC	CCG	CTG	GGG	GGC	ACG	CCC	ACC	CTG	TCG	CCC	CCG	CTC	TGC	TCG	2064
Gly	Ala	Pro	Leu	Gly	Gly	Thr	Pro	Thr	Leu	Ser	Pro	Pro	Leu	Cys	Ser	
		675					680					685				
CCC	AAC	GGC	TAC	CTG	GGC	AGC	CTC	AAG	CCC	GGC	GTG	CAG	GGC	AAG	AAG	2112
Pro	Asn	Gly	Tyr	Leu	Gly	Ser	Leu	Lys	Pro	Gly	Val	Gln	Gly	Lys	Lys	
	690					695					700					

GTC	CGC	AAG	CCC	AGC	AGC	AAA	GGC	CTG	GCC	TGT	GGA	AGC	AAG	GAG	GCC	2160
Val	Arg	Lys	Pro	Ser	Ser	Lys	Gly	Leu	Ala	Cys	Gly	Ser	Lys	Glu	Ala	
705					710					715					720	
AAG	GAC	CTC	AAG	GCA	CGG	AGG	AAG	AAG	TCC	CAG	GAT	GGC	AAG	GGC	TGC	2208
Lys	Asp	Leu	Lys	Ala	Arg	Arg	Lys	Lys	Ser	Gln	Asp	Gly	Lys	Gly	Cys	
				725					730					735		
CTG	CTG	GAC	AGC	TCC	GGC	ATG	CTC	TCG	CCC	GTG	GAC	TCC	CTG	GAG	TCA	2256
Leu	Leu	Asp	Ser	Ser	Gly	Met	Leu	Ser	Pro	Val	Asp	Ser	Leu	Glu	Ser	
			740					745					750			
CCC	CAT	GGC	TAC	CTG	TCA	GAC	GTG	GCC	TCG	CCG	CCA	CTG	CTG	CCC	TCC	2304
Pro	His	Gly	Tyr	Leu	Ser	Asp	Val	Ala	Ser	Pro	Pro	Leu	Leu	Pro	Ser	
		755					760					765				
CCG	TTC	CAG	CAG	TCT	CCG	TCC	GTG	CCC	CTC	AAC	CAC	CTG	CCT	GGG	ATG	2352
Pro	Phe	Gln	Gln	Ser	Pro	Ser	Val	Pro	Leu	Asn	His	Leu	Pro	Gly	Met	
	770					775					780					
CCC	GAC	ACC	CAC	CTG	GGC	ATC	GGG	CAC	CTG	AAC	GTG	GCG	GCC	AAG	CCC	2400
Pro	Asp	Thr	His	Leu	Gly	Ile	Gly	His	Leu	Asn	Val	Ala	Ala	Lys	Pro	
785					790					795					800	
GAG	ATG	GCG	GCG	CTG	GGT	GGG	GGC	GGC	CGG	CTG	GCC	TTT	GAG	ACT	GGC	2448
Glu	Met	Ala	Ala	Leu	Gly	Gly	Gly	Gly	Arg	Leu	Ala	Phe	Glu	Thr	Gly	
				805					810					815		
CCA	CCT	CGT	CTC	TCC	CAC	CTG	CCT	GTG	GCC	TCT	GGC	ACC	AGC	ACC	GTC	2496
Pro	Pro	Arg	Leu	Ser	His	Leu	Pro	Val	Ala	Ser	Gly	Thr	Ser	Thr	Val	
			820					825					830			
CTG	GGC	TCC	AGC	AGC	GGA	GGG	GCC	CTG	AAT	TTC	ACT	GTG	GGC	GGG	TCC	2544
Leu	Gly	Ser	Ser	Ser	Gly	Gly	Ala	Leu	Asn	Phe	Thr	Val	Gly	Gly	Ser	
		835					840					845				
ACC	AGT	TTG	AAT	GGT	CAA	TGC	GAG	TGG	CTG	TCC	CGG	CTG	CAG	AGC	GGC	2592
Thr	Ser	Leu	Asn	Gly	Gln	Cys	Glu	Trp	Leu	Ser	Arg	Leu	Gln	Ser	Gly	
	850					855					860					
ATG	GTG	CCG	AAC	CAA	TAC	AAC	CCT	CTG	CGG	GGG	AGT	GTG	GCA	CCA	GGC	2640
Met	Val	Pro	Asn	Gln	Tyr	Asn	Pro	Leu	Arg	Gly	Ser	Val	Ala	Pro	Gly	
865					870					875					880	
CCC	CTG	AGC	ACA	CAG	GCC	CCC	TCC	CTG	CAG	CAT	GGC	ATG	GTA	GGC	CCG	2688
Pro	Leu	Ser	Thr	Gln	Ala	Pro	Ser	Leu	Gln	His	Gly	Met	Val	Gly	Pro	
				885					890					895		
CTG	CAC	AGT	AGC	CTT	GCT	GCC	AGC	GCC	CTG	TCC	CAG	ATG	ATG	AGC	TAC	2736
Leu	His	Ser	Ser	Leu	Ala	Ala	Ser	Ala	Leu	Ser	Gln	Met	Met	Ser	Tyr	
			900					905					910			
CAG	GGC	CTG	CCC	AGC	ACC	CGG	CTG	GCC	ACC	CAG	CCT	CAC	CTG	GTG	CAG	2784
Gln	Gly	Leu	Pro	Ser	Thr	Arg	Leu	Ala	Thr	Gln	Pro	His	Leu	Val	Gln	
		915					920					925				
ACC	CAG	CAG	GTG	CAG	CCA	CAA	AAC	TTA	CAG	ATG	CAG	CAG	CAG	AAC	CTG	2832
Thr	Gln	Gln	Val	Gln	Pro	Gln	Asn	Leu	Gln	Met	Gln	Gln	Gln	Asn	Leu	
	930					935					940					
CAG	CCA	GCA	AAC	ATC	CAG	CAG	CAG	CAA	AGC	CTG	CAG	CCG	CCA	CCA	CCA	2880
Gln	Pro	Ala	Asn	Ile	Gln	Gln	Gln	Gln	Ser	Leu	Gln	Pro	Pro	Pro	Pro	
945					950					955					960	
CCA	CCA	CAG	CCG	CAC	CTT	GGC	GTG	AGC	TCA	GCA	GCC	AGC	GGC	CAC	CTG	2928
Pro	Pro	Gln	Pro	His	Leu	Gly	Val	Ser	Ser	Ala	Ala	Ser	Gly	His	Leu	
				965				970					975			
GGC	CGG	AGC	TTC	CTG	AGT	GGA	GAG	CCG	AGC	CAG	GCA	GAC	GTG	CAG	CCA	2976
Gly	Arg	Ser	Phe	Leu	Ser	Gly	Glu	Pro	Ser	Gln	Ala	Asp	Val	Gln	Pro	

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980	985	990	
CTG GGC CCC AGC AGC CTG GCG GTG CAC ACT ATT CTG CCC CAG GAG AGC Leu Gly Pro Ser Ser Leu Ala Val His Thr Ile Leu Pro Gln Glu Ser 995 1000 1005			3024
CCC GCC CTG CCC ACG TCG CTG CCA TCC TCG CTG GTC CCA CCC GTG ACC Pro Ala Leu Pro Thr Ser Leu Pro Ser Ser Leu Val Pro Pro Val Thr 1010 1015 1020			3072
GCA GCC CAG TTC CTG ACG CCC CCC TCG CAG CAC AGC TAC TCC TCG CCT Ala Ala Gln Phe Leu Thr Pro Pro Ser Gln His Ser Tyr Ser Ser Pro 1025 1030 1035 1040			3120
GTG GAC AAC ACC CCC AGC CAC CAG CTA CAG GTG CCT GTT CCT GTA ATG Val Asp Asn Thr Pro Ser His Gln Leu Gln Val Pro Val Pro Val Met 1045 1050 1055			3168
GTA ATG ATC CGA TCT TCG GAT CCT TCT AAA GGC TCA TCA ATT TTG ATC Val Met Ile Arg Ser Ser Asp Pro Ser Lys Gly Ser Ser Ile Leu Ile 1060 1065 1070			3216
GAA GCT CCC GAC TCA TGG Glu Ala Pro Asp Ser Trp 1075			3234

(2) INFORMATION FOR SEQ ID NO:32:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1078 amino acids
(B) TYPE: amino acid
(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:32:

Cys	Gln	Glu	Asp	Ala	Gly	Asn	Lys	Val	Cys	Ser	Leu	Gln	Cys	Asn	Asn	1	5	10	15
His	Ala	Cys	Gly	Trp	Asp	Gly	Gly	Asp	Cys	Ser	Leu	Asn	Phe	Asn	Asp	20	25	30	
Pro	Trp	Lys	Asn	Cys	Thr	Gln	Ser	Leu	Gln	Cys	Trp	Lys	Tyr	Phe	Ser	35	40	45	
Asp	Gly	His	Cys	Asp	Ser	Gln	Cys	Asn	Ser	Ala	Gly	Cys	Leu	Phe	Asp	50	55	60	
Gly	Phe	Asp	Cys	Gln	Arg	Ala	Glu	Gly	Gln	Cys	Asn	Pro	Leu	Tyr	Asp	65	70	75	80
Gln	Tyr	Cys	Lys	Asp	His	Phe	Ser	Asp	Gly	His	Cys	Asp	Gln	Gly	Cys	85	90	95	
Asn	Ser	Ala	Glu	Cys	Glu	Trp	Asp	Gly	Leu	Asp	Cys	Ala	Glu	His	Val	100	105	110	
Pro	Glu	Arg	Leu	Ala	Ala	Gly	Thr	Leu	Val	Val	Val	Val	Leu	Met	Pro	115	120	125	
Pro	Glu	Gln	Leu	Arg	Asn	Ser	Ser	Phe	His	Phe	Leu	Arg	Glu	Leu	Ser	130	135	140	
Arg	Val	Leu	His	Thr	Asn	Val	Val	Phe	Lys	Arg	Asp	Ala	His	Gly	Gln	145	150	155	160
Gln	Met	Ile	Phe	Pro	Tyr	Tyr	Gly	Arg	Glu	Glu	Glu	Leu	Arg	Lys	His	165	170	175	

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Pro Ile Lys Arg Ala Ala Glu Gly Trp Ala Ala Pro Asp Ala Leu Leu
 180 185 190
 Gly Gln Val Lys Ala Ser Leu Leu Pro Gly Gly Ser Glu Gly Gly Arg
 195 200 205
 Arg Arg Arg Glu Leu Asp Pro Met Asp Val Arg Gly Ser Ile Val Tyr
 210 215 220
 Leu Glu Ile Asp Asn Arg Gln Cys Val Gln Ala Ser Ser Gln Cys Phe
 225 230 235 240
 Gln Ser Ala Thr Asp Val Ala Ala Phe Leu Gly Ala Leu Ala Ser Leu
 245 250 255
 Gly Ser Leu Asn Ile Pro Tyr Lys Ile Glu Ala Val Gln Ser Glu Thr
 260 265 270
 Val Glu Pro Pro Pro Pro Ala Gln Leu His Phe Met Tyr Val Ala Ala
 275 280 285
 Ala Ala Phe Val Leu Leu Phe Phe Val Gly Cys Gly Val Leu Leu Ser
 290 295 300
 Arg Lys Arg Arg Arg Gln His Gly Gln Leu Trp Phe Pro Glu Gly Phe
 305 310 315 320
 Lys Val Ser Glu Ala Ser Lys Lys Lys Arg Arg Glu Pro Leu Gly Glu
 325 330 335
 Asp Ser Val Gly Leu Lys Pro Leu Lys Asn Ala Ser Asp Gly Ala Leu
 340 345 350
 Met Asp Asp Asn Gln Asn Glu Trp Gly Asp Glu Asp Leu Glu Thr Lys
 355 360 365
 Lys Phe Arg Phe Glu Glu Pro Val Val Leu Pro Asp Leu Asp Asp Gln
 370 375 380
 Thr Asp His Arg Gln Trp Thr Gln Gln His Leu Asp Ala Ala Asp Leu
 385 390 395 400
 Arg Met Ser Ala Met Ala Pro Thr Pro Pro Gln Gly Glu Val Asp Ala
 405 410 415
 Asp Cys Met Asp Val Asn Val Arg Gly Pro Asp Gly Phe Thr Pro Leu
 420 425 430
 Met Ile Ala Ser Cys Ser Gly Gly Gly Leu Glu Thr Gly Asn Ser Glu
 435 440 445
 Glu Glu Glu Asp Ala Pro Ala Val Ile Ser Asp Phe Ile Tyr Gln Gly
 450 455 460
 Ala Ser Leu His Asn Gln Thr Asp Arg Thr Gly Glu Thr Ala Leu His
 465 470 475 480
 Leu Ala Ala Arg Tyr Ser Arg Ser Asp Ala Ala Lys Arg Leu Leu Glu
 485 490 495
 Ala Ser Ala Asp Ala Asn Ile Gln Asp Asn Met Gly Arg Thr Pro Leu
 500 505 510
 His Ala Ala Val Ser Ala Asp Ala Gln Gly Val Phe Gln Ile Leu Ile
 515 520 525
 Arg Asn Arg Ala Thr Asp Leu Asp Ala Arg Met His Asp Gly Thr Thr
 530 535 540
 Pro Leu Ile Leu Ala Ala Arg Leu Ala Val Glu Gly Met Leu Glu Asp

545		550		555		560
Leu Ile Asn Ser His Ala Asp Val Asn Ala Val Asp Asp Leu Gly Lys						
		565		570		575
Ser Ala Leu His Trp Ala Ala Ala Val Asn Asn Val Asp Ala Ala Val						
		580		585		590
Val Leu Leu Lys Asn Gly Ala Asn Lys Asp Met Gln Asn Asn Arg Glu						
		595		600		605
Glu Thr Pro Leu Phe Leu Ala Ala Arg Glu Gly Ser Tyr Glu Thr Ala						
		610		615		620
Lys Val Leu Leu Asp His Phe Ala Asn Arg Asp Ile Thr Asp His Met						
		625		630		640
Asp Arg Leu Pro Arg Asp Ile Ala Gln Glu Arg Met His His Asp Ile						
		645		650		655
Val Arg Leu Leu Asp Glu Tyr Asn Leu Val Arg Ser Pro Gln Leu His						
		660		665		670
Gly Ala Pro Leu Gly Gly Thr Pro Thr Leu Ser Pro Pro Leu Cys Ser						
		675		680		685
Pro Asn Gly Tyr Leu Gly Ser Leu Lys Pro Gly Val Gln Gly Lys Lys						
		690		695		700
Val Arg Lys Pro Ser Ser Lys Gly Leu Ala Cys Gly Ser Lys Glu Ala						
		705		710		715
Lys Asp Leu Lys Ala Arg Arg Lys Lys Ser Gln Asp Gly Lys Gly Cys						
		725		730		735
Leu Leu Asp Ser Ser Gly Met Leu Ser Pro Val Asp Ser Leu Glu Ser						
		740		745		750
Pro His Gly Tyr Leu Ser Asp Val Ala Ser Pro Pro Leu Leu Pro Ser						
		755		760		765
Pro Phe Gln Gln Ser Pro Ser Val Pro Leu Asn His Leu Pro Gly Met						
		770		775		780
Pro Asp Thr His Leu Gly Ile Gly His Leu Asn Val Ala Ala Lys Pro						
		785		790		795
Glu Met Ala Ala Leu Gly Gly Gly Gly Arg Leu Ala Phe Glu Thr Gly						
		805		810		815
Pro Pro Arg Leu Ser His Leu Pro Val Ala Ser Gly Thr Ser Thr Val						
		820		825		830
Leu Gly Ser Ser Ser Gly Gly Ala Leu Asn Phe Thr Val Gly Gly Ser						
		835		840		845
Thr Ser Leu Asn Gly Gln Cys Glu Trp Leu Ser Arg Leu Gln Ser Gly						
		850		855		860
Met Val Pro Asn Gln Tyr Asn Pro Leu Arg Gly Ser Val Ala Pro Gly						
		865		870		875
Pro Leu Ser Thr Gln Ala Pro Ser Leu Gln His Gly Met Val Gly Pro						
		885		890		895
Leu His Ser Ser Leu Ala Ala Ser Ala Leu Ser Gln Met Met Ser Tyr						
		900		905		910
Gln Gly Leu Pro Ser Thr Arg Leu Ala Thr Gln Pro His Leu Val Gln						
		915		920		925

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Thr Gln Gln Val Gln Pro Gln Asn Leu Gln Met Gln Gln Gln Asn Leu
 930 935 940
 Gln Pro Ala Asn Ile Gln Gln Gln Gln Ser Leu Gln Pro Pro Pro Pro
 945 950 955 960
 Pro Pro Gln Pro His Leu Gly Val Ser Ser Ala Ala Ser Gly His Leu
 965 970 975
 Gly Arg Ser Phe Leu Ser Gly Glu Pro Ser Gln Ala Asp Val Gln Pro
 980 985 990
 Leu Gly Pro Ser Ser Leu Ala Val His Thr Ile Leu Pro Gln Glu Ser
 995 1000 1005
 Pro Ala Leu Pro Thr Ser Leu Pro Ser Ser Leu Val Pro Pro Val Thr
 1010 1015 1020
 Ala Ala Gln Phe Leu Thr Pro Pro Ser Gln His Ser Tyr Ser Ser Pro
 1025 1030 1035 1040
 Val Asp Asn Thr Pro Ser His Gln Leu Gln Val Pro Val Pro Val Met
 1045 1050 1055
 Val Met Ile Arg Ser Ser Asp Pro Ser Lys Gly Ser Ser Ile Leu Ile
 1060 1065 1070
 Glu Ala Pro Asp Ser Trp
 1075

(2) INFORMATION FOR SEQ ID NO:33:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 4268 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 2..1972

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:33:

G GAG GTG GAT GTG TTA GAT GTG AAT GTC CGT GGC CCA GAT GGC TGC	46
Glu Val Asp Val Leu Asp Val Asn Val Arg Gly Pro Asp Gly Cys	
1 5 10 15	
ACC CCA TTG ATG TTG GCT TCT CTC CGA GGA GGC AGC TCA GAT TTG AGT	94
Thr Pro Leu Met Leu Ala Ser Leu Arg Gly Gly Ser Ser Asp Leu Ser	
20 25 30	
GAT GAA GAT GAA GAT GCA GAG GAC TCT TCT GCT AAC ATC ATC ACA GAC	142
Asp Glu Asp Glu Asp Ala Glu Asp Ser Ser Ala Asn Ile Ile Thr Asp	
35 40 45	
TTG GTC TAC CAG GGT GCC AGC CTC CAG GCC CAG ACA GAC CGG ACT GGT	190
Leu Val Tyr Gln Gly Ala Ser Leu Gln Ala Gln Thr Asp Arg Thr Gly	
50 55 60	
GAG ATG GCC CTG CAC CTT GCA GCC CGC TAC TCA CGG GCT GAT GCT GCC	238
Glu Met Ala Leu His Leu Ala Ala Arg Tyr Ser Arg Ala Asp Ala Ala	
65 70 75	
AAG CGT CTC CTG GAT GCA GGT GCA GAT GCC AAT GCC CAG GAC AAC ATG	286
Lys Arg Leu Leu Asp Ala Gly Ala Asp Ala Asn Ala Gln Asp Asn Met	

80	85	90	95	
GGC CGC TGT CCA CTC CAT GCT GCA GTG GCA GCT GAT GCC CAA GGT GTC Gly Arg Cys Pro Leu His Ala Ala Val Ala Ala Asp Ala Gln Gly Val 100 105 110				334
TTC CAG ATT CTG ATT CGC AAC CGA GTA ACT GAT CTA GAT GCC AGG ATG Phe Gln Ile Leu Ile Arg Asn Arg Val Thr Asp Leu Asp Ala Arg Met 115 120 125				382
AAT GAT GGT ACT ACA CCC CTG ATC CTG GCT GCC CGC CTG GCT GTG GAG Asn Asp Gly Thr Thr Pro Leu Ile Leu Ala Ala Arg Leu Ala Val Glu 130 135 140				430
GGA ATG GTG GCA GAA CTG ATC AAC TGC CAA GCG GAT GTG AAT GCA GTG Gly Met Val Ala Glu Leu Ile Asn Cys Gln Ala Asp Val Asn Ala Val 145 150 155				478
GAT GAC CAT GGA AAA TCT GCT CTT CAC TGG GCA GCT GCT GTC AAT AAT Asp Asp His Gly Lys Ser Ala Leu His Trp Ala Ala Ala Val Asn Asn 160 165 170 175				526
GTG GAG GCA ACT CTT TTG TTG TTG AAA AAT GGG GCC AAC CGA GAC ATG Val Glu Ala Thr Leu Leu Leu Lys Asn Gly Ala Asn Arg Asp Met 180 185 190				574
CAG GAC AAC AAG GAA GAG ACA CCT CTG TTT CTT GCT GCC CGG GAG GGG Gln Asp Asn Lys Glu Glu Thr Pro Leu Phe Leu Ala Ala Arg Glu Gly 195 200 205				622
AGC TAT GAA GCA GCC AAG ATC CTG TTA GAC CAT TTT GCC AAT CGA GAC Ser Tyr Glu Ala Ala Lys Ile Leu Leu Asp His Phe Ala Asn Arg Asp 210 215 220				670
ATC ACA GAC CAT ATG GAT CGT CTT CCC CGG GAT GTG GCT CGG GAT CGC Ile Thr Asp His Met Asp Arg Leu Pro Arg Asp Val Ala Arg Asp Arg 225 230 235				718
ATG CAC CAT GAC ATT GTG CGC CTT CTG GAT GAA TAC AAT GTG ACC CCA Met His His Asp Ile Val Arg Leu Leu Asp Glu Tyr Asn Val Thr Pro 240 245 250 255				766
AGC CCT CCA GGC ACC GTG TTG ACT TCT GCT CTC TCA CCT GTC ATC TGT Ser Pro Pro Gly Thr Val Leu Thr Ser Ala Leu Ser Pro Val Ile Cys 260 265 270				814
GGG CCC AAC AGA TCT TTC CTC AGC CTG AAG CAC ACC CCA ATG GGC AAG Gly Pro Asn Arg Ser Phe Leu Ser Leu Lys His Thr Pro Met Gly Lys 275 280 285				862
AAG TCT AGA CGG CCC AGT GCC AAG AGT ACC ATG CCT ACT AGC CTC CCT Lys Ser Arg Arg Pro Ser Ala Lys Ser Thr Met Pro Thr Ser Leu Pro 290 295 300				910
AAC CTT GCC AAG GAG GCA AAG GAT GCC AAG GGT AGT AGG AGG AAG AAG Asn Leu Ala Lys Glu Ala Lys Asp Ala Lys Gly Ser Arg Arg Lys Lys 305 310 315				958
TCT CTG AGT GAG AAG GTC CAA CTG TCT GAG AGT TCA GTA ACT TTA TCC Ser Leu Ser Glu Lys Val Gln Leu Ser Glu Ser Ser Val Thr Leu Ser 320 325 330 335				1006
CCT GTT GAT TCC CTA GAA TCT CCT CAC ACG TAT GTT TCC GAC ACC ACA Pro Val Asp Ser Leu Glu Ser Pro His Thr Tyr Val Ser Asp Thr Thr 340 345 350				1054
TCC TCT CCA ATG ATT ACA TCC CCT GGG ATC TTA CAG GCC TCA CCC AAC Ser Ser Pro Met Ile Thr Ser Pro Gly Ile Leu Gln Ala Ser Pro Asn 355 360 365				1102

CCT	ATG	TTG	GCC	ACT	GCC	GCC	CCT	CCT	GCC	CCA	GTC	CAT	GCC	CAG	CAT	1150
Pro	Met	Leu	Ala	Thr	Ala	Ala	Pro	Pro	Ala	Pro	Val	His	Ala	Gln	His	
		370					375					380				
GCA	CTA	TCT	TTT	TCT	AAC	CTT	CAT	GAA	ATG	CAG	CCT	TTG	GCA	CAT	GGG	1198
Ala	Leu	Ser	Phe	Ser	Asn	Leu	His	Glu	Met	Gln	Pro	Leu	Ala	His	Gly	
	385					390					395					
GCC	AGC	ACT	GTG	CTT	CCC	TCA	GTG	AGC	CAG	TTG	CTA	TCC	CAC	CAC	CAC	1246
Ala	Ser	Thr	Val	Leu	Pro	Ser	Val	Ser	Gln	Leu	Leu	Ser	His	His	His	
400					405					410					415	
ATT	GTG	TCT	CCA	GGC	AGT	GGC	AGT	GCT	GGA	AGC	TTG	AGT	AGG	CTC	CAT	1294
Ile	Val	Ser	Pro	Gly	Ser	Gly	Ser	Ala	Gly	Ser	Leu	Ser	Arg	Leu	His	
				420					425					430		
CCA	GTC	CCA	GTC	CCA	GCA	GAT	TGG	ATG	AAC	CGC	ATG	GAG	GTG	AAT	GAG	1342
Pro	Val	Pro	Val	Pro	Ala	Asp	Trp	Met	Asn	Arg	Met	Glu	Val	Asn	Glu	
			435				440						445			
ACC	CAG	TAC	AAT	GAG	ATG	TTT	GGT	ATG	GTC	CTG	GCT	CCA	GCT	GAG	GGC	1390
Thr	Gln	Tyr	Asn	Glu	Met	Phe	Gly	Met	Val	Leu	Ala	Pro	Ala	Glu	Gly	
	450						455					460				
ACC	CAT	CCT	GGC	ATA	GCT	CCC	CAG	AGC	AGG	CCA	CCT	GAA	GGG	AAG	CAC	1438
Thr	His	Pro	Gly	Ile	Ala	Pro	Gln	Ser	Arg	Pro	Pro	Glu	Gly	Lys	His	
	465					470					475					
ATA	ACC	ACC	CCT	CGG	GAG	CCC	TTG	CCC	CCC	ATT	GTG	ACT	TTC	CAG	CTC	1486
Ile	Thr	Thr	Pro	Arg	Glu	Pro	Leu	Pro	Pro	Ile	Val	Thr	Phe	Gln	Leu	
480					485					490					495	
ATC	CCT	AAA	GGC	AGT	ATT	GCC	CAA	CCA	GCG	GGG	GCT	CCC	CAG	CCT	CAG	1534
Ile	Pro	Lys	Gly	Ser	Ile	Ala	Gln	Pro	Ala	Gly	Ala	Pro	Gln	Pro	Gln	
				500					505					510		
TCC	ACC	TGC	CCT	CCA	GCT	GTT	GCG	GGC	CCC	CTG	CCC	ACC	ATG	TAC	CAG	1582
Ser	Thr	Cys	Pro	Pro	Ala	Val	Ala	Gly	Pro	Leu	Pro	Thr	Met	Tyr	Gln	
			515					520					525			
ATT	CCA	GAA	ATG	GCC	CGT	TTG	CCC	AGT	GTG	GCT	TTC	CCC	ACT	GCC	ATG	1630
Ile	Pro	Glu	Met	Ala	Arg	Leu	Pro	Ser	Val	Ala	Phe	Pro	Thr	Ala	Met	
	530					535						540				
ATG	CCC	CAG	CAG	GAC	GGG	CAG	GTA	GCT	CAG	ACC	ATT	CTC	CCA	GCC	TAT	1678
Met	Pro	Gln	Gln	Asp	Gly	Gln	Val	Ala	Gln	Thr	Ile	Leu	Pro	Ala	Tyr	
	545					550					555					
CAT	CCT	TTC	CCA	GCC	TCT	GTG	GGC	AAG	TAC	CCC	ACA	CCC	CCT	TCA	CAG	1726
His	Pro	Phe	Pro	Ala	Ser	Val	Gly	Lys	Tyr	Pro	Thr	Pro	Pro	Ser	Gln	
560					565					570					575	
CAC	AGT	TAT	GCT	TCC	TCA	AAT	GCT	GCT	GAG	CGA	ACA	CCC	AGT	CAC	AGT	1774
His	Ser	Tyr	Ala	Ser	Ser	Asn	Ala	Ala	Glu	Arg	Thr	Pro	Ser	His	Ser	
				580					585					590		
GGT	CAC	CTC	CAG	GGT	GAG	CAT	CCC	TAC	CTG	ACA	CCA	TCC	CCA	GAG	TCT	1822
Gly	His	Leu	Gln	Gly	Glu	His	Pro	Tyr	Leu	Thr	Pro	Ser	Pro	Glu	Ser	
			595				600						605			
CCT	GAC	CAG	TGG	TCA	AGT	TCA	TCA	CCC	CAC	TCT	GCT	TCT	GAC	TGG	TCA	1870
Pro	Asp	Gln	Trp	Ser	Ser	Ser	Ser	Pro	His	Ser	Ala	Ser	Asp	Trp	Ser	
		610					615					620				
GAT	GTG	ACC	ACC	AGC	CCT	ACC	CCT	GGG	GGT	GCT	GGA	GGA	GGT	CAG	CGG	1918
Asp	Val	Thr	Thr	Ser	Pro	Thr	Pro	Gly	Gly	Ala	Gly	Gly	Gly	Gln	Arg	
	625					630					635					
GGA	CCT	GGG	ACA	CAC	ATG	TCT	GAG	CCA	CCA	CAC	AAC	AAC	ATG	CAG	GTT	1966
Gly	Pro	Gly	Thr	His	Met	Ser	Glu	Pro	Pro	His	Asn	Asn	Met	Gln	Val	

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640	645	650	655	
TAT GCG TGAGAGAGTC CACCTCCAGT GTAGAGACAT AACTGACTTT TGTAATGCT				2022
Tyr Ala				
GCTGAGGAAC AAATGAAGGT CATCCGGGAG AGAAATGAAG AAATCTCTGG AGCCAGCTTC				2082
TAGAGGTAGG AAAGAGAAGA TGTTCTTATT CAGATAATGC AAGAGAAGCA ATTCGTCAGT				2142
TTCAGTGGGT ATCTGCAAGG CTTATTGATT ATTCTAATCT AATAAGACAA GTTTGTGGAA				2202
ATGCAAGATG AATACAAGCC TTGGGTCCAT GTTACTCTC TTCTATTTGG AGAATAAGAT				2262
GGATGCTTAT TGAAGCCCAG ACATTCTTGC AGCTTGGA CTGATTTTAAG CCCTGCAGGC				2322
TTCTGCCATA TCCATGAGAA GATTCTACAC TAGCGTCCTG TTGGGAATTA TGCCCTGGAA				2382
TTCTGCCTGA ATTGACCTAC GCATCTCCTC CTCCTTGGA CTGATTTTGT CTCATTGG				2442
TGCTTTTGGT TTTGCACCTC TCCGTGATTG TAGCCCTACC AGCATGTTAT AGGGCAAGAC				2502
CTTTGTGCTT TTGATCATTG TGGCCCATGA AAGCAACTTT GGTCTCCTTT CCCCTCCTGT				2562
CTTCCCGGTA TCCCTTGGA TCTCACAAGG TTTACTTTGG TATGGTTCTC AGCACAACC				2622
TTCAAGTAT GTTGTTTCTT TGGAAAATGG ACATACTGTA TTGTGTTCTC CTGCATATAT				2682
CATTCCTGGA GAGAGAAGGG GAGAAGAATA CTTTTCTTCA ACAAATTTTG GGGGCAGGAG				2742
ATCCCTTCAA GAGGCTGCAC CTTAATTTTT CTTGTCTGTG TGCAGGTCTT CATATAAACT				2802
TTACCAGGAA GAAGGGTGTG AGTTTGTGT TTTTCTGTGT ATGGGCCTGG TCAGTGTA				2862
GTTTTATCCT TGATAGTCTA GTTACTATGA CCCTCCCCAC TTTTTTAAA CCAGAAAAG				2922
GTTTGGAATG TTGGAATGAC CAAGAGACAA GTTAACCTCGT GCAAGAGCCA GTTACCCACC				2982
CACAGGTCCC CCTACTTCCT GCCAAGCATT CCATTGACTG CCTGTATGGA ACACATTGT				3042
CCCAGATCTG AGCATTCTAG GCCTGTTTCA CTCACTCACC CAGCATATGA AACTAGTCTT				3102
AACTGTTGAG CCTTTCCTTT CATATCCACA GAAGACACTG TCTCAAATGT TGTACCCTTG				3162
CCATTTAGGA CTGAACCTTC CTTAGCCCAA GGGACCCAGT GACAGTTGTC TTCCGTTTGT				3222
CAGATGATCA GTCTCTACTG ATTATCTTGC TGCTTAAAGG CCTGCTCACC AATCTTCTT				3282
TCACACCGTG TGGTCCGTGT TACTGGTATA CCCAGTATGT TCTCACTGAA GACATGGACT				3342
TTATATGTTT AAGTGCAGGA ATTGGAAAGT TGGACTTGTT TTCTATGATC CAAAACAGCC				3402
CTATAAGAAG GTTGGAAGAG GAGGAAGTAT ATAGCAGCCT TTGCTATTTT CTGCTACCAT				3462
TTCTTTTCCT CTGAAGCGGC CATGACATTC CCTTTGGCAA CTAACGTAGA AACTCAACAG				3522
AACATTTTCC TTTCTAGAG TCACCTTTTA GATGATAATG GACAACTATA GACTTGCTCA				3582
TTGTTTCAAG TGATTGCCCC TCACCTGAAT CCACTCTCTG TATTCATGCT CTTGGCAATT				3642
TCTTTGACTT TCTTTTAAGG GCAGAAGCAT TTTAGTTAAT TGTAAGATAA GAATAGTTTT				3702
CTTCTCTTC TCCTTGGGCC AGTTAATAAT TGGTCCATGG CTACACTGCA ACTCCGTCC				3762
AGTGCTGTGA TGCCCATGAC ACCTGCAAAA TAAGTTCTGC CTGGGCATTT TGTAAGATAT				3822
AACAGGTGAA TTCCCGACTC TTTTGGTTTG AATGACAGTT CTCATTCCTT CTATGGCTGC				3882
AAGTATGCAT CAGTGCTTCC CACTTACCTG ATTTGTCTGT CGGTGGCCCC ATATGGAAAC				3942

CCTGCGTGTC TGTTGGCATA ATAGTTTACA AATGGTTTTT TCAGTCCTAT CCAAATTTAT 4002
 TGAACCAACA AAAATAATTA CTTCTGCCCT GAGATAAGCA GATTAAGTTT GTTCATTCTC 4062
 TGCTTTATTC TCTCCATGTG GCAACATTCT GTCAGCCTCT TTCATAGTGT GCAAACATTT 4122
 TATCATTCTA AATGGTGACT CTCTGCCCTT GGACCCATTT ATTATTCACA GATGGGGAGA 4182
 ACCTATCTGC ATGGACCCTC ACCATCCTCT GTGCAGCACA CACAGTGCAG GGAGCCAGTG 4242
 GCGATGGCGA TGACTTTCTT CCCCTG 4268

(2) INFORMATION FOR SEQ ID NO:34:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 657 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:34:

Glu Val Asp Val Leu Asp Val Asn Val Arg Gly Pro Asp Gly Cys Thr
 1 5 10 15
 Pro Leu Met Leu Ala Ser Leu Arg Gly Gly Ser Ser Asp Leu Ser Asp
 20 25 30
 Glu Asp Glu Asp Ala Glu Asp Ser Ser Ala Asn Ile Ile Thr Asp Leu
 35 40 45
 Val Tyr Gln Gly Ala Ser Leu Gln Ala Gln Thr Asp Arg Thr Gly Glu
 50 55 60
 Met Ala Leu His Leu Ala Ala Arg Tyr Ser Arg Ala Asp Ala Ala Lys
 65 70 75 80
 Arg Leu Leu Asp Ala Gly Ala Asp Ala Asn Ala Gln Asp Asn Met Gly
 85 90 95
 Arg Cys Pro Leu His Ala Ala Val Ala Ala Asp Ala Gln Gly Val Phe
 100 105 110
 Gln Ile Leu Ile Arg Asn Arg Val Thr Asp Leu Asp Ala Arg Met Asn
 115 120 125
 Asp Gly Thr Thr Pro Leu Ile Leu Ala Ala Arg Leu Ala Val Glu Gly
 130 135 140
 Met Val Ala Glu Leu Ile Asn Cys Gln Ala Asp Val Asn Ala Val Asp
 145 150 155 160
 Asp His Gly Lys Ser Ala Leu His Trp Ala Ala Ala Val Asn Asn Val
 165 170 175
 Glu Ala Thr Leu Leu Leu Leu Lys Asn Gly Ala Asn Arg Asp Met Gln
 180 185 190
 Asp Asn Lys Glu Glu Thr Pro Leu Phe Leu Ala Ala Arg Glu Gly Ser
 195 200 205
 Tyr Glu Ala Ala Lys Ile Leu Leu Asp His Phe Ala Asn Arg Asp Ile
 210 215 220
 Thr Asp His Met Asp Arg Leu Pro Arg Asp Val Ala Arg Asp Arg Met
 225 230 235 240
 His His Asp Ile Val Arg Leu Leu Asp Glu Tyr Asn Val Thr Pro Ser

255

Asp Gln Trp Ser Ser Ser Ser Pro His Ser Ala Ser Asp Trp Ser Asp
610 615 620

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Val Thr Thr Ser Pro Thr Pro Gly Gly Ala Gly Gly Gly Gln Arg Gly
625 630 635 640

Pro Gly Thr His Met Ser Glu Pro Pro His Asn Asn Met Gln Val Tyr
645 650 655

Ala

(2) INFORMATION FOR SEQ ID NO:35:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 654 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS: single

(D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:35:

Thr Pro Pro Gln Gly Glu Ile Glu Ala Asp Cys Met Asp Val Asn Val
1 5 10 15

Arg Gly Pro Asp Gly Phe Thr Pro Leu Met Ile Ala Ser Cys Ser Gly
20 25 30

Gly Gly Leu Glu Thr Gly Asn Ser Glu Glu Glu Glu Asp Ala Ser Ala
35 40 45

Asn Met Ile Ser Asp Phe Ile Gly Gln Gly Ala Gln Leu His Asn Gln
50 55 60

Thr Asp Arg Thr Gly Glu Thr Ala Leu His Leu Ala Ala Arg Tyr Ala
65 70 75 80

Arg Ala Asp Ala Ala Lys Arg Leu Leu Glu Ser Ser Ala Asp Ala Asn
85 90 95

Val Gln Asp Asn Met Gly Arg Thr Pro Leu His Ala Ala Val Ala Ala
100 105 110

Asp Ala Gln Gly Val Phe Gln Ile Leu Ile Arg Asn Arg Ala Thr Asp
115 120 125

Leu Asp Ala Arg Met Phe Asp Gly Thr Thr Pro Leu Ile Leu Ala Ala
130 135 140

Arg Leu Ala Val Glu Gly Met Val Glu Glu Leu Ile Asn Ala His Ala
145 150 155 160

Asp Val Asn Ala Val Asp Glu Phe Gly Lys Ser Ala Leu His Trp Ala
165 170 175

Ala Ala Val Asn Asn Val Asp Ala Ala Ala Val Leu Leu Lys Asn Ser
180 185 190

Ala Asn Lys Asp Met Gln Asn Asn Lys Glu Glu Thr Ser Leu Phe Leu
195 200 205

Ala Ala Arg Glu Gly Ser Tyr Glu Thr Ala Lys Val Leu Leu Asp His
210 215 220

Tyr Ala Asn Arg Asp Ile Thr Asp His Met Asp Arg Leu Pro Arg Asp
225 230 235 240

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Ile Ala Gln Glu Arg Met His His Asp Ile Val His Leu Leu Asp Glu
 245 250 255
 Tyr Asn Leu Val Lys Ser Pro Thr Leu His Asn Gly Pro Leu Gly Ala
 260 265 270
 Thr Thr Leu Ser Pro Pro Ile Cys Ser Pro Asn Gly Tyr Met Gly Asn
 275 280 285
 Met Lys Pro Ser Val Gln Ser Lys Lys Ala Arg Lys Pro Ser Ile Lys
 290 295 300
 Gly Asn Gly Cys Lys Glu Ala Lys Glu Leu Lys Ala Arg Arg Lys Lys
 305 310 315 320
 Ser Gln Asp Gly Lys Thr Thr Leu Leu Asp Ser Gly Ser Ser Gly Val
 325 330 335
 Leu Ser Pro Val Asp Ser Leu Glu Ser Thr His Gly Tyr Leu Ser Asp
 340 345 350
 Val Ser Ser Pro Pro Leu Met Thr Ser Pro Phe Gln Gln Ser Pro Ser
 355 360 365
 Met Pro Leu Asn His Leu Thr Ser Met Pro Glu Ser Gln Leu Gly Met
 370 375 380
 Asn His Ile Asn Met Ala Thr Lys Gln Glu Met Ala Ala Gly Ser Asn
 385 390 395 400
 Arg Met Ala Phe Asp Ala Met Val Pro Arg Leu Thr His Leu Asn Ala
 405 410 415
 Ser Ser Pro Asn Thr Ile Met Ser Asn Gly Ser Met His Phe Thr Val
 420 425 430
 Gly Gly Ala Pro Thr Met Asn Ser Gln Cys Asp Trp Leu Ala Arg Leu
 435 440 445
 Gln Asn Gly Met Val Gln Asn Gln Tyr Asp Pro Ile Arg Asn Gly Ile
 450 455 460
 Gln Gln Gly Asn Ala Gln Gln Ala Gln Ala Leu Gln His Gly Leu Met
 465 470 475 480
 Thr Ser Leu His Asn Gly Leu Pro Ala Thr Thr Leu Ser Gln Met Met
 485 490 495
 Thr Tyr Gln Ala Met Pro Asn Thr Arg Leu Ala Asn Gln Pro His Leu
 500 505 510
 Met Gln Ala Gln Gln Met Gln Gln Gln Gln Asn Leu Gln Leu His Gln
 515 520 525
 Ser Met Gln Gln Gln His His Asn Ser Ser Thr Thr Ser Thr His Ile
 530 535 540
 Asn Ser Pro Phe Cys Ser Ser Asp Ile Ser Gln Thr Asp Leu Gln Gln
 545 550 555 560
 Met Ser Ser Asn Asn Ile His Ser Val Met Pro Gln Asp Thr Gln Ile
 565 570 575
 Phe Ala Ala Ser Leu Pro Ser Asn Leu Thr Gln Ser Met Thr Thr Ala
 580 585 590
 Gln Phe Leu Thr Pro Pro Ser Gln His Ser Tyr Ser Ser Pro Met Asp
 595 600 605
 Asn Thr Pro Ser His Gln Leu Gln Val Pro Asp His Pro Phe Leu Thr

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610	615	620
Pro Ser Pro Glu Ser Pro Asp Gln Trp Ser Ser Ser Ser Pro His Ser		
625	630	635 640
Asn Met Ser Asp Trp Ser Glu Gly Ile Ser Ser Pro Pro Thr		
645	650	

(2) INFORMATION FOR SEQ ID NO:36:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 666 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:36:

Thr	Pro	Pro	Gln	Gly	Glu	Val	Asp	Ala	Asp	Cys	Met	Asp	Val	Asn	Val
1				5					10					15	
Arg	Gly	Pro	Asp	Gly	Phe	Thr	Pro	Leu	Met	Ile	Ala	Ser	Cys	Ser	Gly
			20					25					30		
Gly	Gly	Leu	Glu	Thr	Gly	Asn	Ser	Glu	Glu	Glu	Glu	Asp	Ala	Pro	Ala
		35					40					45			
Val	Ile	Ser	Asp	Phe	Ile	Tyr	Gln	Gly	Ala	Ser	Leu	His	Asn	Gln	Thr
	50					55					60				
Asp	Arg	Thr	Gly	Glu	Thr	Ala	Leu	His	Leu	Ala	Ala	Arg	Tyr	Ser	Arg
65					70					75					80
Ser	Asp	Ala	Ala	Lys	Arg	Leu	Leu	Glu	Ala	Ser	Ala	Asp	Ala	Asn	Ile
				85					90					95	
Gln	Asp	Asn	Met	Gly	Arg	Thr	Pro	Leu	His	Ala	Ala	Val	Ser	Ala	Asp
			100					105					110		
Ala	Gln	Gly	Val	Phe	Gln	Ile	Leu	Leu	Arg	Asn	Arg	Ala	Thr	Asp	Leu
		115					120					125			
Asp	Ala	Arg	Met	His	Asp	Gly	Thr	Thr	Pro	Leu	Ile	Leu	Ala	Ala	Arg
	130					135					140				
Leu	Ala	Val	Glu	Gly	Met	Leu	Glu	Asp	Leu	Ile	Asn	Ser	His	Ala	Asp
145					150					155					160
Val	Asn	Ala	Val	Asp	Asp	Leu	Gly	Lys	Ser	Ala	Leu	His	Trp	Ala	Ala
				165					170					175	
Ala	Val	Asn	Asn	Val	Asp	Ala	Ala	Val	Val	Leu	Leu	Lys	Asn	Gly	Ala
			180					185					190		
Asn	Lys	Asp	Met	Gln	Asn	Asn	Lys	Glu	Glu	Thr	Pro	Leu	Phe	Leu	Ala
		195					200					205			
Ala	Arg	Glu	Gly	Ser	Tyr	Glu	Thr	Ala	Lys	Val	Leu	Leu	Asp	His	Phe
	210					215					220				
Ala	Asn	Arg	Asp	Ile	Thr	Asp	His	Met	Asp	Arg	Leu	Pro	Arg	Asp	Ile
225					230				235						240
Ala	Gln	Glu	Arg	Met	His	His	Asp	Ile	Val	Arg	Leu	Leu	Asp	Glu	Tyr
			245						250					255	

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Asn Leu Val Arg Ser Pro Gln Leu His Gly Thr Ala Leu Gly Gly Thr
 260 265 270
 Pro Thr Leu Ser Pro Thr Leu Cys Ser Pro Asn Gly Tyr Leu Gly Asn
 275 280 285
 Leu Lys Ser Ala Thr Gln Gly Lys Lys Ala Arg Lys Pro Ser Thr Lys
 290 295 300
 Gly Leu Ala Cys Ser Ser Lys Glu Ala Lys Asp Leu Lys Ala Arg Arg
 305 310 315 320
 Lys Lys Ser Gln Asp Gly Lys Gly Cys Leu Leu Asp Ser Ser Ser Met
 325 330 335
 Leu Ser Pro Val Asp Ser Leu Glu Ser Pro His Gly Tyr Leu Ser Asp
 340 345 350
 Val Ala Ser Pro Pro Leu Pro Ser Pro Phe Gln Gln Ser Pro Ser Met
 355 360 365
 Pro Leu Ser His Leu Pro Gly Met Pro Asp Thr His Leu Gly Ile Ser
 370 375 380
 His Leu Asn Val Ala Ala Lys Pro Glu Met Ala Ala Leu Ala Gly Gly
 385 390 395 400
 Ser Arg Leu Ala Phe Glu Pro Pro Pro Pro Arg Leu Ser His Leu Pro
 405 410 415
 Val Ala Ser Ser Ala Ser Thr Val Leu Ser Thr Asn Gly Thr Gly Ala
 420 425 430
 Met Asn Phe Thr Val Gly Ala Pro Ala Ser Leu Asn Gly Gln Cys Glu
 435 440 445
 Trp Leu Pro Arg Leu Gln Asn Gly Met Val Pro Ser Gln Tyr Asn Pro
 450 455 460
 Leu Arg Pro Gly Val Thr Pro Gly Thr Leu Ser Thr Gln Ala Ala Gly
 465 470 475 480
 Leu Gln His Gly Met Met Ser Pro Ile His Ser Ser Leu Ser Thr Asn
 485 490 495
 Thr Leu Ser Pro Ile Ile Tyr Gln Gly Leu Pro Asn Thr Arg Leu Ala
 500 505 510
 Thr Gln Pro His Leu Val Gln Thr Gln Gln Val Gln Pro Gln Asn Leu
 515 520 525
 Gln Ile Gln Pro Gln Asn Leu Gln Pro Pro Ser Gln Pro His Leu Ser
 530 535 540
 Val Ser Ser Ala Ala Asn Gly His Leu Gly Arg Ser Phe Leu Ser Gly
 545 550 555 560
 Glu Pro Ser Gln Ala Asp Val Gln Pro Leu Gly Pro Ser Ser Leu Pro
 565 570 575
 Val His Thr Ile Leu Pro Gln Glu Ser Gln Ala Leu Pro Thr Ser Leu
 580 585 590
 Pro Ser Ser Met Val Pro Pro Met Thr Thr Thr Gln Phe Leu Thr Pro
 595 600 605
 Pro Ser Gln His Ser Tyr Ser Ser Ser Pro Val Asp Asn Thr Pro Ser
 610 615 620
 His Gln Leu Gln Val Pro Glu His Pro Phe Leu Thr Pro Ser Pro Glu

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625		630		635		640									
Ser	Pro	Asp	Gln	Trp	Ser	Ser	Ser	Ser	Arg	His	Ser	Asn	Ile	Ser	Asp
				645					650					655	
Trp	Ser	Glu	Gly	Ile	Ser	Ser	Pro	Pro	Thr						
			660						665						

(2) INFORMATION FOR SEQ ID NO:37:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 681 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:37:

Thr	Pro	Pro	Gln	Gly	Glu	Val	Asp	Ala	Asp	Cys	Met	Asp	Val	Asn	Val
1				5					10					15	
Arg	Gly	Pro	Asp	Gly	Phe	Thr	Pro	Leu	Met	Ile	Ala	Ser	Cys	Ser	Gly
			20					25					30		
Gly	Gly	Leu	Glu	Thr	Gly	Asn	Ser	Glu	Glu	Glu	Glu	Asp	Ala	Pro	Ala
		35					40					45			
Val	Ile	Ser	Asp	Phe	Ile	Tyr	Gln	Gly	Ala	Ser	Leu	His	Asn	Gln	Thr
	50					55					60				
Asp	Arg	Thr	Gly	Glu	Thr	Ala	Leu	His	Leu	Ala	Ala	Arg	Tyr	Ser	Arg
65					70					75				80	
Ser	Asp	Ala	Ala	Lys	Arg	Leu	Leu	Glu	Ala	Ser	Ala	Asp	Ala	Asn	Ile
				85					90					95	
Gln	Asp	Asn	Met	Gly	Arg	Thr	Pro	Leu	His	Ala	Ala	Val	Ser	Ala	Asp
			100					105					110		
Ala	Gln	Gly	Val	Phe	Gln	Ile	Leu	Ile	Arg	Asn	Arg	Ala	Thr	Asp	Leu
		115					120					125			
Asp	Ala	Arg	Met	His	Asp	Gly	Thr	Thr	Pro	Leu	Ile	Leu	Ala	Ala	Arg
	130					135					140				
Leu	Ala	Val	Glu	Gly	Met	Leu	Glu	Asp	Leu	Ile	Asn	Ser	His	Ala	Asp
145					150					155					160
Val	Asn	Ala	Val	Asp	Asp	Leu	Gly	Lys	Ser	Ala	Leu	His	Trp	Ala	Ala
				165					170					175	
Ala	Val	Asn	Asn	Val	Asp	Ala	Ala	Val	Val	Leu	Leu	Lys	Asn	Gly	Ala
			180					185					190		
Asn	Lys	Asp	Met	Gln	Asn	Asn	Arg	Glu	Glu	Thr	Pro	Leu	Phe	Leu	Ala
		195					200					205			
Ala	Arg	Glu	Gly	Ser	Tyr	Glu	Thr	Ala	Lys	Val	Leu	Leu	Asp	His	Phe
	210					215					220				
Ala	Asn	Arg	Asp	Ile	Thr	Asp	His	Met	Asp	Arg	Leu	Pro	Arg	Asp	Ile
225					230					235					240
Ala	Gln	Glu	Arg	Met	His	His	Asp	Ile	Val	Arg	Leu	Leu	Asp	Glu	Tyr
			245						250					255	

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Asn	Leu	Val	Arg	Ser	Pro	Gln	Leu	His	Gly	Ala	Pro	Leu	Gly	Gly	Thr
			260					265					270		
Pro	Thr	Leu	Ser	Pro	Pro	Leu	Cys	Ser	Pro	Asn	Gly	Tyr	Leu	Gly	Ser
		275					280					285			
Leu	Lys	Pro	Gly	Val	Gln	Gly	Lys	Lys	Val	Arg	Lys	Pro	Ser	Ser	Lys
	290					295					300				
Gly	Leu	Ala	Cys	Gly	Ser	Lys	Glu	Ala	Lys	Asp	Leu	Lys	Ala	Arg	Arg
305					310					315					320
Lys	Lys	Ser	Gln	Asp	Gly	Lys	Gly	Cys	Leu	Leu	Asp	Ser	Ser	Gly	Met
				325					330					335	
Leu	Ser	Pro	Val	Asp	Ser	Leu	Glu	Ser	Pro	His	Gly	Tyr	Leu	Ser	Asp
			340					345					350		
Val	Ala	Ser	Pro	Pro	Leu	Leu	Pro	Ser	Pro	Phe	Gln	Gln	Ser	Pro	Ser
		355					360					365			
Val	Pro	Leu	Asn	His	Leu	Pro	Gly	Met	Pro	Asp	Thr	His	Leu	Gly	Ile
	370					375					380				
Gly	His	Leu	Asn	Val	Ala	Ala	Lys	Pro	Glu	Met	Ala	Ala	Leu	Gly	Gly
385					390					395					400
Gly	Gly	Arg	Leu	Ala	Phe	Glu	Thr	Gly	Pro	Pro	Arg	Leu	Ser	His	Leu
				405					410					415	
Pro	Val	Ala	Ser	Gly	Thr	Ser	Thr	Val	Leu	Gly	Ser	Ser	Ser	Gly	Gly
			420					425					430		
Ala	Leu	Asn	Phe	Thr	Val	Gly	Gly	Ser	Thr	Ser	Leu	Asn	Gly	Gln	Cys
		435					440					445			
Glu	Trp	Leu	Ser	Arg	Leu	Gln	Ser	Gly	Met	Val	Pro	Asn	Gln	Tyr	Asn
	450					455					460				
Pro	Leu	Arg	Gly	Ser	Val	Ala	Pro	Gly	Pro	Leu	Ser	Thr	Gln	Ala	Pro
465					470					475					480
Ser	Leu	Gln	His	Gly	Met	Val	Gly	Pro	Leu	His	Ser	Ser	Leu	Ala	Ala
				485					490					495	
Ser	Ala	Leu	Ser	Gln	Met	Met	Ser	Tyr	Gln	Gly	Leu	Pro	Ser	Thr	Arg
			500					505					510		
Leu	Ala	Thr	Gln	Pro	His	Leu	Val	Gln	Thr	Gln	Gln	Val	Gln	Pro	Gln
		515					520					525			
Asn	Leu	Gln	Met	Gln	Gln	Gln	Asn	Leu	Gln	Pro	Ala	Asn	Ile	Gln	Gln
	530					535					540				
Gln	Gln	Ser	Leu	Gln	Pro	Pro	Pro	Pro	Pro	Pro	Gln	Pro	His	Leu	Gly
545					550					555					560
Val	Ser	Ser	Ala	Ala	Ser	Gly	His	Leu	Gly	Arg	Ser	Phe	Leu	Ser	Gly
				565					570				575		
Glu	Pro	Ser	Gln	Ala	Asp	Val	Gln	Pro	Leu	Gly	Pro	Ser	Ser	Leu	Ala
			580					585					590		
Val	His	Thr	Ile	Leu	Pro	Gln	Glu	Ser	Pro	Ala	Leu	Pro	Thr	Ser	Leu
		595					600					605			
Pro	Ser	Ser	Leu	Val	Pro	Pro	Val	Thr	Ala	Ala	Gln	Phe	Leu	Thr	Pro
	610					615					620				
Pro	Ser	Gln	His	Ser	Tyr	Ser	Ser	Pro	Val	Glu	Asn	Thr	Pro	Ser	His

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625					630					635					640
Gln	Leu	Gln	Val	Pro	Glu	His	Pro	Phe	Leu	Thr	Pro	Ser	Pro	Glu	Ser
				645					650					655	
Pro	Asp	Gln	Trp	Ser	Ser	Ser	Ser	Pro	His	Ser	Asn	Val	Ser	Asp	Trp
			660					665					670		
Ser	Glu	Gly	Val	Ser	Ser	Pro	Pro	Thr							
		675					680								

WHAT IS CLAIMED IS:

1. A substantially purified human Notch protein.
2. A substantially purified protein comprising an amino acid sequence encoded by the DNA sequence depicted in Figure 19A (SEQ ID NO: 13), 19B (SEQ ID NO: 14) or 19C (SEQ ID NO: 15), which is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.
3. A substantially purified protein comprising an amino acid sequence encoded by the DNA sequence depicted in Figure 20A (SEQ ID NO: 16), 20B (SEQ ID NO: 17), 20C (SEQ ID NO: 18), or 20D (SEQ ID NO: 19), which is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.
4. A substantially purified protein comprising an amino acid sequence encoded by the DNA sequence depicted in Figure 21A (SEQ ID NO:20), or 21B (SEQ ID NO:21), which is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.
5. A substantially purified protein comprising an amino acid sequence encoded by the DNA sequence depicted in Figure 22A (SEQ ID NO:22), 22B (SEQ ID NO:23), 22C (SEQ ID NO:24), or 22D (SEQ ID NO:25), which is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.
6. A substantially purified protein comprising an amino acid sequence encoded by the DNA sequence depicted in Figure 19A (SEQ ID NO: 13), 19B (SEQ ID NO: 14), 19C (SEQ ID NO: 15), 20A (SEQ ID NO: 16), 20B (SEQ ID NO: 17), 20C (SEQ ID NO: 18), 20D

(SEQ ID NO: 19), 21 A (SEQ ID NO:20), 21 B (SEQ ID NO:21), 22A (SEQ ID NO:22), 22B (SEQ ID NO:23), 22C (SEQ ID NO:24), or 22D (SEQ ID NO:25), which is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.

7. A substantially purified protein comprising a Notch amino acid sequence encoded by the DNA sequence depicted in Figure 19A (SEQ ID NO: 13), 19B (SEQ ID NO: 14), 19C (SEQ ID NO: 15), 20A (SEQ ID NO: 16), 20B (SEQ ID NO: 17), 20C (SEQ ID NO: 18), 20D (SEQ ID NO: 19), 21 A (SEQ ID NO:20), 21 B (SEQ ID NO:21), 22A (SEQ ID NO:22), 22B (SEQ ID NO:23), 22C (SEQ ID NO:24), or 22D (SEQ ID NO:25), which displays one or more functional activities associated with a full-length Notch protein.

8. A substantially purified protein comprising: a fragment of a human Notch protein consisting of at least 77 amino acids.

9. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the extracellular domain of the protein.

10. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the intracellular domain of the protein.

11. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the extracellular and transmembrane domains of the protein.

12. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the intracellular domain of the protein, as encoded by a portion of

plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or as encoded by a portion of plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

13. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the region containing the cdcl0 repeats of the protein.

14. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the region containing the cdcl0 repeats, as encoded by a portion of plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or as encoded by a portion of plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

15. A substantially purified protein comprising a region of a human Notch protein containing the epidermal growth factor-like repeats of the protein.

16. A substantially purified protein comprising a region of a human Notch protein containing the Notch/lin-12 repeats of the protein.

17. A substantially purified fragment of a human Notch protein substantially lacking the epidermal growth factor-like repeats of the protein, which fragment is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.

18. A substantially purified fragment of a human Notch protein lacking a portion of the epidermal growth factor-like repeats of the protein, which fragment is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species.

19. A substantially purified protein comprising an amino acid sequence encoded by at least 121 nucleotides of the human cDNA sequence contained in plasmid hN3k as deposited with the ATCC and assigned accession number 68609.

20. A substantially purified protein comprising an amino acid sequence encoded by at least 121 nucleotides of the human cDNA sequence contained in plasmid hN4k as deposited with the ATCC and assigned accession number 68610.

21. A substantially purified protein comprising an amino acid sequence encoded by at least 121 nucleotides of the human cDNA sequence contained in plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

22. A substantially purified fragment of a human Notch protein consisting essentially of the intracellular domain of the protein.

23. A substantially purified fragment of a human Notch protein consisting essentially of the extracellular domain of the protein.

24. A substantially purified fragment of a human Notch protein consisting essentially of the extracellular and transmembrane domains of the protein.

25. A chimeric protein comprising the fragment of claim 8 joined to a heterologous protein sequence.

26. A chimeric protein comprising the fragment of claim 9 joined to a heterologous protein sequence.

27. A substantially purified protein comprising a functionally active portion of a human Notch protein.

28. A substantially purified protein comprising a functionally active portion of the Notch protein sequence encoded by the human cDNA sequence contained in plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or encoded by the human cDNA sequence contained in plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

29. A substantially purified protein comprising a functionally active portion of the Notch protein sequence encoded by the human cDNA sequence contained in plasmid hN4k as deposited with the ATCC and assigned accession number 68610.

30. A substantially purified protein comprising the amino acid sequence depicted in Figure 23.

31. A substantially purified protein comprising the amino acid sequence depicted in Figure 24.

32. A substantially purified protein comprising the Notch amino acid sequence encoded by the human Notch DNA sequence contained in plasmid hN3k as deposited with the ATCC and assigned accession number 68609.

33. A substantially purified protein comprising the Notch amino acid sequence encoded by the human Notch DNA sequence contained in plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

34. A fragment of the protein of claim 30 which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Delta protein expressed on the surface of a second cell.

35. A fragment of the protein of claim 31 which is characterized by the ability in vitro, when expressed on the

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surface of a first cell, to bind to a Delta protein expressed on the surface of a second cell.

36. A substantially purified protein comprising the portion of a human Notch protein with the greatest homology to the epidermal growth factor-like repeats 11 and 12 of the Drosophila Notch sequence as shown in Figure 8 (SEQ ID NO:1).

37. A substantially purified derivative of the protein of claim 1, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Delta protein expressed on the surface of a second cell, said derivative having an insertion, deletion or substitution relative to the fragment.

38. A chimeric protein comprising the protein of claim 1 joined to a heterologous protein sequence.

39. A chimeric protein comprising the protein of claim 6 joined to a heterologous protein sequence.

40. A chimeric protein comprising the protein of claim 7 joined to a heterologous protein sequence.

41. A substantially purified fragment of a Notch protein, which fragment is characterized by the ability in vitro, when expressed on the surface of a first cell to bind to a Delta protein expressed on the surface of a second cell, in which the fragment does not contain epidermal growth factor-like repeats 7-9.

42. A substantially purified fragment of a Notch protein, which fragment is characterized by the ability in vitro, when expressed on the surface of a first cell to bind to a Delta protein expressed on the surface of a second cell, in which the fragment does not contain epidermal growth factor-like repeats 17-26.

43. A substantially purified fragment of a Notch protein, which fragment is characterized by the ability in vitro, when expressed on the surface of a first cell to bind to a Delta protein expressed on the surface of a second cell, in which the fragment does not contain epidermal growth factor-like repeats 7-9 and 17-30.

44. A substantially purified fragment of a Notch protein, which fragment is characterized by the ability in vitro, when expressed on the surface of a first cell to bind to a Delta protein expressed on the surface of a second cell, in which the fragment does not contain epidermal growth factor-like repeats 1-10 and 13-36.

45. The fragment of claim 41, 42, 43 or 44 consisting essentially of the portion of the Notch protein with the greatest homology to the epidermal growth factor-like repeats 11 and 12 of the Drosophila Notch protein.

46. The fragment of claim 41, 42, 43 or 44 in which the Notch protein is a Drosophila Notch protein.

47. The fragment of claim 41, 42, 43 or 44 in which the Notch protein is a Xenopus Notch protein.

48. The fragment of claim 41, 42, 43 or 44 in which the Notch protein is a human Notch protein.

49. A chimeric protein comprising the fragment of claim 48 joined to a heterologous protein sequence.

50. A substantially purified fragment of a Drosophila Notch protein consisting essentially of the epidermal growth factor-like repeats 11 and 12 of the protein.

51. A chimeric protein comprising the fragment of claim 41, 42, 43, 44 or 47 joined to a heterologous protein sequence.

52. A substantially purified fragment of a Delta protein, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Notch protein expressed on the surface of a second cell.

53. The fragment of claim 52 which is the portion of the Delta protein with the greatest homology to amino acid numbers 1-230 as depicted in Figure 13 (SEQ ID NO:6).

54. A chimeric protein comprising the fragment of claim 52 joined to a heterologous protein sequence.

55. A substantially purified fragment of a Delta protein, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a second Delta protein or fragment expressed on the surface of a second cell.

56. The fragment of claim 55 which is the portion of the Delta protein with the greatest homology to about amino acid numbers 32-230 as depicted in Figure 13 (SEQ ID NO:6).

57. A chimeric protein comprising the fragment of claim 55 joined to a heterologous protein sequence.

58. A substantially purified fragment of a Serrate protein, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Notch protein expressed on the surface of a second cell.

59. A substantially purified fragment of a Serrate protein which is the portion of the Serrate protein with the greatest homology to the amino acid sequence as depicted in Figure 15 (SEQ ID NO:9) from about amino acid numbers 85-283.

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60. A chimeric protein comprising the fragment of claim 59 joined to a heterologous protein sequence.

61. A substantially purified derivative of the fragment of claim 41, 42, 43 or 44 which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Delta protein expressed on the surface of a second cell, said derivative having an insertion, deletion or substitution relative to the fragment.

62. A substantially purified derivative of the fragment of claim 52, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Notch protein expressed on the surface of a second cell, said derivative having an insertion, deletion or substitution relative to the fragment.

63. A substantially purified derivative of the fragment of claim 55, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a second Delta protein expressed on the surface of a second cell, said derivative having an insertion, deletion or substitution relative to the fragment.

64. A substantially purified derivative of the fragment of claim 58, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a second protein expressed on the surface of a second cell, which second protein is selected from the group consisting of a Notch protein, a Delta protein, and a second Serrate protein, said derivative having an insertion, deletion or substitution relative to the fragment.

65. A substantially purified fragment of a human Notch protein consisting of at least 40 amino acids.

66. A substantially purified nucleic acid encoding a human Notch protein.

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67. A substantially purified nucleic acid comprising a cDNA sequence encoding a human Notch protein.

68. A substantially purified nucleic acid comprising a human nucleotide sequence complementary to and capable of hybridizing to the cDNA sequence of claim 67.

69. A substantially purified cDNA sequence encoding a functionally active portion of a human Notch protein.

70. A substantially purified nucleic acid comprising a human nucleotide sequence complementary to and capable of hybridizing to the cDNA sequence of claim 69.

71. A substantially purified cDNA molecule comprising the DNA sequence depicted in Figure 19A (SEQ ID NO: 13), 19B (SEQ ID NO: 14), 19C (SEQ ID NO: 15), 20A (SEQ ID NO: 16), 20B (SEQ ID NO: 17), 20C (SEQ ID NO: 18), 20D (SEQ ID NO: 19), 21A (SEQ ID NO: 20), 21B (SEQ ID NO: 21), 22A (SEQ ID NO: 22), 22B (SEQ ID NO: 23), 22C (SEQ ID NO: 24), or 22D (SEQ ID NO: 25).

72. The nucleic acid of claim 66 in which the Notch protein comprises an amino acid sequence encoded by the DNA sequence depicted in Figure 19A (SEQ ID NO: 13), 19B (SEQ ID NO: 14), 19C (SEQ ID NO: 15), 20A (SEQ ID NO: 16), 20B (SEQ ID NO: 17), 20C (SEQ ID NO: 18), 20D (SEQ ID NO: 19), 21A (SEQ ID NO: 20), 21B (SEQ ID NO: 21), 22A (SEQ ID NO: 22), 22B (SEQ ID NO: 23), 22C (SEQ ID NO: 24), or 22D (SEQ ID NO: 25).

73. A substantially purified nucleic acid comprising a DNA sequence encoding at least a 77 amino acid portion of a human Notch protein, which portion has the greatest homology to the epidermal growth factor-like repeats 11 and 12 of the Drosophila Notch sequence as shown in Figure 8 (SEQ ID NO:1).

74. A substantially purified nucleic acid comprising the human Notch cDNA contained in plasmid hN4k, as deposited with the ATCC and assigned accession number 68610.

75. A substantially purified nucleic acid comprising the human Notch cDNA contained in plasmid hN3k, as deposited with the ATCC and assigned accession number 68609.

76. A substantially purified nucleic acid comprising the human Notch cDNA contained in plasmid hN5k, as deposited with the ATCC and assigned accession number 68611.

77. A substantially purified nucleic acid comprising the DNA coding sequence depicted in Figure 23.

78. A substantially purified nucleic acid comprising the DNA coding sequence depicted in Figure 24.

79. A substantially purified nucleic acid comprising a cDNA sequence encoding the extracellular domain of a human Notch protein.

80. A substantially purified nucleic acid comprising a cDNA sequence encoding the intracellular domain of a human Notch protein.

81. A substantially purified nucleic acid comprising a cDNA sequence encoding the extracellular and transmembrane domains of a human Notch protein.

82. A substantially purified nucleic acid comprising a cDNA sequence encoding the epidermal growth factor-like repeats of a human Notch protein.

83. A substantially purified nucleic acid comprising a cDNA sequence encoding the Notch/lin-12 repeats of a human Notch protein.

84. A substantially purified cDNA molecule encoding a fragment of a human Notch protein of at least 77 amino acids.

85. A substantially purified cDNA molecule encoding a fragment of a human Notch protein of at least 40 amino acids.

86. A substantially purified nucleic acid encoding the amino acid sequence depicted in Figure 23.

87. A substantially purified nucleic acid encoding the amino acid sequence depicted in Figure 24.

88. A substantially purified nucleic acid encoding the protein of claim 36.

89. A substantially purified nucleic acid encoding the fragment of claim 41, 42, 43, or 44.

90. A substantially purified nucleic acid encoding the fragment of claim 48.

91. A substantially purified nucleic acid encoding the fragment of claim 50.

92. A substantially purified nucleic acid encoding the fragment of claim 52.

93. A substantially purified nucleic acid encoding the fragment of claim 55.

94. A substantially purified nucleic acid encoding the fragment of claim 58.

95. A nucleic acid encoding the chimeric protein of claim 51.

96. A nucleic acid encoding the chimeric protein of claim 54.

97. A nucleic acid encoding the chimeric protein of claim 57.

98. A nucleic acid vector comprising the nucleic acid of claim 66.

99. A nucleic acid vector comprising the cDNA molecule of claim 69.

100. A nucleic acid vector comprising the nucleic acid of claim 88.

101. A nucleic acid vector comprising the nucleic acid of claim 89.

102. A nucleic acid vector comprising the nucleic acid of claim 90.

103. A nucleic acid vector comprising the nucleic acid of claim 91.

104. A nucleic acid vector comprising the nucleic acid of claim 92.

105. A nucleic acid vector comprising the nucleic acid of claim 94.

106. A recombinant cell containing the nucleic acid vector of claim 98.

107. A recombinant cell containing the nucleic acid vector of claim 99.

108. A recombinant cell containing the nucleic acid vector of claim 100.

109. A recombinant cell containing the nucleic acid vector of claim 101.

110. A recombinant cell containing the nucleic acid vector of claim 102.

111. A recombinant cell containing the nucleic acid vector of claim 103.

112. A recombinant cell containing the nucleic acid vector of claim 104.

113. A recombinant cell containing the nucleic acid vector of claim 105.

114. A method for producing a human Notch protein comprising growing the recombinant cell of claim 106, such that the human Notch protein is expressed by the cell; and isolating the expressed human Notch protein.

115. A method for producing a portion of a human Notch protein comprising growing the recombinant cell of claim 107, such that the portion of human Notch is expressed by the cell; and isolating the expressed human Notch portion.

116. A method for producing a protein comprising growing the recombinant cell of claim 108 such that the protein is expressed by the cell; and isolating the expressed protein.

117. A method for producing a fragment of a Notch protein comprising growing the recombinant cell of claim 109 such that the fragment is expressed by the cell; and isolating the expressed fragment of a Notch protein.

118. A method for producing a fragment of a human Notch protein comprising growing the recombinant cell of claim 110 such that the fragment is expressed by the cell; and isolating the expressed fragment of a human Notch protein.

119. A method for producing a fragment of a Drosophila Notch protein comprising growing the recombinant cell of claim 111 such that the fragment is expressed by the cell; and isolating the expressed fragment of a Drosophila Notch protein.

120. A method for producing a fragment of a Delta protein comprising growing the recombinant cell of claim 112 such that the fragment is expressed by the cell; and isolating the expressed fragment of a Delta protein.

121. A method for producing a fragment of a Serrate protein comprising growing the recombinant cell of claim 113 such that the fragment is expressed by the cell; and isolating the expressed fragment of a Serrate protein.

122. An antibody which binds to a human Notch protein and which does not bind to a Notch protein of another species.

123. An antibody which binds to the fragment of claim 41, 42, 43 or 44.

124. An antibody which binds to the fragment of claim 52.

125. An antibody which binds to the fragment of claim 55.

126. An antibody which binds to the fragment of claim 58.

127. A fragment or derivative of the antibody of claim 122 containing the idiotype of the antibody.

128. A fragment or derivative of the antibody of claim 123 containing the idiotype of the antibody.

129. An antibody which binds to the Notch protein sequence encoded by plasmid hN3k, as deposited with the ATCC and assigned accession number 68609, or to the Notch protein sequence encoded by plasmid hN5k, as deposited with the ATCC and assigned accession number 68611, and which does not bind to a Drosophila Notch protein.

130. A substantially purified nucleic acid which encodes a protein or peptide which comprises (a) a first amino acid sequence homologous to both a Serrate protein and a Delta

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protein; and (b) a second amino acid sequence which is not homologous to either a Serrate protein or a Delta protein.

131. A substantially purified fragment of a Notch protein, which is characterized by the ability in vitro, when expressed on the surface of a first cell, to bind to a Serrate protein expressed on the surface of a second cell.

132. A substantially purified fragment of a Serrate protein which is the portion of the Serrate protein with the greatest homology to the amino acid sequence as depicted in Figure 15 (SEQ ID NO:9) from about amino acid numbers 79-282.

133. A substantially purified fragment or derivative of a first Delta protein, which is characterized by (a) the ability in vitro, when expressed on the surface of a first cell to bind to a second Delta protein or fragment or derivative expressed on the surface of a second cell; and (b) the inability, in vitro, when expressed on the surface of a third cell, to bind to a Notch protein expressed on the surface of a fourth cell, said derivative having an insertion, deletion or substitution relative to the first Delta protein.

134. A method of delivering an agent into a cell expressing a Notch protein comprising exposing a Notch-expressing cell to a molecule such that the molecule is delivered into the cell, in which the molecule comprises a Delta protein or Delta fragment or derivative bound to an agent, in which the Delta protein, fragment, or derivative is characterized by the ability, in vitro, when expressed on the surface of a first cell, to bind to a Notch protein expressed on the surface of a second cell, said derivative having an insertion, deletion or substitution relative to the Delta protein.

135. A substantially purified nucleic acid comprising at least 25 nucleotides of the DNA coding sequence depicted in Figure 23 or 24.

136. A method of isolating a human Notch nucleic acid or hybridizable portion thereof comprising:

(a) contacting a sample containing nucleic acids comprising human nucleotide sequences with a nucleic acid probe, said probe comprising a nucleotide sequence complementary to and capable of specifically hybridizing to at least a portion of a human Notch cDNA, under conditions such that hybridization can occur; and

(b) isolating a nucleic acid in the sample that hybridizes to the probe.

137. The method according to claim 136 in which the sample contains human cDNA.

138. The method according to claim 136 in which the human Notch cDNA comprises the DNA sequence shown in Figure 23.

139. The method according to claim 136 in which the human Notch cDNA comprises the DNA sequence shown in Figure 24.

140. A method of identifying an adhesive toporythmic protein analog comprising:

(a) testing a molecule for binding to a human Notch protein or portion thereof comprising epidermal growth factor-like repeats 11 and 12; and

(b) identifying a molecule which binds in step (a); in which binding to the human Notch protein or portion thereof indicates that the molecule is an adhesive toporythmic protein analog.

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141. The method according to claim 140 in which said binding is to a human Notch protein or portion thereof present on the surface of a cell in which it is expressed.

142. The fragment of claim 52, 53, 55 or 56 which lacks the intracellular domain of the Delta protein.

143. The fragment of claim 142 which also lacks the epidermal growth factor-like and transmembrane regions of the Delta protein.

144. The protein of claim 54 or 57 in which said fragment lacks the intracellular domain of the Delta protein.

145. The protein of claim 144 in which said fragment also lacks the epidermal growth factor-like and transmembrane regions of the Delta protein.

146. The derivative of claim 62 or 63 which lacks the intracellular domain of the Delta protein.

147. The derivative of claim 146 which also lacks the epidermal growth factor-like and transmembrane regions of the Delta protein.

148. The derivative of claim 64 which does not contain a complete epidermal growth factor-like repeat of the Serrate protein.

149. A method for the manipulation of cell differentiation comprising contacting in vitro a cell with an amount of a toporythmic protein effective to manipulate the differentiation of the contacted cell.

150. The method according to claim 149 wherein the toporythmic protein is a Delta protein.

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151. The method according to claim 149 wherein the toporythmic protein is a Serrate protein.

152. The method according to claim 149 wherein the toporythmic protein is a Notch protein.

153. A method for the manipulation of cell differentiation comprising contacting in vitro a cell with an amount of a fragment or derivative of a first toporythmic protein effective to manipulate the differentiation of the contacted cell, wherein the fragment or derivative is characterized by the ability to bind a second toporythmic protein, said derivative having an insertion, deletion or substitution relative to the first toporythmic protein.

154. The method according to claim 153 wherein the second toporythmic protein is a Notch protein.

155. The method according to claim 153 wherein the second toporythmic protein is a Delta protein.

156. The method according to claim 153 wherein the second toporythmic protein is a Serrate protein.

157. The method according to claim 155 or 156 wherein the first toporythmic protein is a Notch protein.

158. The method according to claim 154 wherein the first toporythmic protein is a Delta protein.

159. The method according to claim 154 wherein the first toporythmic protein is a Serrate protein.

160. A method for the manipulation of cell differentiation comprising contacting in vitro a cell with an amount of an antibody or fragment thereof containing the idiotype thereof which binds to a toporythmic protein effective to manipulate the differentiation of the contacted cell.

161. The method according to claim 160 wherein the antibody or fragment or derivative thereof binds to the adhesive portion of the toporythmic protein.

162. The method according to claim 160 wherein the antibody or fragment or derivative thereof binds to a toporythmic protein selected from the group consisting of Notch, Delta and Serrate.

163. The method according to claim 160 wherein the antibody binds to the extracellular domain of a toporythmic protein.

164. A substantially purified protein comprising: a fragment of a human Notch protein consisting of at least 77 amino acids in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

165. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the extracellular domain of the protein in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

166. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the intracellular domain of the protein in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a

second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

167. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the extracellular and transmembrane domains of the protein in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

168. A substantially purified protein comprising: a fragment of a human Notch protein consisting essentially of the region containing the cdcl0 repeats of the protein in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

169. A substantially purified protein comprising a region of a human Notch protein containing the epidermal growth factor-like repeats of the protein in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and

assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

170. A substantially purified protein comprising a region of a human Notch protein containing the Notch/lin-12 repeats of the protein in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

171. A substantially purified fragment of a human Notch protein substantially lacking the epidermal growth factor-like repeats of the protein, which fragment is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

172. A substantially purified fragment of a human Notch protein lacking a portion of the epidermal growth factor-like repeats of the protein, which fragment is able to be bound by an antibody to a human Notch protein but not to a Notch protein of another species, and in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession

number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

173. A substantially purified fragment of a human Notch protein consisting essentially of the intracellular domain of the protein, in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

174. A substantially purified fragment of a human Notch protein consisting essentially of the extracellular domain of the protein, in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

175. A substantially purified fragment of a human Notch protein consisting essentially of the extracellular and transmembrane domains of the protein, in which the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

176. A substantially purified protein comprising a functionally active portion of a human Notch protein, in which

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the human Notch protein is encoded by a nucleic acid sequence hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

177. A substantially purified human Notch protein, encoded by a first nucleic acid hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

178. A substantially purified first nucleic acid that encodes a human Notch protein, which first nucleic acid is hybridizable to a second nucleic acid having the human Notch nucleotide sequence contained in (a) plasmid hN3k as deposited with the ATCC and assigned accession number 68609, or (b) plasmid hN5k as deposited with the ATCC and assigned accession number 68611.

179. A method for producing an antibody according to claim 122 comprising administering to a host animal a protein or fragment according to any one of claims 1 to 24 and selecting an antibody that binds to said protein or fragment.

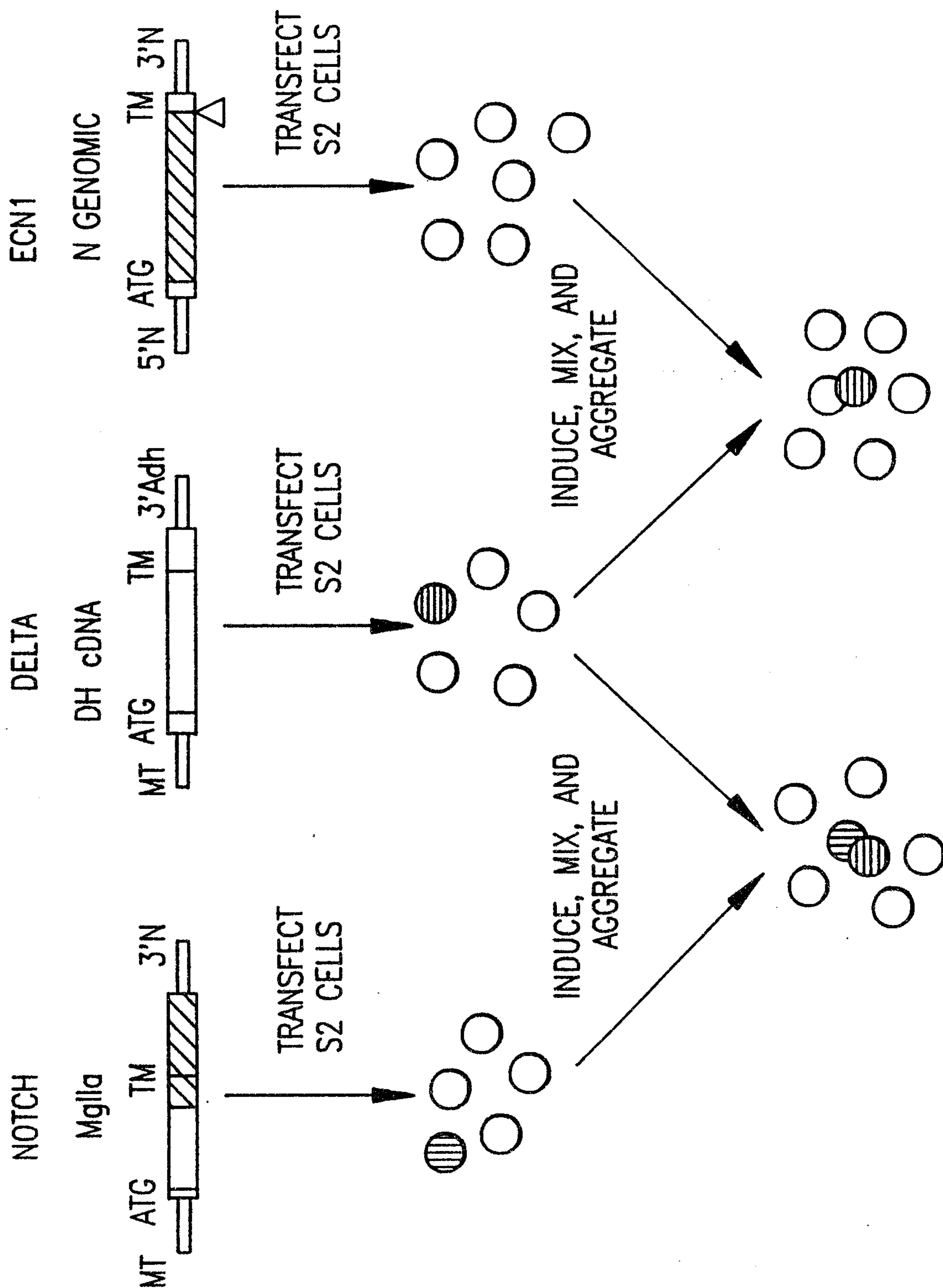
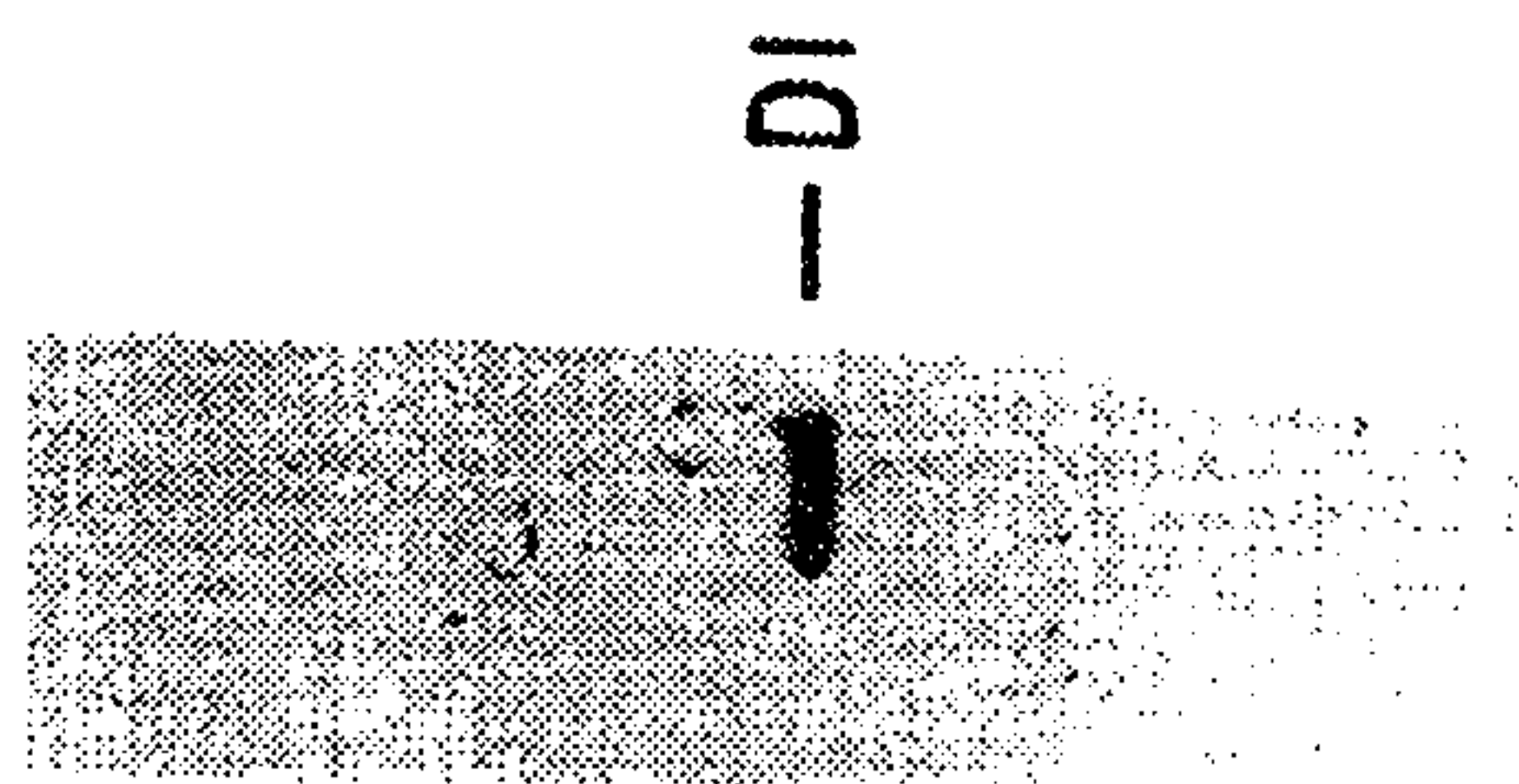


FIG.1

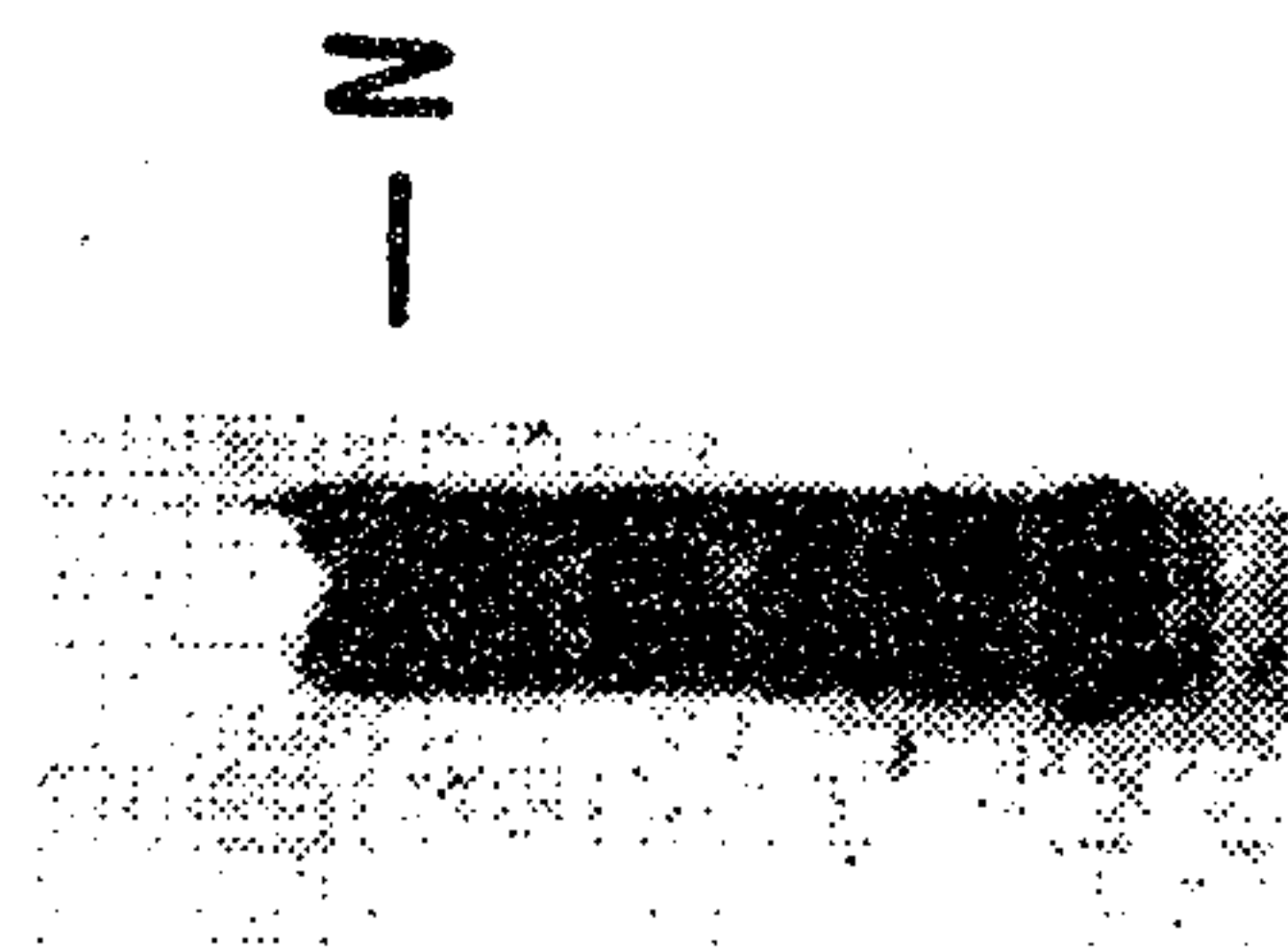
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FIG. 2B



S2 DI

FIG. 2A



S2 N

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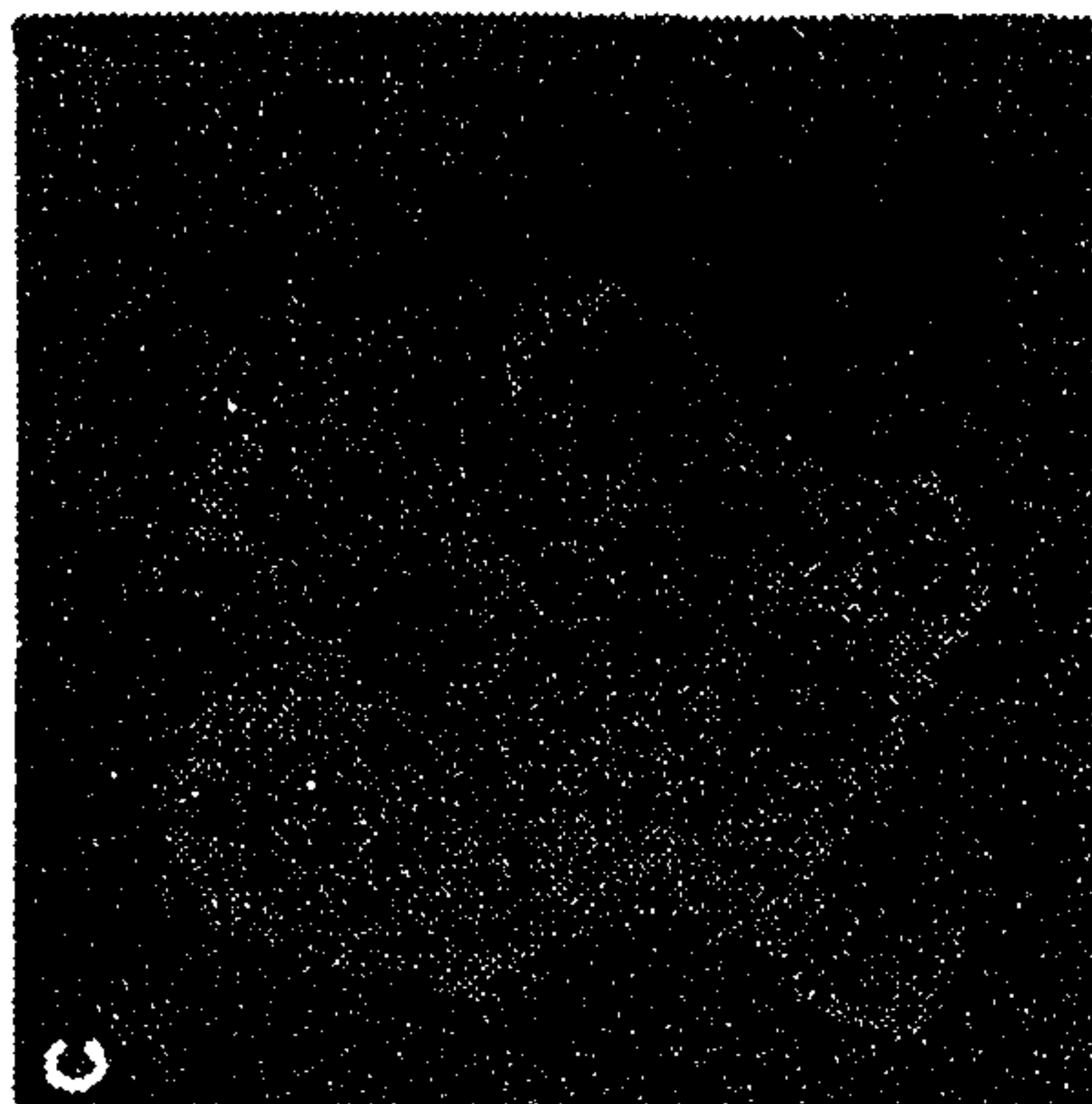


FIG. 3C

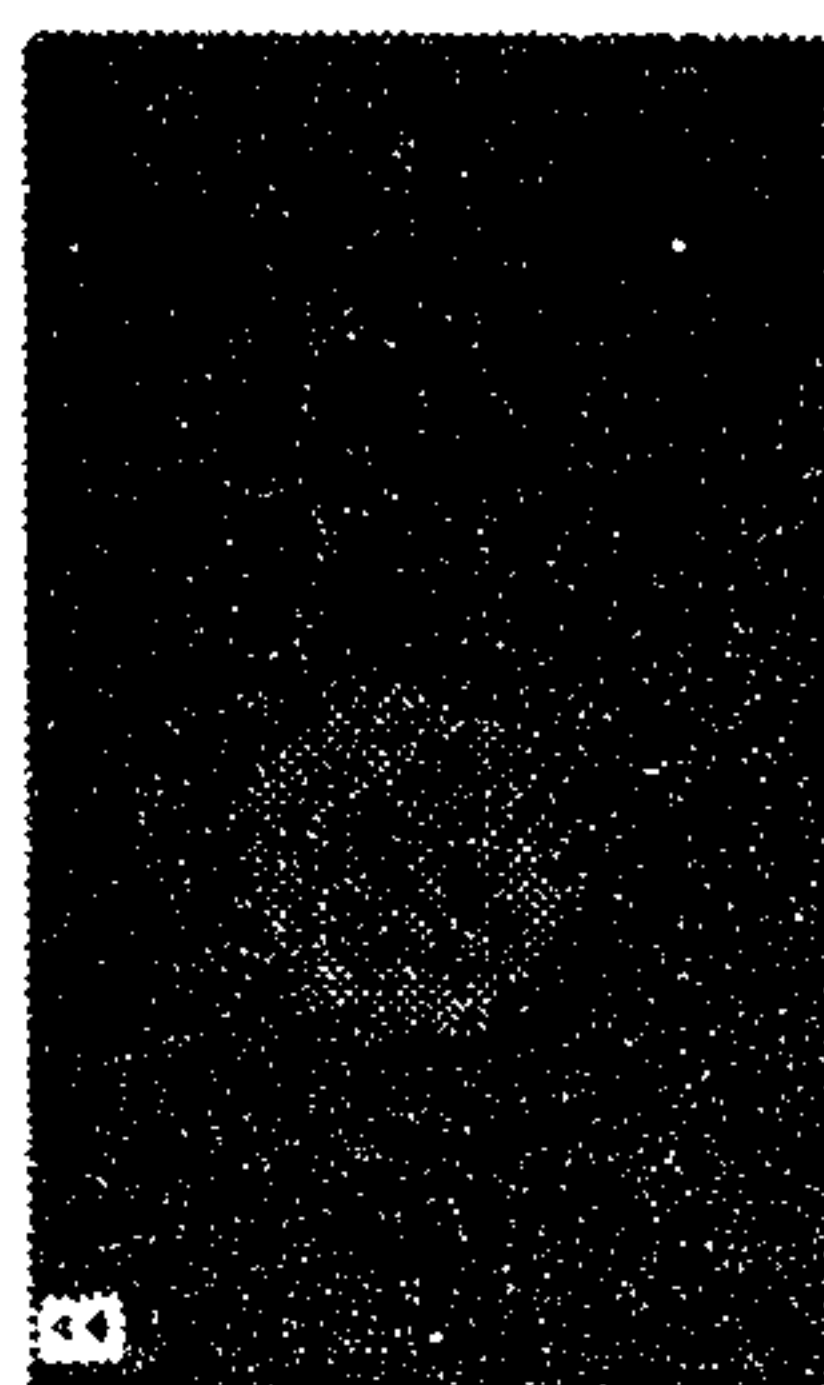


FIG. 3B

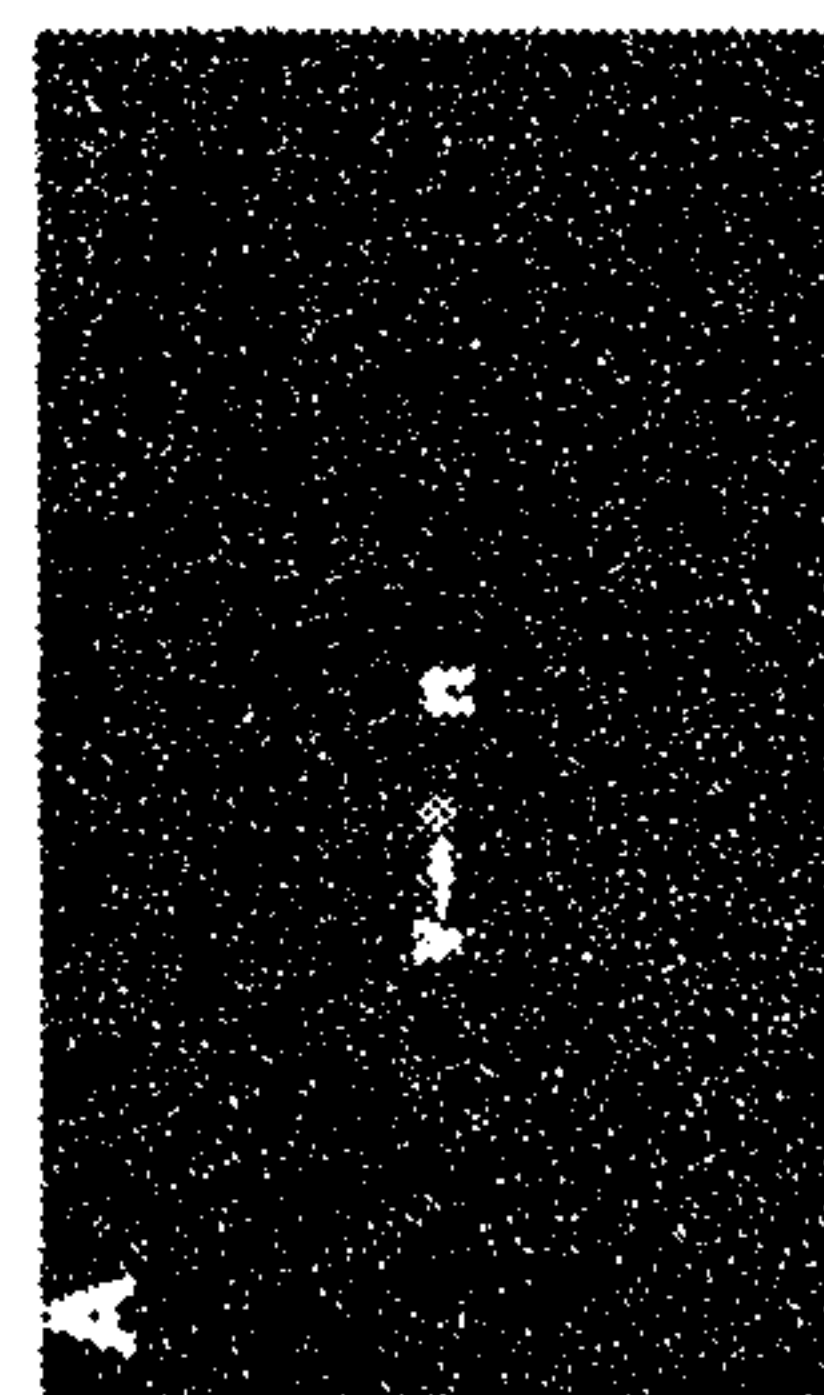


FIG. 3A

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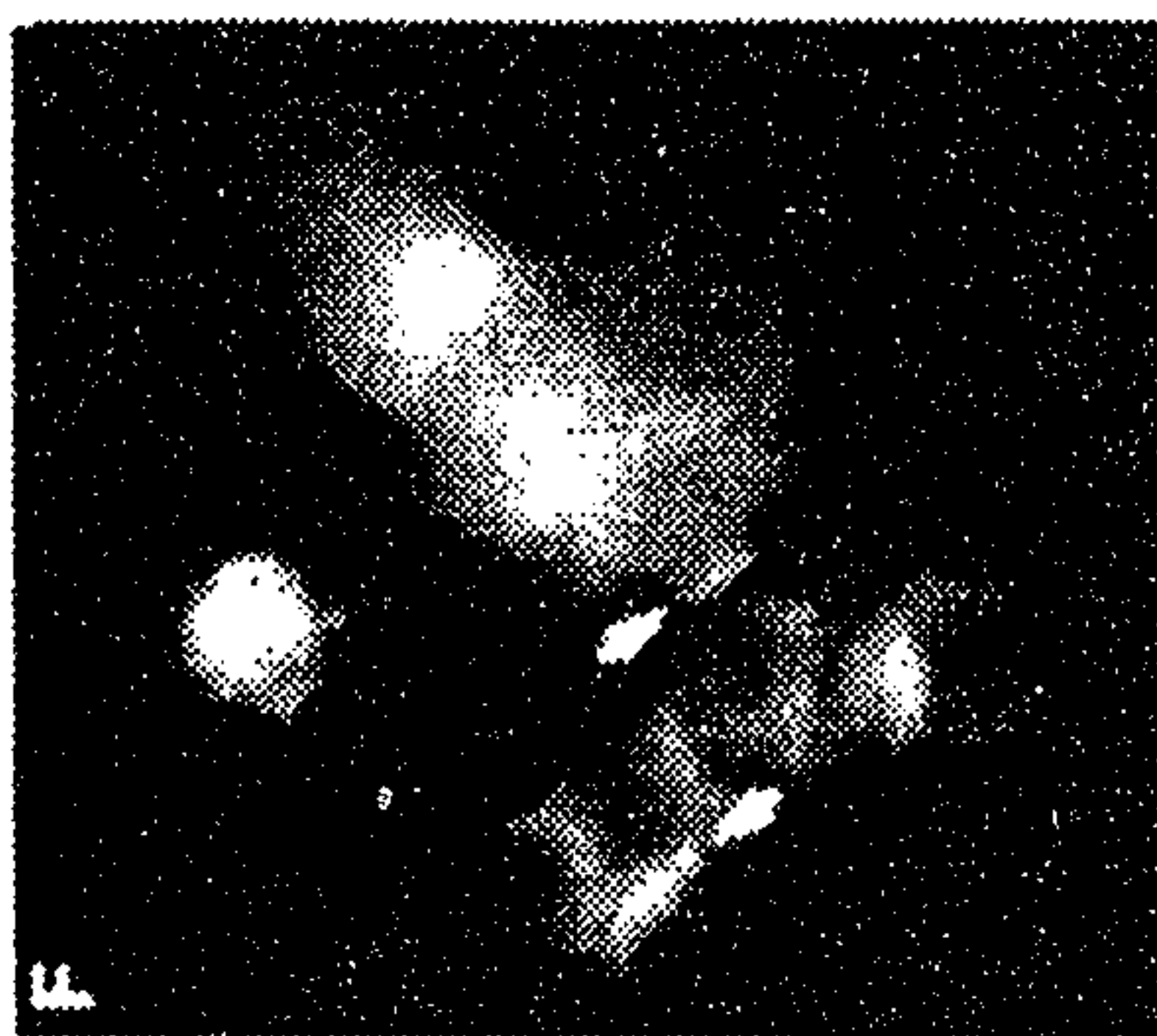


FIG.3F



FIG.3E

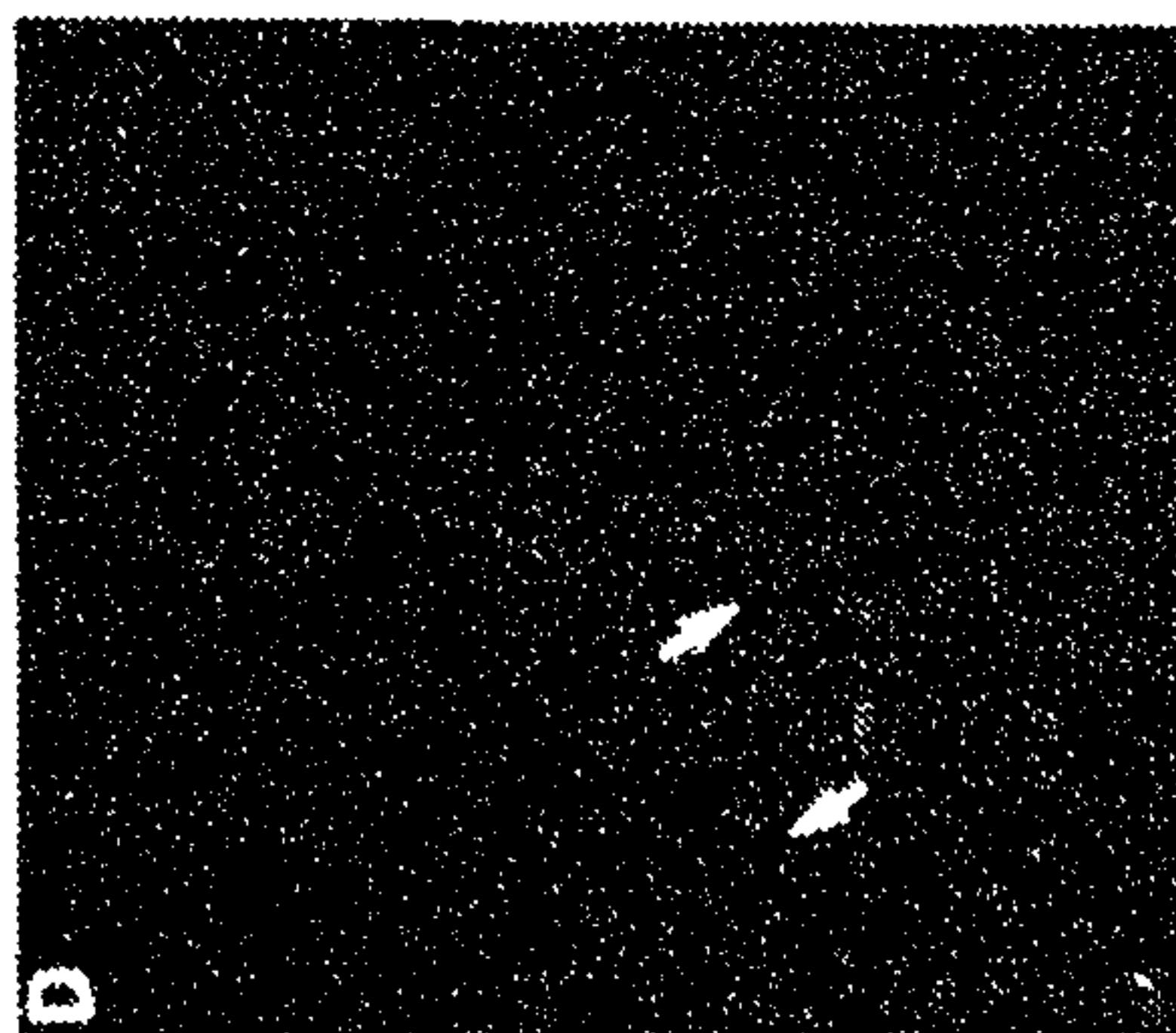


FIG.3D

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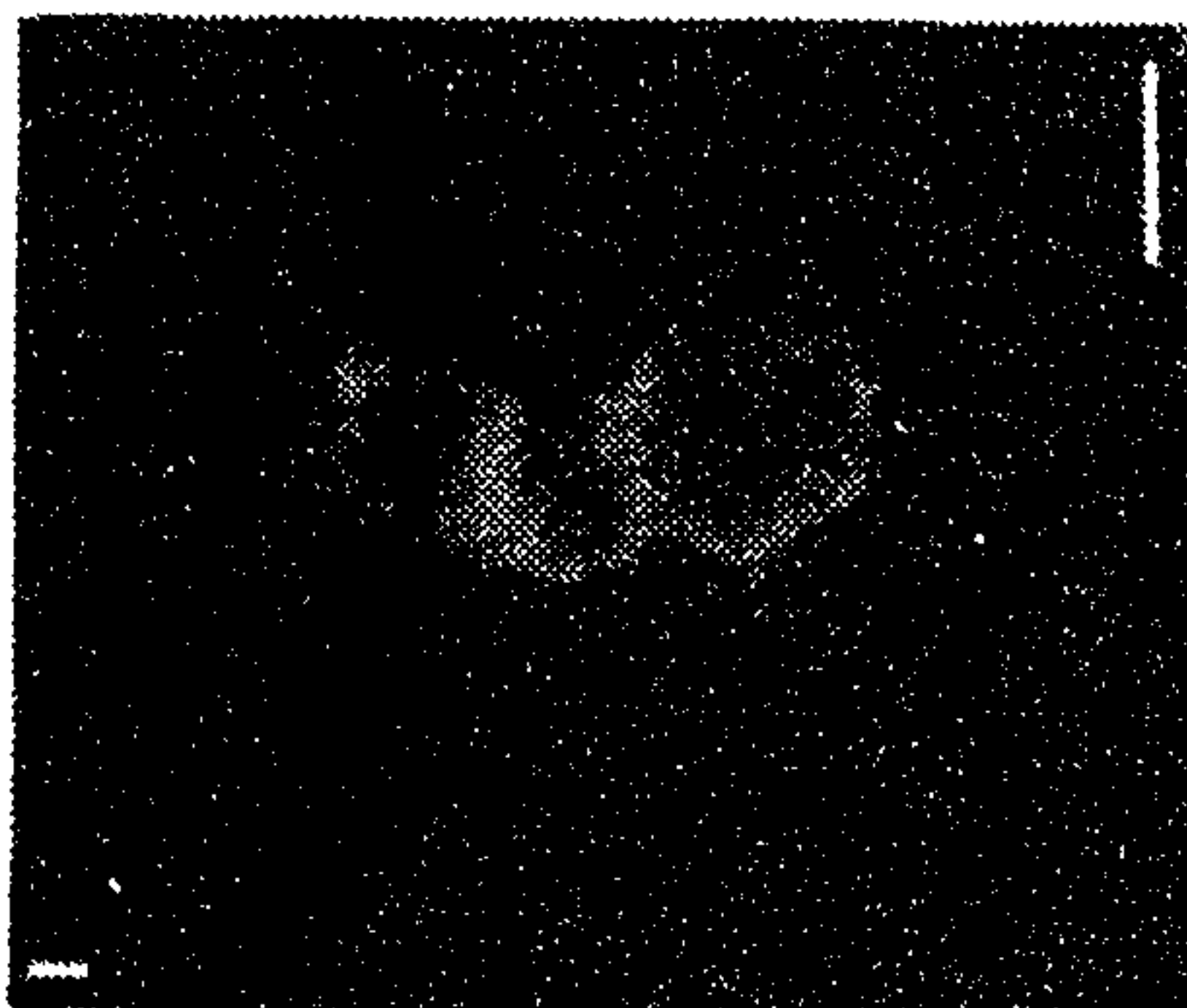


FIG.3I

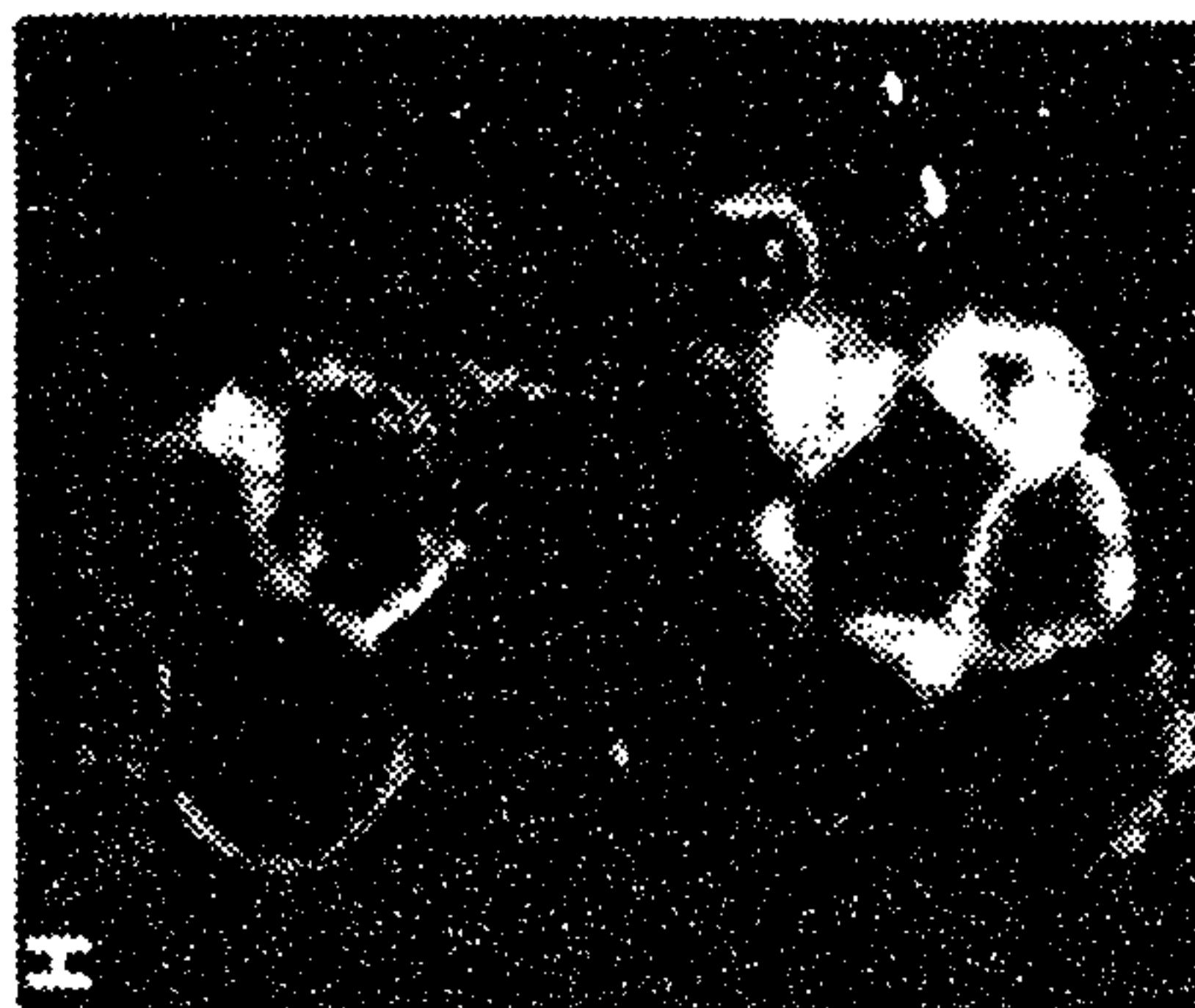


FIG.3H

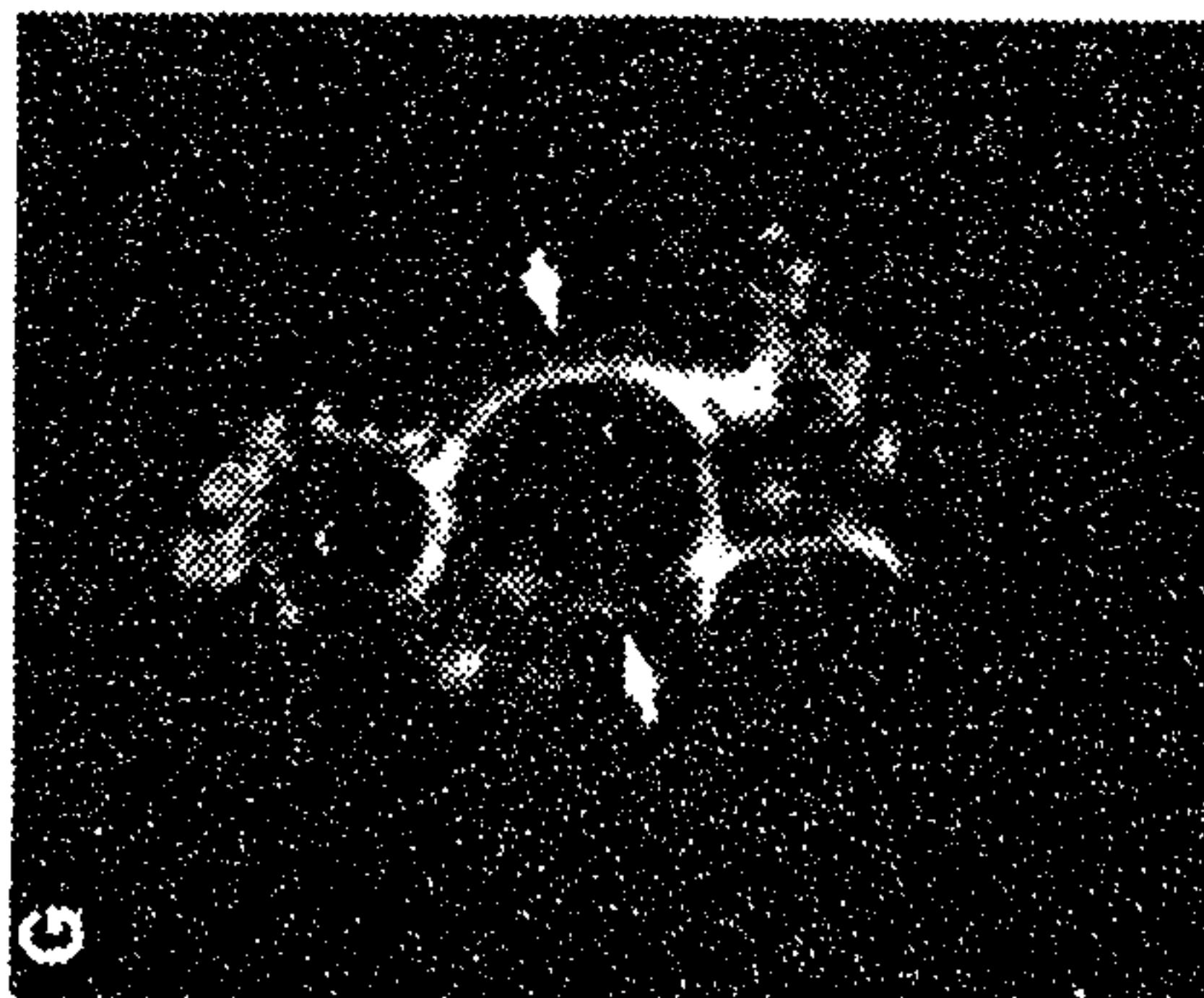


FIG.3G

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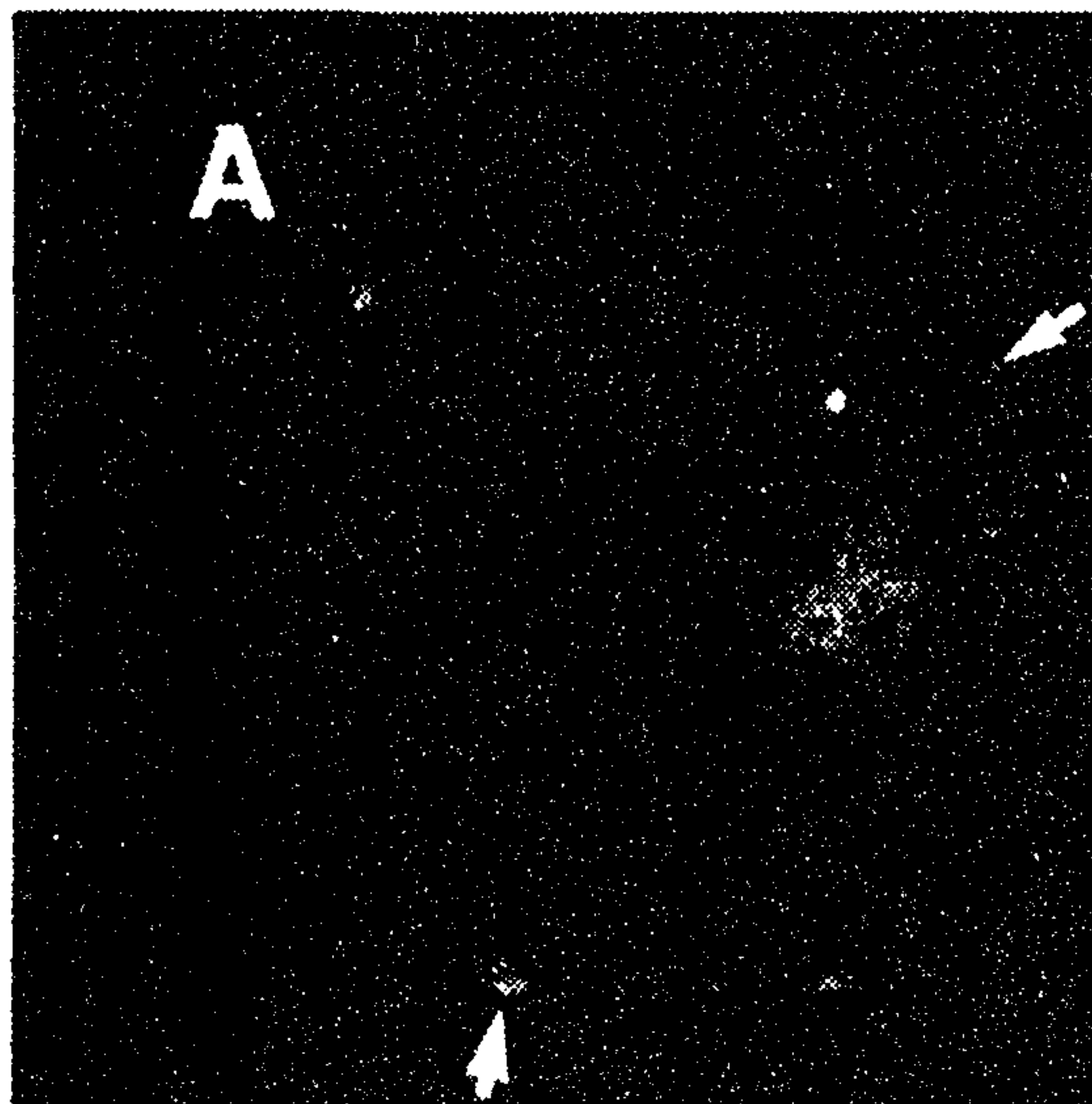


FIG. 4A

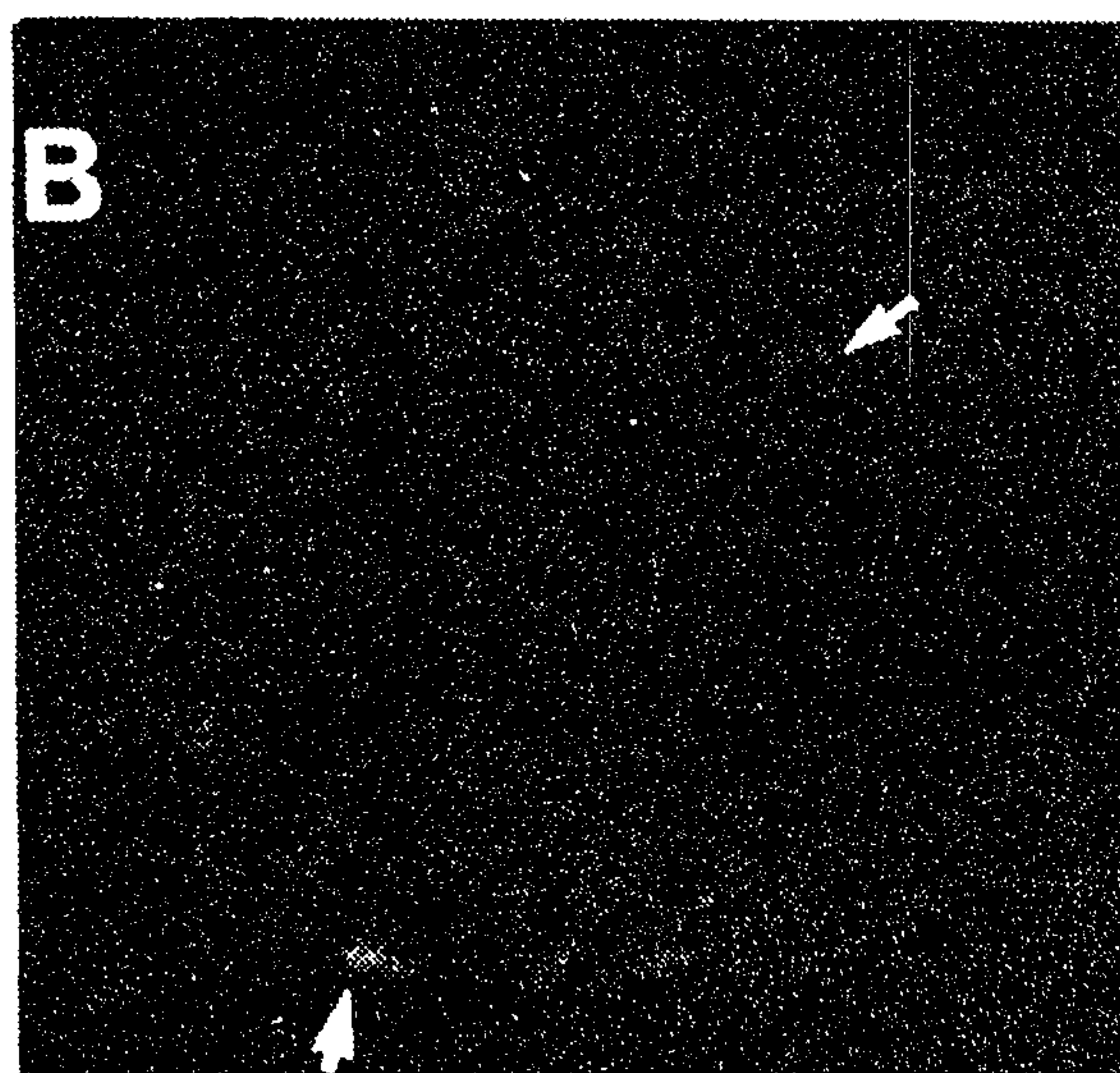


FIG. 4B

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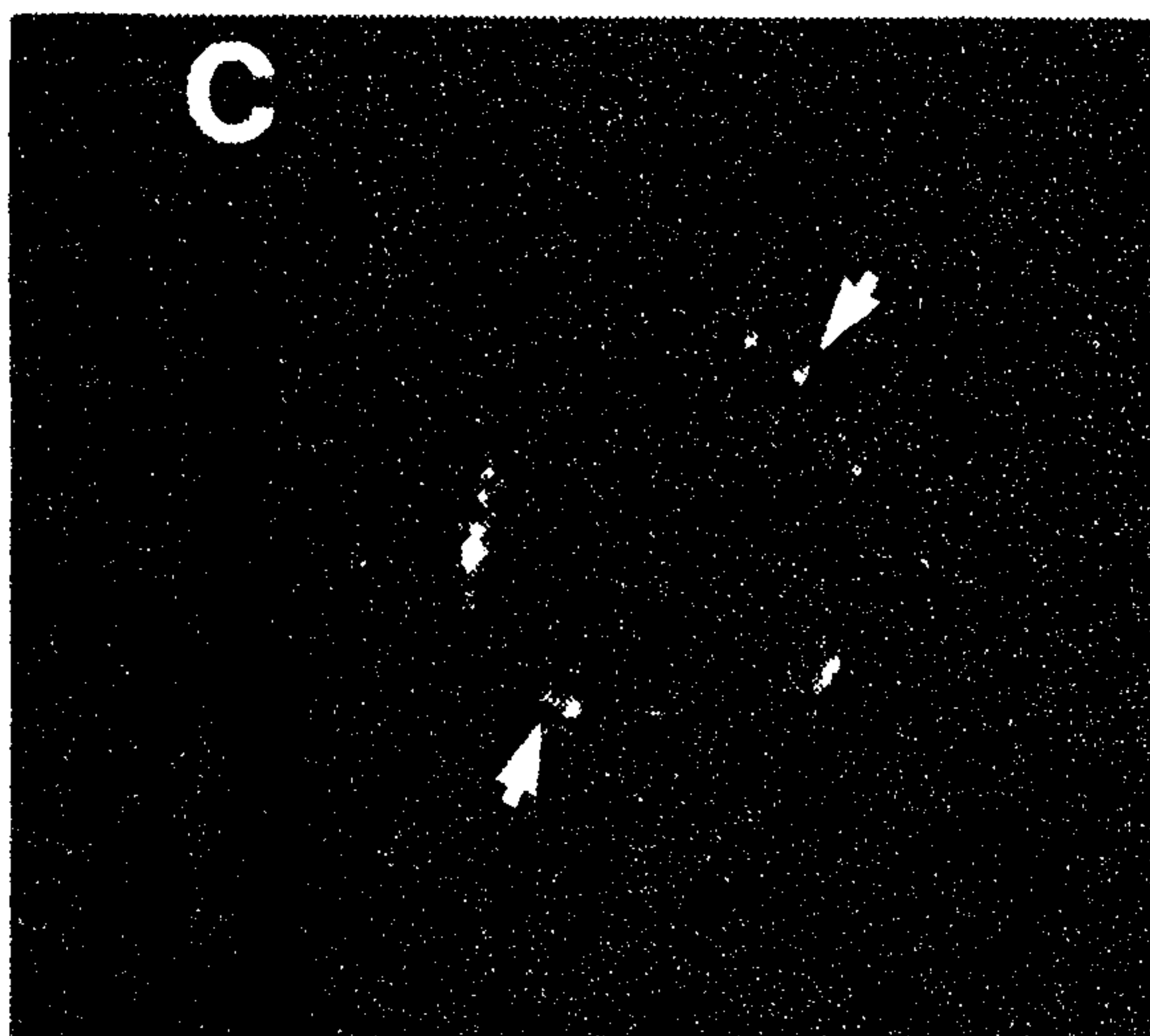


FIG. 4C



FIG. 4D

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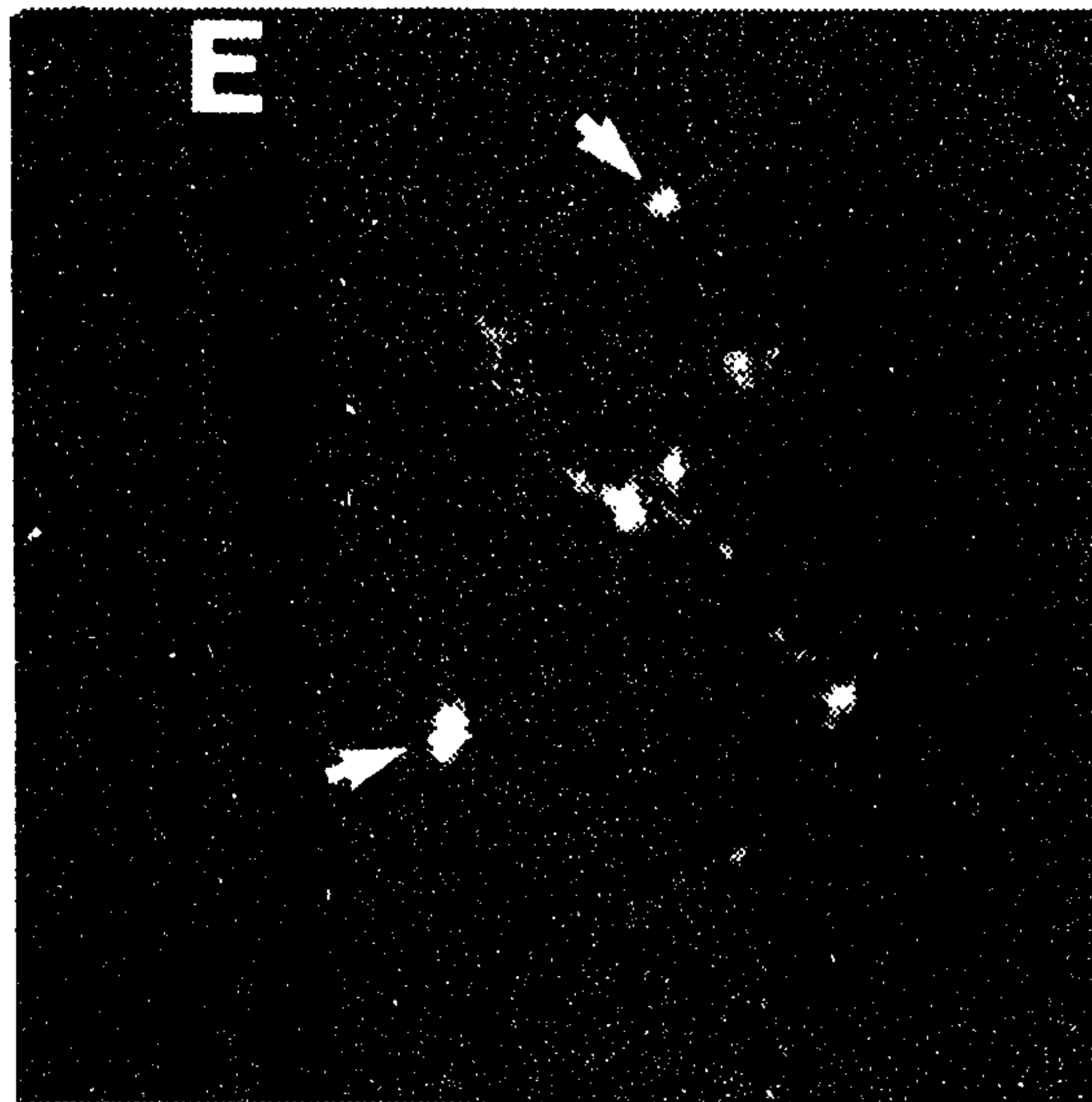


FIG. 4E



FIG. 4F

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FIG. 5B

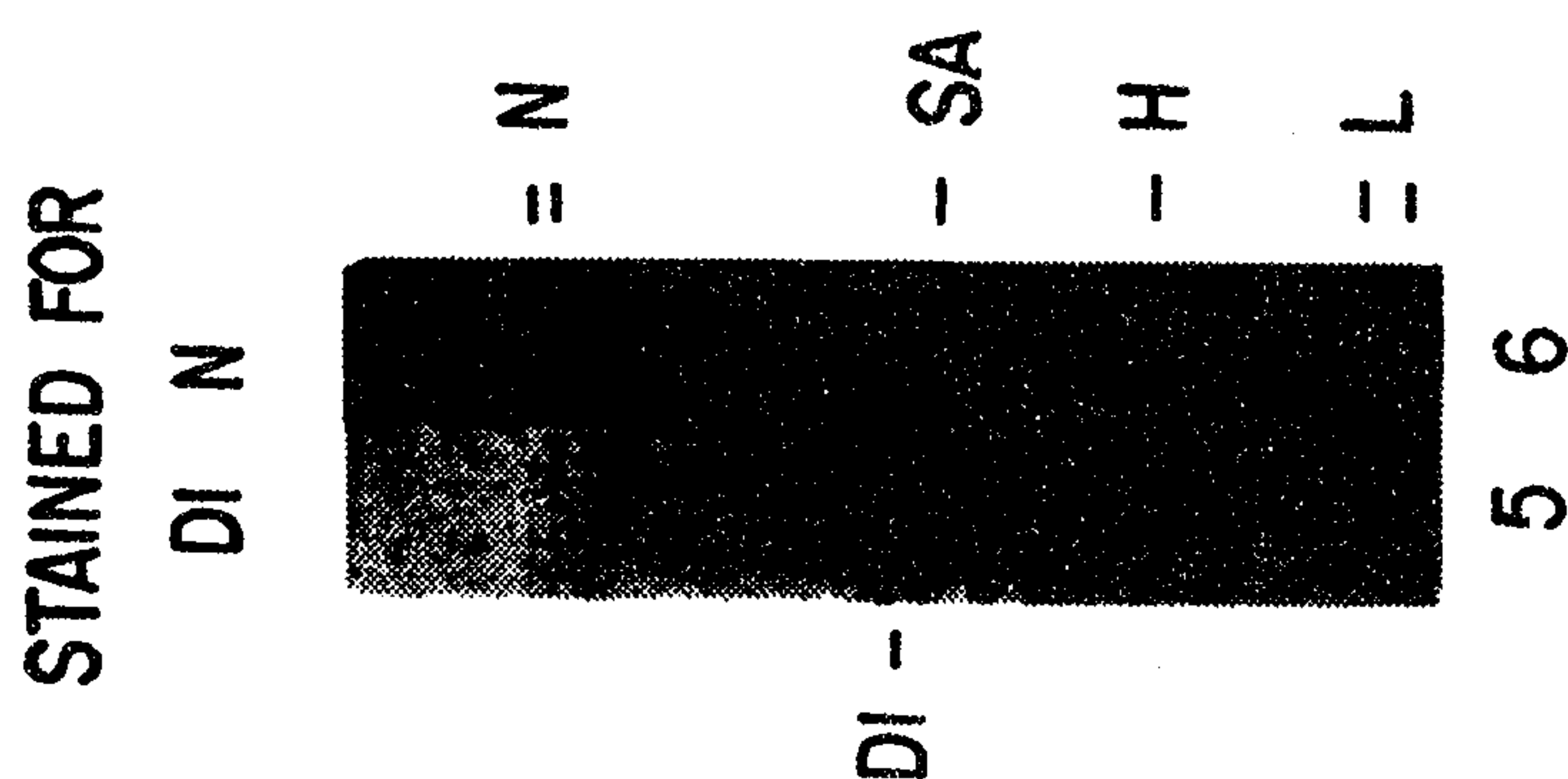
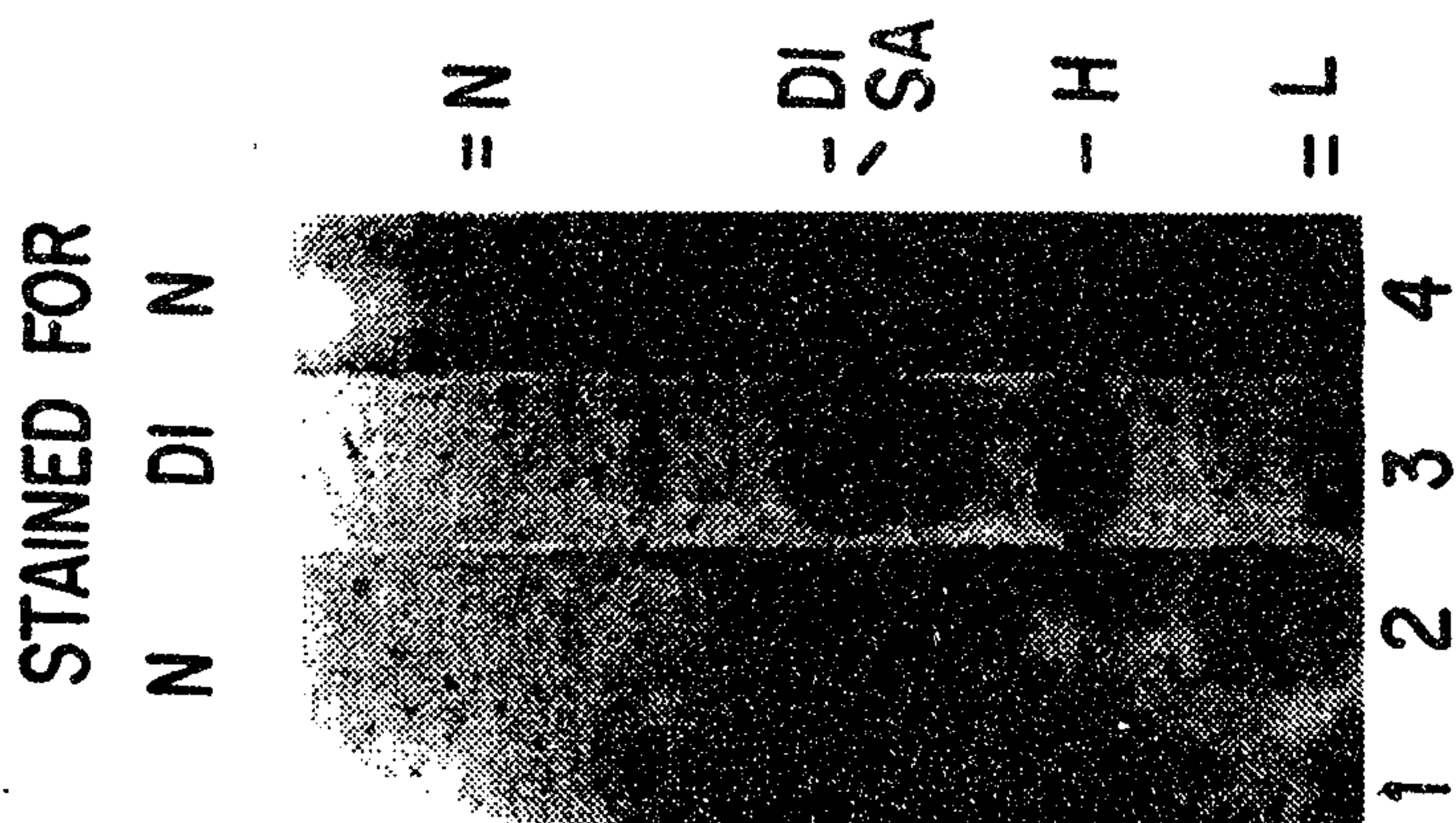


FIG. 5A



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	SP	EGF	N	TM	cdc10	PA	opa	% AGGREGATION WITH DI WITH Ser	
1.pMtNMg								40	21
2.ΔSph	1		32					0	nt
3.ΔClo	7		31					0	nt
4.ΔEGF(7-17)	7	17						0	nt
5.ΔEGF(9-26)	9	26						0	nt
6.ΔEGF(17-30)	17	31						22	nt
7.ΔEGF(7-9)	7 9							20	14
8.ΔEGF(9-17)	9	17						0	0
9.ΔEGF(17-26)	17	26						10	8
10.ΔEGF(26-30)	26	31						5	7
11.ΔEGF(9-30)	9	30						0	nt
12.ΔEGF(7-26)	7	26						0	nt
13.ΔClo+EGF(9-17)	7 9 17		31					35	20
14.ΔClo+EGF(17-26)	7	17 26 31						0	nt
15.ΔSPLIT	14							42	nt
16.ΔClo+EGF(9-13)	7 9 13		31					47	25

FIG.6A

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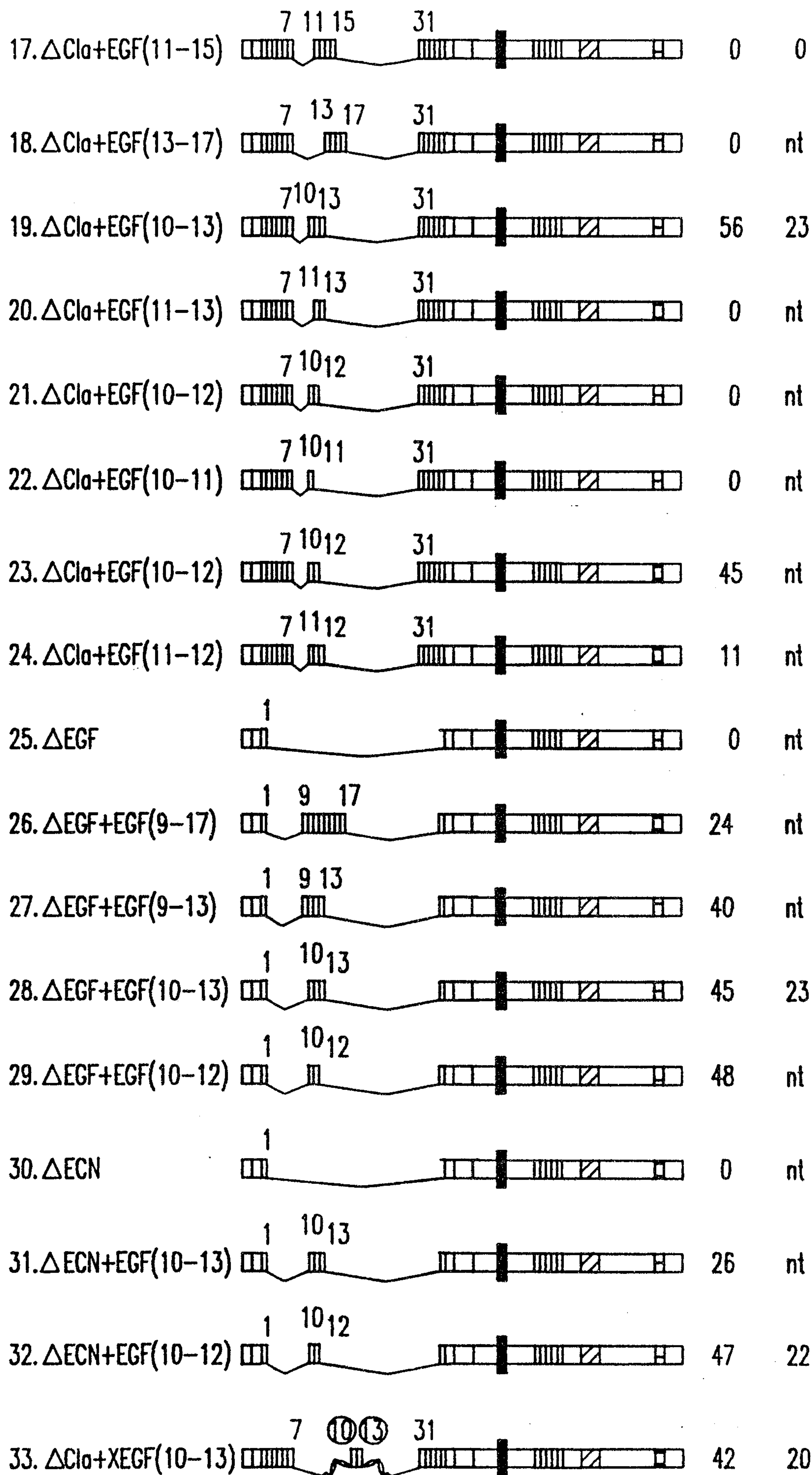


FIG.6B

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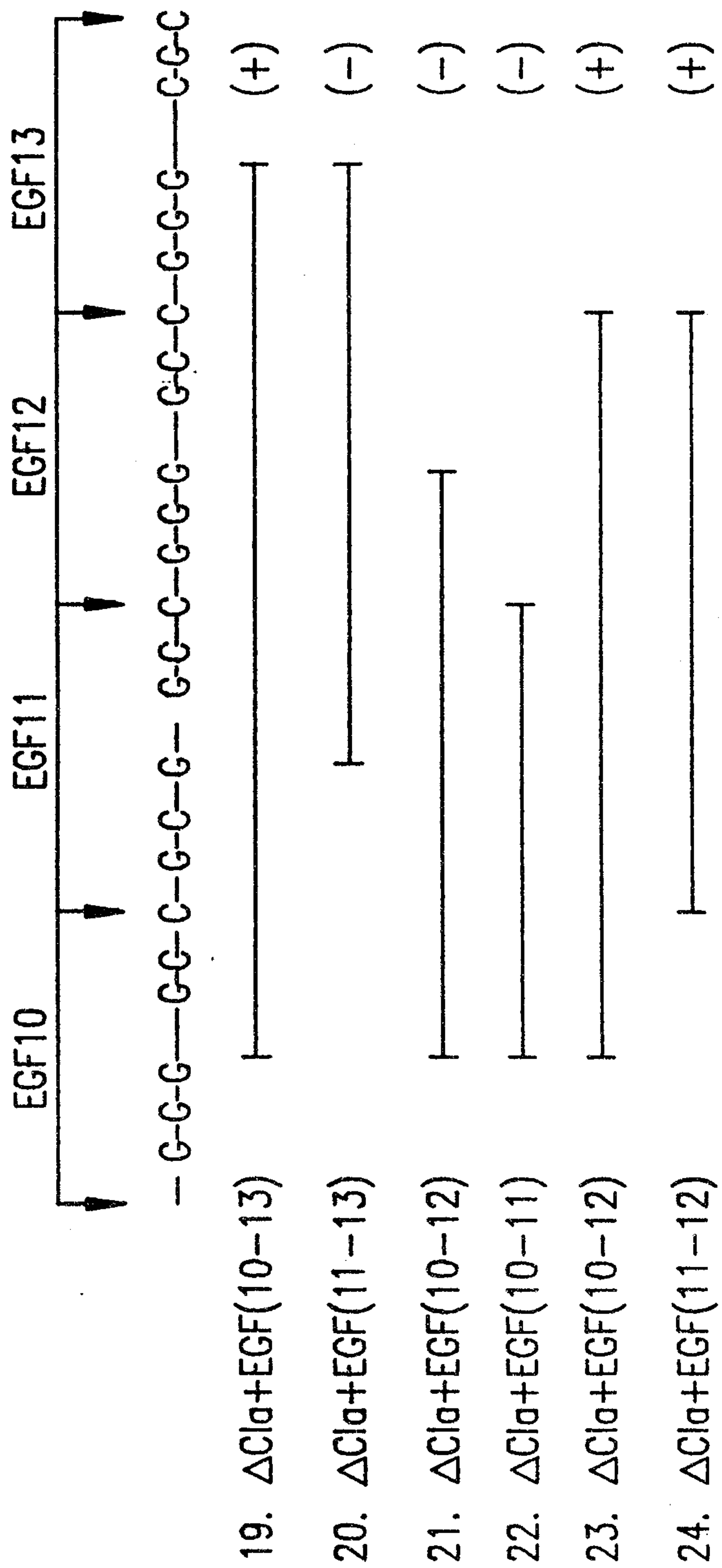


FIG. 7

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FIG. 8

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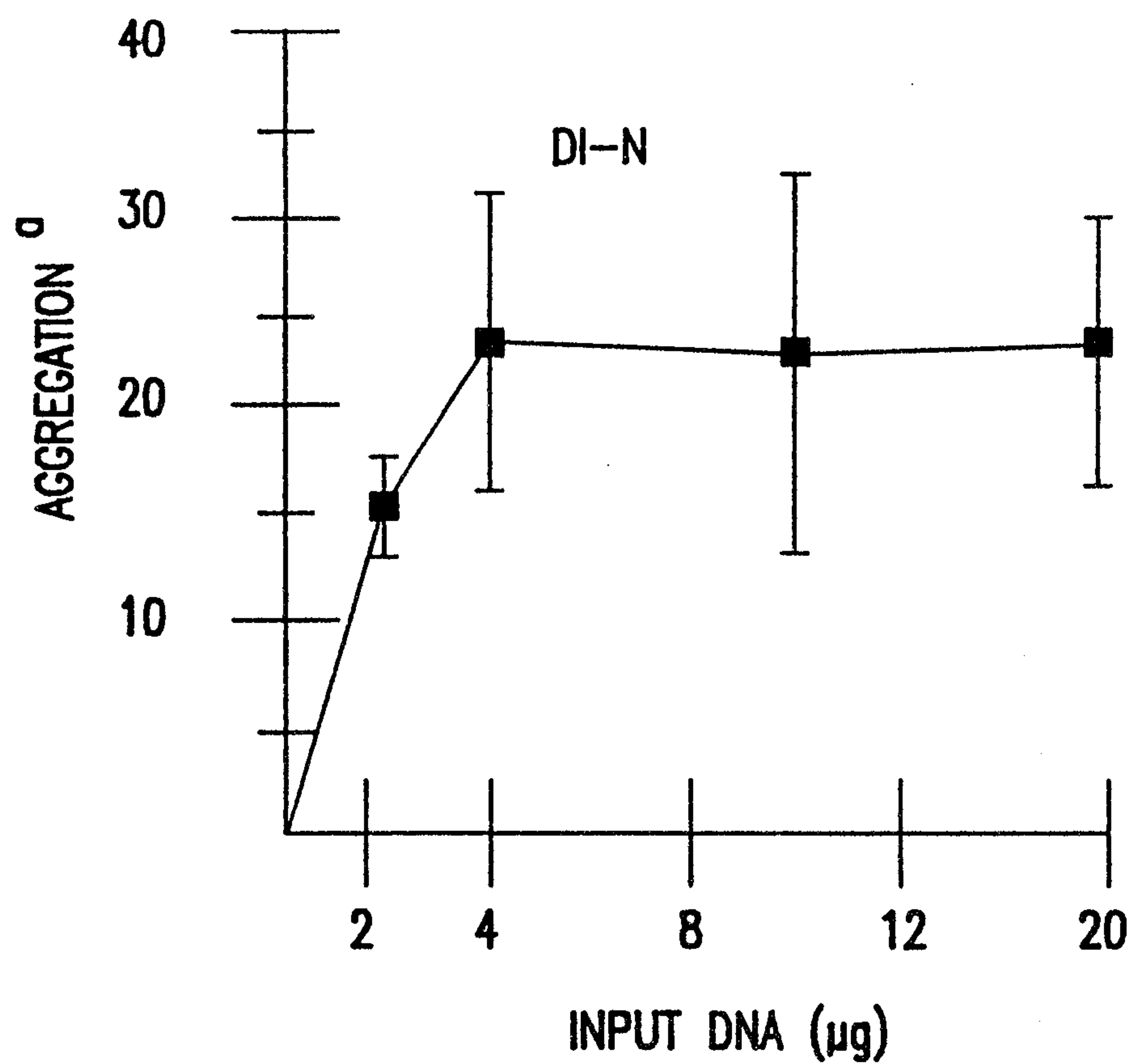


FIG.9A

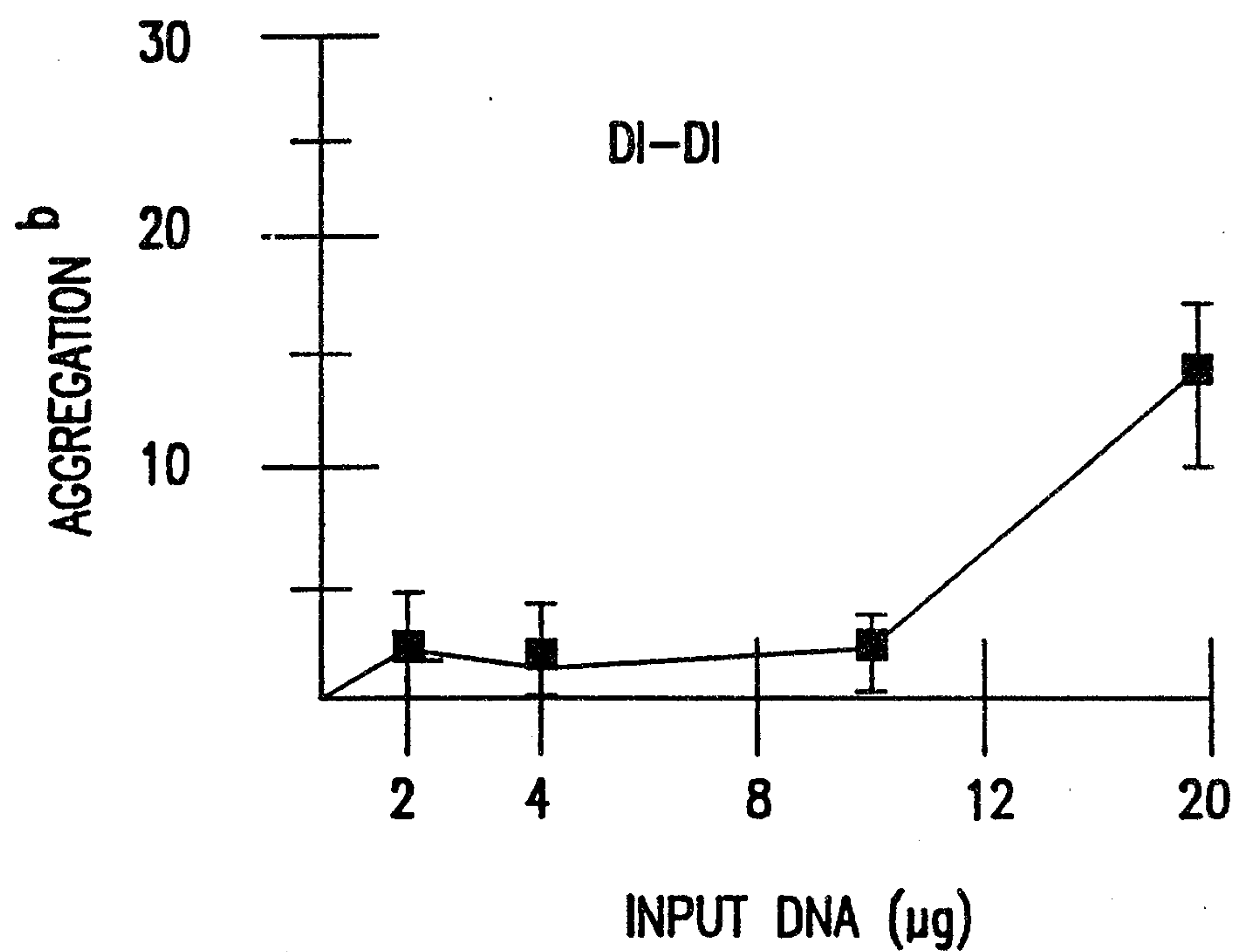


FIG.9B

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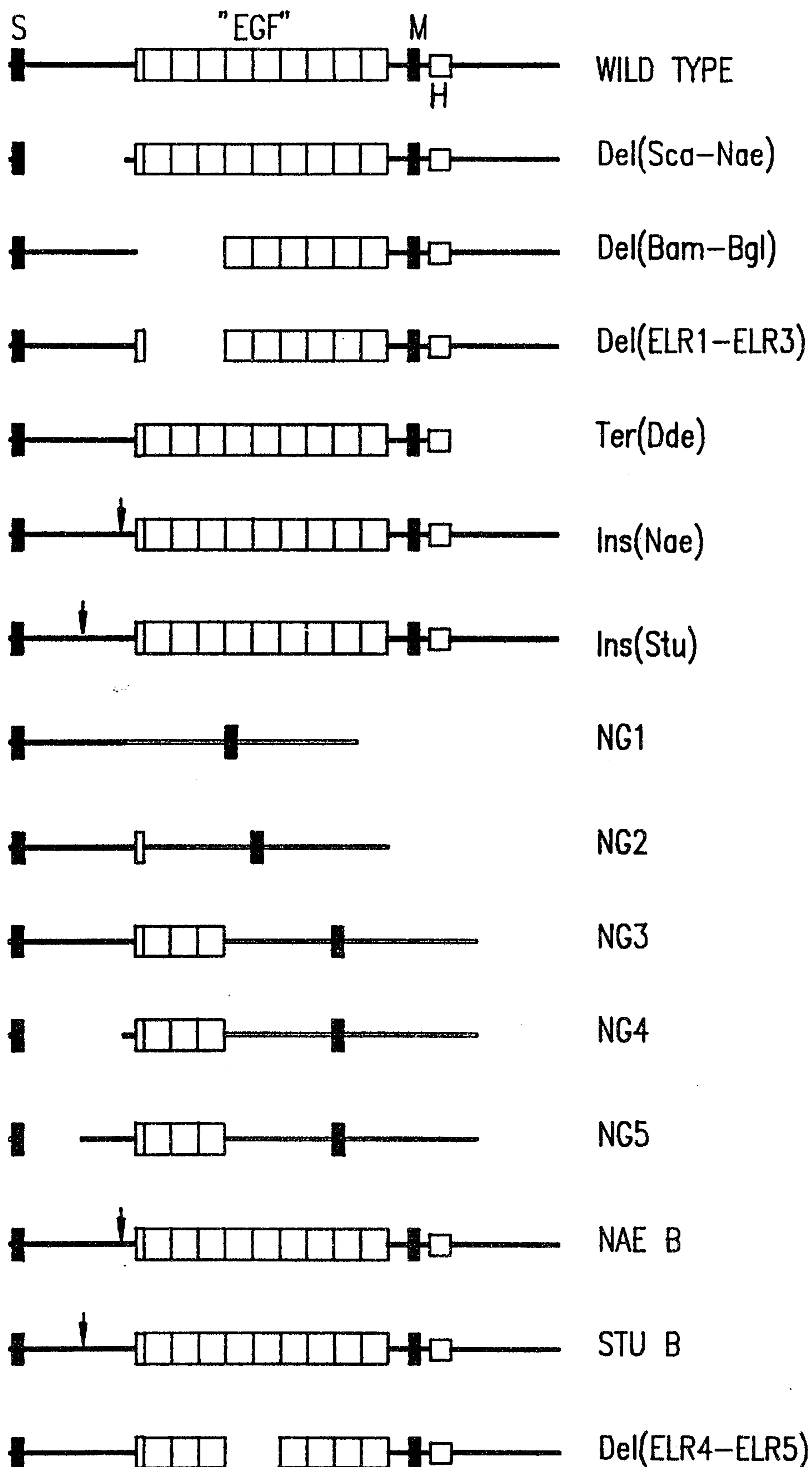


FIG.9C

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FIG. 10

DI 24

GSFELRLKYFSNDHGRDNEGRCCSGESDGTGKLG.S.CKTRFRVCLKHYQATIDTTS...QC
GNFELEILEISNTNSHLLNGYCCGMPAELRATKTIGCSPCTTAFRLCLKKEYQTTEQGASISTGC

N1

SER85

STU B
EGKIFPW

TYGDVITPILGENSVNLTDQRFQNKGFNP IQFPFSFSWPGTFSLIVEAW
SFGNATTKILGGSSFVSDPG.....VGAIVLPFTFRVTKSFTLILQAL

N2

HDTNNSGNARTNKLLIQRLLVQQVLEVSSEWKTNKSESQYTSLEYDFRVT
DMYNTS..YPDAERLIEETSYSGVILPSPEWKTLDHIGNARITYRVRVQ

NAE B
CRKIFR

226

CDLNYYGSGCAKFCRPRDDSFHSTCSETGEIICLTGWQGDYC
CAVTYNTTCTTFCRPRDDQFGHYACGSEGQKLCNGWQGVNC

N3

283

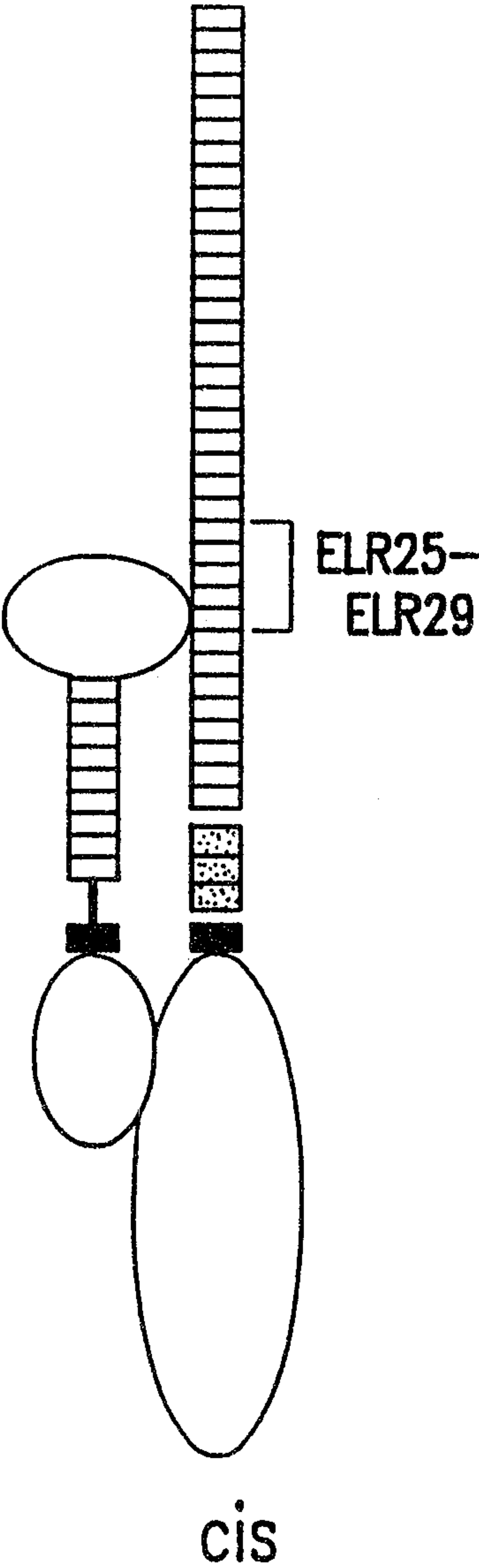
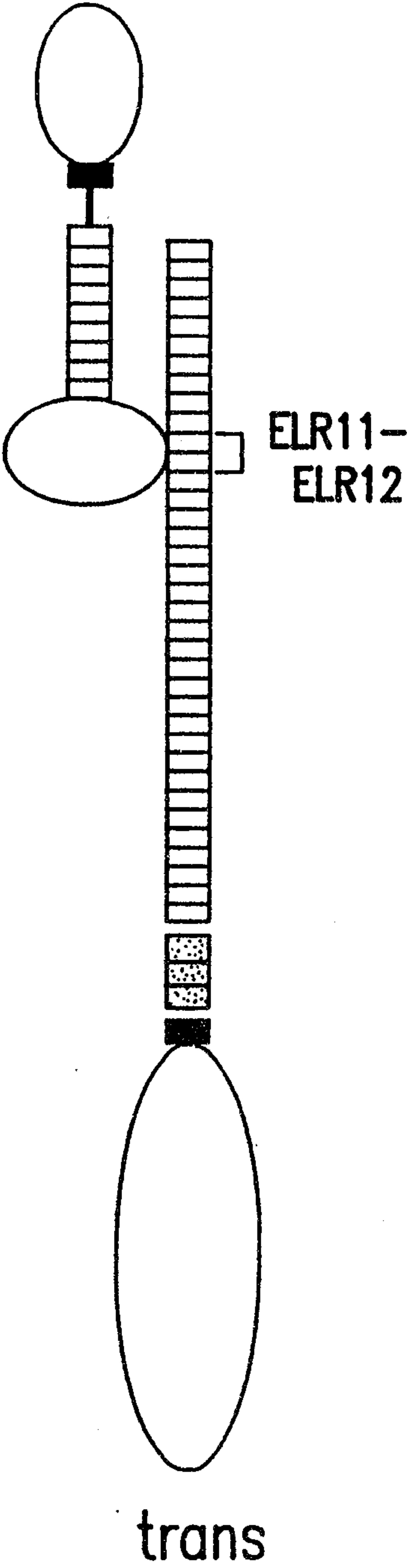
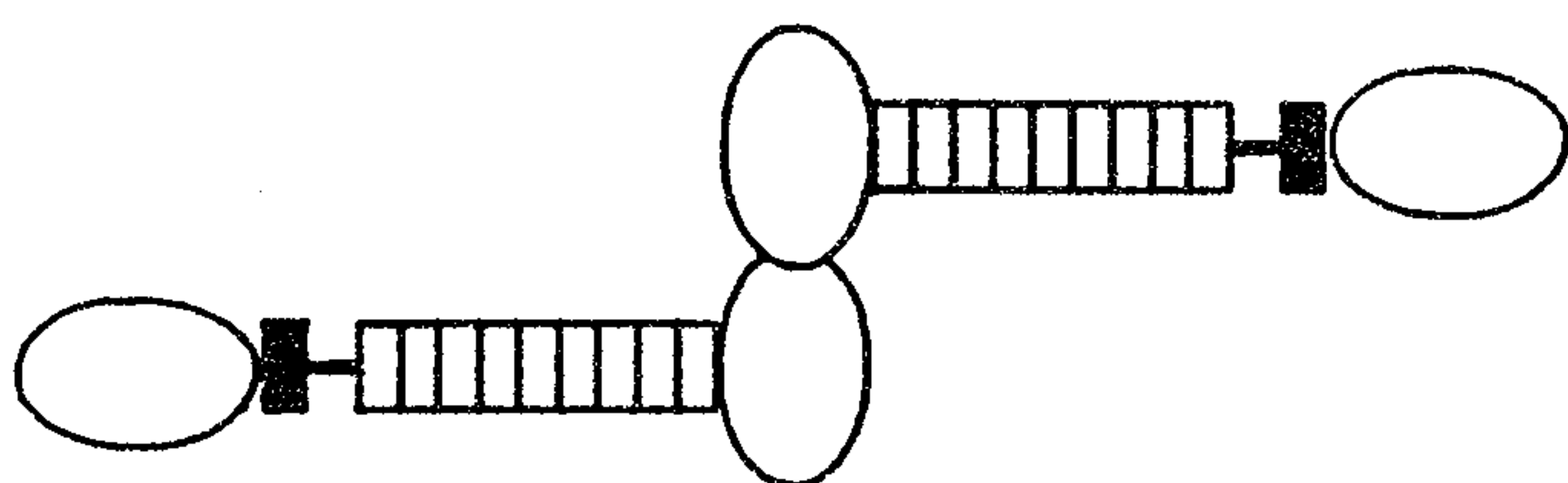


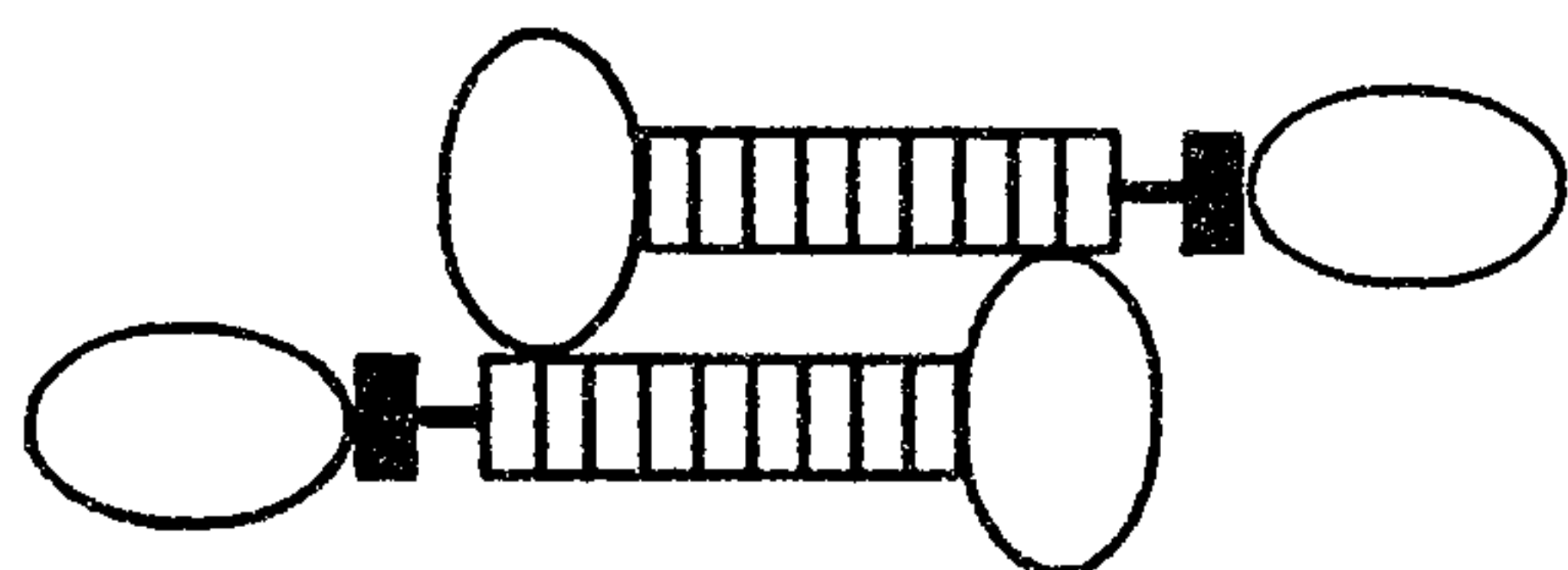
FIG.11A

FIG.11B

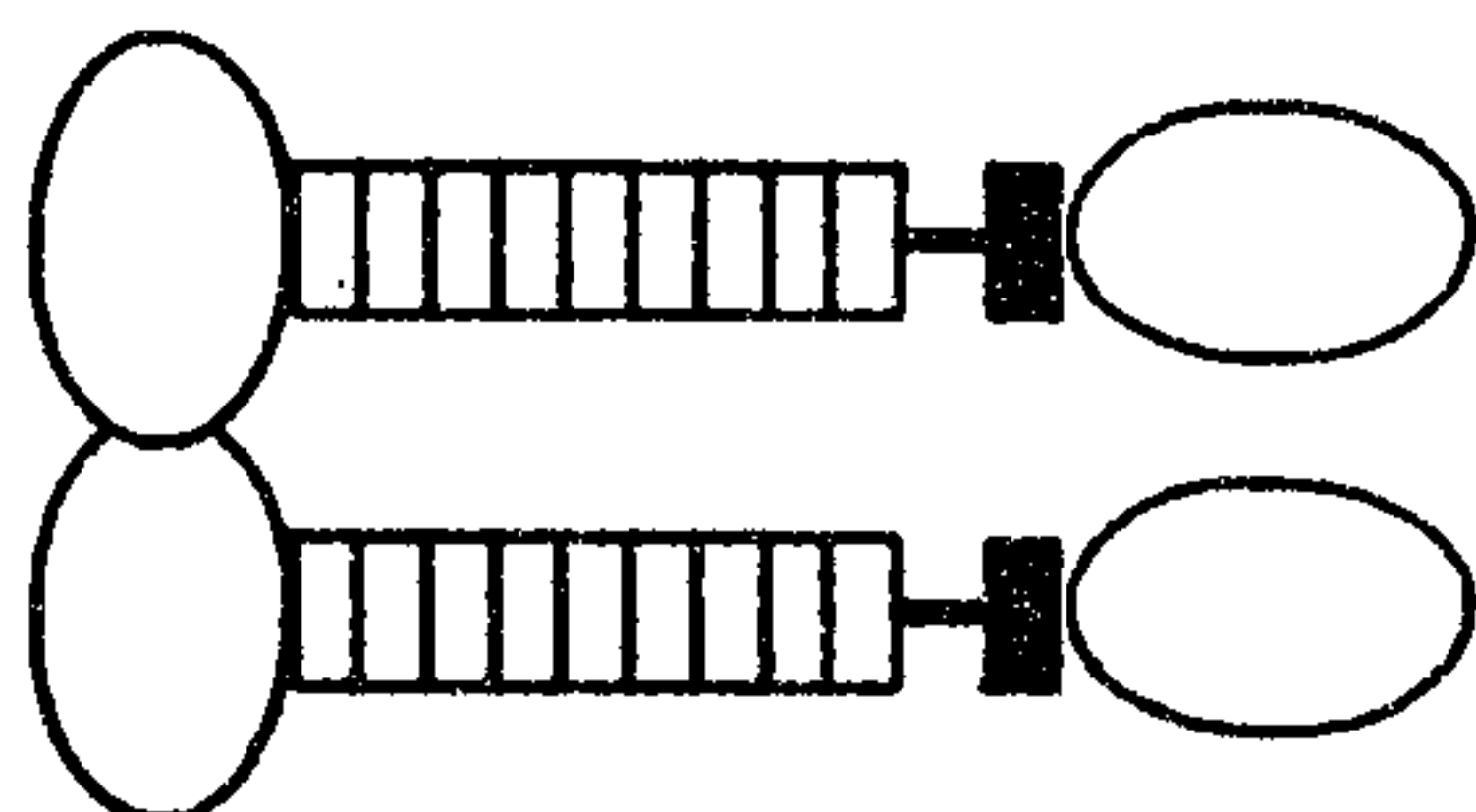
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trans



trans



cis

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FIG.12A

FIG.12B

FIG.12C

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GAATTCGGAG GAATTATTCA AAACATAAAC ACAATAAACA ATTTGAGTAG TTGCCGCACA	60
CACACACACA CACAGCCCGT GGATTATTAC ACTAAAAGCG ACACTCAATC CAAAAAATCA	120
GCAACAAAAA CATCAATAAA C ATG CAT TGG ATT AAA TGT TTA TTA ACA GCA	171
Met His Trp Ile Lys Cys Leu Leu Thr Ala	
1 5 10	
TTC ATT TGC TTC ACA GTC ATC GTG CAG GTT CAC AGT TCC GGC AGC TTT	219
Phe Ile Cys Phe Thr Val Ile Val Gln Val His Ser Ser Gly Ser Phe	
15 20 25	
GAG TTG CGC CTG AAG TAC TTC AGC AAC GAT CAC GGG CGG GAC AAC GAG	267
Glu Leu Arg Leu Lys Tyr Phe Ser Asn Asp His Gly Arg Asp Asn Glu	
30 35 40	
GGT CGC TGC TGC AGC GGG GAG TCG GAC GGA GCG ACG GGC AAG TGC CTG	315
Gly Arg Cys Cys Ser Gly Glu Ser Asp Gly Ala Thr Gly Lys Cys Leu	
45 50 55	
GGC AGC TGC AAG ACG CGG TTT CGC GTC TGC CTA AAG CAC TAC CAG GCC	363
Gly Ser Cys Lys Thr Arg Phe Arg Val Cys Leu Lys His Tyr Gln Ala	
60 65 70	
ACC ATC GAC ACC ACC TCC CAG TGC ACC TAC GGG GAC GTG ATC ACG CCC	411
Thr Ile Asp Thr Thr Ser Gln Cys Thr Tyr Gly Asp Val Ile Thr Pro	
75 80 85 90	
ATT CTC GGC GAG AAC TCG GTC AAT CTG ACC GAC GCC CAG CGC TTC CAG	459
Ile Leu Gly Glu Asn Ser Val Asn Leu Thr Asp Ala Gln Arg Phe Gln	
95 100 105	
AAC AAG GGC TTC ACG AAT CCC ATC CAG TTC CCC TTC TCG TTC TCA TGG	507
Asn Lys Gly Phe Thr Asn Pro Ile Gln Phe Pro Phe Ser Phe Ser Trp	
110 115 120	

FIG.13A

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CCG	GGT	ACC	TTC	TCG	CTG	ATC	GTC	GAG	GCC	TGG	CAT	GAT	ACG	AAC	AAT	555
Pro	Gly	Thr	Phe	Ser	Leu	Ile	Val	Glu	Ala	Trp	His	Asp	Thr	Asn	Asn	
		125					130					135				

AGC	GGC	AAT	GCG	CGA	ACC	AAC	AAG	CTC	CTC	ATC	CAG	CGA	CTC	TTG	GTG	603
Ser	Gly	Asn	Ala	Arg	Thr	Asn	Lys	Leu	Leu	Ile	Gln	Arg	Leu	Leu	Val	
	140					145					150					

CAG	CAG	GTA	CTG	GAG	GTG	TCC	TCC	GAA	TGG	AAG	ACG	AAC	AAG	TCG	GAA	651
Gln	Gln	Val	Leu	Glu	Val	Ser	Ser	Glu	Trp	Lys	Thr	Asn	Lys	Ser	Glu	
155					160					165					170	

TCG	CAG	TAC	ACG	TCG	CTG	GAG	TAC	GAT	TTC	CGT	GTC	ACC	TGC	GAT	CTC	699
Ser	Gln	Tyr	Thr	Ser	Leu	Glu	Tyr	Asp	Phe	Arg	Val	Thr	Cys	Asp	Leu	
				175					180					185		

AAC	TAC	TAC	GGA	TCC	GGC	TGT	GCC	AAG	TTC	TGC	CGG	CCC	CGC	GAC	GAT	747
Asn	Tyr	Tyr	Gly	Ser	Gly	Cys	Ala	Lys	Phe	Cys	Arg	Pro	Arg	Asp	Asp	
			190					195					200			

TCA	TTT	GGA	CAC	TCG	ACT	TGC	TCG	GAG	ACG	GGC	GAA	ATT	ATC	TGT	TTG	795
Ser	Phe	Gly	His	Ser	Thr	Cys	Ser	Glu	Thr	Gly	Glu	Ile	Ile	Cys	Leu	
	205						210					215				

ACC	GGA	TGG	CAG	GGC	GAT	TAC	TGT	CAC	ATA	CCC	AAA	TGC	GCC	AAA	GGC	843
Thr	Gly	Trp	Gln	Gly	Asp	Tyr	Cys	His	Ile	Pro	Lys	Cys	Ala	Lys	Gly	
	220					225					230					

TGT	GAA	CAT	GGA	CAT	TGC	GAC	AAA	CCC	AAT	CAA	TGC	GTT	TGC	CAA	CTG	891
Cys	Glu	His	Gly	His	Cys	Asp	Lys	Pro	Asn	Gln	Cys	Val	Cys	Gln	Leu	
235					240					245					250	

GGC	TGG	AAG	GGA	GCC	TTG	TGC	AAC	GAG	TGC	GTT	CTG	GAA	CCG	AAC	TGC	939
Gly	Trp	Lys	Gly	Ala	Leu	Cys	Asn	Glu	Cys	Val	Leu	Glu	Pro	Asn	Cys	
				255				260						265		

FIG.13B

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ATC CAT GGC ACC TGC AAC AAA CCC TGG ACT TGC ATC TGC AAC GAG GGT	987
Ile His Gly Thr Cys Asn Lys Pro Trp Thr Cys Ile Cys Asn Glu Gly	
270 275 280	
TGG GGA GGC TTG TAC TGC AAC CAG GAT CTG AAC TAC TGC ACC AAC CAC	1035
Trp Gly Gly Leu Tyr Cys Asn Gln Asp Leu Asn Tyr Cys Thr Asn His	
285 290 295	
AGA CCC TGC AAG AAT GGC GGA ACC TGC TTC AAC ACC GGC GAG GGA TTG	1083
Arg Pro Cys Lys Asn Gly Gly Thr Cys Phe Asn Thr Gly Glu Gly Leu	
300 305 310	
TAC ACA TGC AAA TGC GCT CCA GGA TAC AGT GGT GAT GAT TGC GAA AAT	1131
Tyr Thr Cys Lys Cys Ala Pro Gly Tyr Ser Gly Asp Asp Cys Glu Asn	
315 320 325 330	
GAG ATC TAC TCC TGC GAT GCC GAT GTC AAT CCC TGC CAG AAT GGT GGT	1179
Glu Ile Tyr Ser Cys Asp Ala Asp Val Asn Pro Cys Gln Asn Gly Gly	
335 340 345	
ACC TGC ATC GAT GAG CCG CAC ACA AAA ACC GGC TAC AAG TGT CAT TGC	1227
Thr Cys Ile Asp Glu Pro His Thr Lys Thr Gly Tyr Lys Cys His Cys	
350 355 360	
GCC AAC GGC TGG AGC GGA AAG ATG TGC GAG GAG AAA GTG CTC ACG TGT	1275
Ala Asn Gly Trp Ser Gly Lys Met Cys Glu Glu Lys Val Leu Thr Cys	
365 370 375	
TCG GAC AAA CCC TGT CAT CAG GGA ATC TGC CGC AAC GTT CGT CCT GGC	1323
Ser Asp Lys Pro Cys His Gln Gly Ile Cys Arg Asn Val Arg Pro Gly	
380 385 390	
TTG GGA AGC AAG GGT CAG GGC TAC CAG TGC GAA TGT CCC ATT GGC TAC	1371
Leu Gly Ser Lys Gly Gln Gly Tyr Gln Cys Glu Cys Pro Ile Gly Tyr	
395 400 405 410	

FIG.13C

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AGC GGA CCC AAC TGC GAT CTC CAG CTG GAC AAC TGC AGT CCG AAT CCA	1419
Ser Gly Pro Asn Cys Asp Leu Gln Leu Asp Asn Cys Ser Pro Asn Pro	
415 420 425	
TGC ATA AAC GGT GGA AGC TGT CAG CCG AGC GGA AAG TGT ATT TGC CCA	1467
Cys Ile Asn Gly Gly Ser Cys Gln Pro Ser Gly Lys Cys Ile Cys Pro	
430 435 440	
GCG GGA TTT TCG GGA ACG AGA TGC GAG ACC AAC ATT GAC GAT TGT CTT	1515
Ala Gly Phe Ser Gly Thr Arg Cys Glu Thr Asn Ile Asp Asp Cys Leu	
445 450 455	
GGC CAC CAG TGC GAG AAC GGA GGC ACC TGC ATA GAT ATG GTC AAC CAA	1563
Gly His Gln Cys Glu Asn Gly Gly Thr Cys Ile Asp Met Val Asn Gln	
460 465 470	
TAT CGC TGC CAA TGC GTT CCC GGT TTC CAT GGC ACC CAC TGT AGT AGC	1611
Tyr Arg Cys Gln Cys Val Pro Gly Phe His Gly Thr His Cys Ser Ser	
475 480 485 490	
AAA GTT GAC TTG TGC CTC ATC AGA CCG TGT GCC AAT GGA GGA ACC TGC	1659
Lys Val Asp Leu Cys Leu Ile Arg Pro Cys Ala Asn Gly Gly Thr Cys	
495 500 505	
TTG AAT CTC AAC AAC GAT TAC CAG TGC ACC TGT CGT GCG GGA TTT ACT	1707
Leu Asn Leu Asn Asn Asp Tyr Gln Cys Thr Cys Arg Ala Gly Phe Thr	
510 515 520	
GGC AAG GAT TGC TCT GTG GAC ATC GAT GAG TGC AGC AGT GGA CCC TGT	1755
Gly Lys Asp Cys Ser Val Asp Ile Asp Glu Cys Ser Ser Gly Pro Cys	
525 530 535	
CAT AAC GGC GGC ACT TGC ATG AAC CGC GTC AAT TCG TTC GAA TGC GTG	1803
His Asn Gly Gly Thr Cys Met Asn Arg Val Asn Ser Phe Glu Cys Val	
540 545 550	

FIG.13D

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TGT	GCC	AAT	GGT	TTC	AGG	GGC	AAG	CAG	TGC	GAT	GAG	GAG	TCC	TAC	GAT	1851
Cys	Ala	Asn	Gly	Phe	Arg	Gly	Lys	Gln	Cys	Asp	Glu	Glu	Ser	Tyr	Asp	
555					560					565					570	

TCG GTG ACC TTC GAT GCC CAC CAA TAT GGA GCG ACC ACA CAA GCG AGA 1899
Ser Val Thr Phe Asp Ala His Gln Tyr Gly Ala Thr Thr Gln Ala Arg
575 580 585

GCC GAT GGT TTG ACC AAT GCC CAG GTA GTC CTA ATT GCT GTT TTC TCC 1947
Ala Asp Gly Leu Thr Asn Ala Gln Val Val Leu Ile Ala Val Phe Ser
590 595 600

GTT GCG ATG CCT TTG GTG GCG GTT ATT GCG GCG TGC GTG GTC TTC TGC 1995
Val Ala Met Pro Leu Val Ala Val Ile Ala Ala Cys Val Val Phe Cys
605 610 615

ATG AAG CGC AAG CGT AAG CGT GCT CAG GAA AAG GAC GAC GCG GAG GCC 2043
Met Lys Arg Lys Arg Lys Arg Ala Gln Glu Lys Asp Asp Ala Glu Ala
620 625 630

AGG AAG CAG AAC GAA CAG AAT GCG GTG GCC ACA ATG CAT CAC AAT GGC 2091
Arg Lys Gln Asn Glu Gln Asn Ala Val Ala Thr Met His His Asn Gly
635 640 645 650

AGT GGG GTG GGT GTA GCT TTG GCT TCA GCC TCT CTG GGC GGC AAA ACT 2139
Ser Gly Val Gly Val Ala Leu Ala Ser Ala Ser Leu Gly Gly Lys Thr
655 660 665

GGC AGC AAC AGC GGT CTC ACC TTC GAT GGC GGC AAC CCG AAT ATC ATC 2187
Gly Ser Asn Ser Gly Leu Thr Phe Asp Gly Gly Asn Pro Asn Ile Ile
670 675 680

AAA AAC ACC TGG GAC AAG TCG GTC AAC AAC ATT TGT GCC TCA GCA GCA 2235
Lys Asn Thr Trp Asp Lys Ser Val Asn Asn Ile Cys Ala Ser Ala Ala
685 690 695

FIG. 13E

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GCA GCG GCG GCG GCG GCA GCA GCG GCG GAC GAG TGT CTC ATG TAC GGC 2283
 Ala Ala Ala Ala Ala Ala Ala Ala Ala Asp Glu Cys Leu Met Tyr Gly
 700 705 710

GGA TAT GTG GCC TCG GTG GCG GAT AAC AAC AAT GCC AAC TCA GAC TTT 2331
 Gly Tyr Val Ala Ser Val Ala Asp Asn Asn Asn Ala Asn Ser Asp Phe
 715 720 725 730

TGT GTG GCT CCG CTA CAA AGA GCC AAG TCG CAA AAG CAA CTC AAC ACC 2379
 Cys Val Ala Pro Leu Gln Arg Ala Lys Ser Gln Lys Gln Leu Asn Thr
 735 740 745

GAT CCC ACG CTC ATG CAC CGC GGT TCG CCG GCA GGC AGC TCA GCC AAG 2427
 Asp Pro Thr Leu Met His Arg Gly Ser Pro Ala Gly Ser Ser Ala Lys
 750 755 760

GGA GCG TCT GGC GGA GGA CCG GGA GCG GCG GAG GGC AAG AGG ATC TCT 2475
 Gly Ala Ser Gly Gly Gly Pro Gly Ala Ala Glu Gly Lys Arg Ile Ser
 765 770 775

GTT TTA GGC GAG GGT TCC TAC TGT AGC CAG CGT TGG CCC TCG TTG GCG 2523
 Val Leu Gly Glu Gly Ser Tyr Cys Ser Gln Arg Trp Pro Ser Leu Ala
 780 785 790

GCG GCG GGA GTG GCC GGA GCC TGT TCA TCC CAG CTA ATG GCT GCA GCT 2571
 Ala Ala Gly Val Ala Gly Ala Cys Ser Ser Gln Leu Met Ala Ala Ala
 795 800 805 810

TCG GCA GCG GGC AGC GGA GCG GGG ACG GCG CAA CAG CAG CGA TCC GTG 2619
 Ser Ala Ala Gly Ser Gly Ala Gly Thr Ala Gln Gln Gln Arg Ser Val
 815 820 825

GTC TGC GGC ACT CCG CAT ATG TAACTCCAAA AATCCGGAAG GGCTCCTGGT 2670
 Val Cys Gly Thr Pro His Met
 830

AAATCCGGAG AAATCCGCAT GGAGGAGCTG ACAGCACATA CACAAAGAAA AGACTGGGTT 2730

GGGTTCAAAA TGTGAGAGAG ACGCCAAAAT GTTGTGTTG ATTGAAGCAG TTAGTCGTC 2790

ACGAAAAATG AAAAATCTGT AACAGGCATA ACTCGTAAAC TCCCTAAAAA ATTTGTATAG 2850

TAATTAGCAA AGCTGTGACC CAGCCGTTTC GATCCCGAAT TC 2892

FIG.13F

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2889 GATCTACTAC

GAGGAGGTTAAGGAGAGCTATGTGGGCGAGCGACGCGAATACGATCCCCACATCACCGATCCCAGGGTC
ACACGCATGAAGATGGCCGGCCTGAAGCCCAACTCCAAATACCGCATCTCCATCACTGCCACCACGAAA
ATGGGCGAGGGATCTGAACACTATATCGAAAAGACCACGCTCAAGGATGCCGTCAATGTGGCCCCCTGCC
ACGCCATCTTTCTCCTGGGAGCAACTGCCATCCGACAATGGACTAGCCAAGTTCCGCATCAACTGGCTG
CCAAGTACCGAGGGTCATCCAGGCACTCACTTCTTTACGATGCACAGGATCAAGGGCGAAACCCAATGG
ATACGCGAGAATGAGGAAAAGAACTCCGATTACCAGGAGGTGGGTGGCTTAGATCCGGAGACCGCCTAC
GAGTTCCGCGTGGTGTCCGTGGATGGCCACTTTAACACGGAGAGTGCCACGCAGGAGATCGACACGAAC
ACCGTTGAGGGACCAATAATGGTGGCCAACGAGACGGTGGCCAATGCCGGATGGTTCATTGGCATGATG
CTGGCCCTGGCCTTCATCATCATCCTCTTCATCATCATCTGCATTATCCGACGCAATCGGGGCGGAAAG
TACGATGTCCACGATCGGGAGCTGGCCAACGGCCGGCGGGATTATCCCGAAGAGGGCGGATTCCACGAG
TACTCGCAACCGTTGGATAACAAGAGCGCTGGTCGCCAATCCGTGAGTTCAGCGAACAACCGGGCGTG
GAAAGCGATACTGATTGATGGCCGAATACGGTGATGGCGATACAGGACAATTTACCGAGGATGGCTCC
TTCATTGGCCAATATGTTCTGGAAAGCTCCAACCGCCGGTTAGCCACAGCCACTGAACAATTCCGCT
GCGGCGCATCAGGCGGCGCCAACCTGCCGGAGGATCGGGAGCAGCCGGATCGGCAGCAGCAGCCGGAGCA
TCGGGTGGAGCATCGTCCGCCGGAGGAGCAGCTGCCAGCAATGGAGGAGCTGCAGCCGGAGCCGTGGCC
ACCTACGTCTAAGCTTGGTACC 3955

FIG.14

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FIG. 15A

1 CCGAGTCGAGCGCCGTGCTTCGAGCGGTGATGAGCCCTTTCTGTCAACGCTAAAGATC
 121 AAGCACATACTAAGTCCATATAATAATAATTGTGTGTGATAACAACATTAT
 241 GGCCGTTATTCAGCTATCCAGAGCAAGTGTAGTGTGCAAAATAGAAACAACAAGGCA
 361 CAATCCAGAGTGATCCGAAACAACCTCCATCTAGATCGCCAACCAAGCATCAGCTCGCA

481 TCGTCGTTGGAGTCAACAATAGAAATCAGCAGACGCTGGGAATGTCCAAGAGACGGCG
 SerSerLeuGluSerThrIleGluSerAlaAspSerLeuGlyMetSerLysLysThrAla

601 CGCGATTGTCGATCATTAAGTCTGCCTGCAACTTAATTGCTTTAATTTAATACTGTTA
 ArgAspCysArgSerLeuLysSerAlaCysAsnLeuIleAlaLeuIleLeuLeu

721 AACAGCCATCTACTCAACGGCTATTGCTGGGCATGCCAGCGGAAGTTAGGGCCACCAAG
 AsnSerHisLeuLeuAsnGlyTyrCysCysGlyMetProAlaGluLeuArgAlaThrLys

841 AC[GAGCAGGGTGCCAGCATATCCACGGGCTGTTGCTTTGGCAAGGCCACCACCAAGATA
 ThrGluGlnGlyAlaSerIleSerThrGlyCysSerPheGlyAsnAlaThrThrLysIle

961 ACGTTTCGTTGGACGAAGTCGTTACGCTGATACGCAGCGGTGGATATGTACACACA
 ThrPheArgTrpThrLysSerPheThrLeuIleLeuGlnAlaLeuAspMetTyrAsnThr

#3

1081 TCGCCGGAGTGGAAGACCTGGACCACATCGGGCGGACGCGGGATCACCTACCGTGTC
 SerProGluTrpLysThrLeuAspHisIleGlyArgAsnAlaArgIleThrTyrArgVal

1201 GACGATCAGTTCGGTCAQTACGCCCTGCGGCTCCGAGGGTCAGAAAGCTCTGCCCTGAATGGC
 AspAspGlnPheGlyHisThrAlaCysGlySerGluGlyGlnLysLeuCysLeuAsnGly

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TACAAACATCAGCGCCTATCAAGTGGAGTGTCAAGTGTGAACAAACAAACGAGAG
CCAAACAAACCAACAAACGAGCAAGTGGAGAAATGATACAGCATCCAGAGTAC
CCAAATCTGCATACATGGCTAATTAGGCTGCCAGCGAATTACATTTGTGTGTGC
AACGCCCCAGATGTACAAATGTTAGGAACATTTTCGGCGAAACACGCTACGTGC
MetPheArgLysHisPheArgArgLysProAlaThrSer 13
ACAAAAGGAGCGTCCGAGGCATCGGTACCCAAATCGCGACCCCTGCCATCGACGATC
ThrLysArgGlnArgProArgHisArgValProLysIleAlaThrLeuProSerThrIle 53
GTCCATAAGATATCCGCAGCTGGTAAC TTCGAGCTGGAAATATTAGAAATCTCAATACC
ValHisLysIleSerAlaAlaGlyAsnPheGluLeuGluIleLeuGluIleSerAsnThr 93
-----#1
ACGATAGGCTGCTGCCATGCACGACGGCATTCGGGCTGTGCCGTGAAGGAGTACCAGACC
ThrIleGlyCysSerProCysThrThrAlaPheArgLeuCysLeuLysGluTyrGlnThr 133
#2
CTGGGTGGCTCCAGCTTTGTGCTCAGCGATCCGGGTGTGGAGCCATTGTGTGCCCTTT
LeuGlyGlySerSerPheValLeuSerAspProGlyValGlyAlaIleValLeuProPhe 173
TCCTATCCAGATCGGAGAGGTTAATTGAGGAACATCATCTCGGGCGTGATACGCGG
SerTyrProAspAlaGluArgLeuIleGluGluThrSerTyrSerGlyValIleLeuPro 213
#4
CGGGTGCAATGCGCCGTACCTACTACAACACGACCTGCACGACCTTGTGCCGTCCGCGG
ArgValGlnCysAlaValThrTyrTyrAsnThrThrCysThrThrPheCysArgProArg 253
TGGCAGGGCGTCAACTCGGAGGAGGCCATATGCAAGGCGGGCTGCACCCCGTCCACGGC
TrpGlnGlyValAsnCysGluGluAlaIleCysLysAlaGlyCysAspProValHisGly 293

FIG. 15B

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FIG. 16C

PRIMER cdc3: 5' TC CAT ATG ATC IGT AAT ITC ICG ATT 3'

 G G T G

 T

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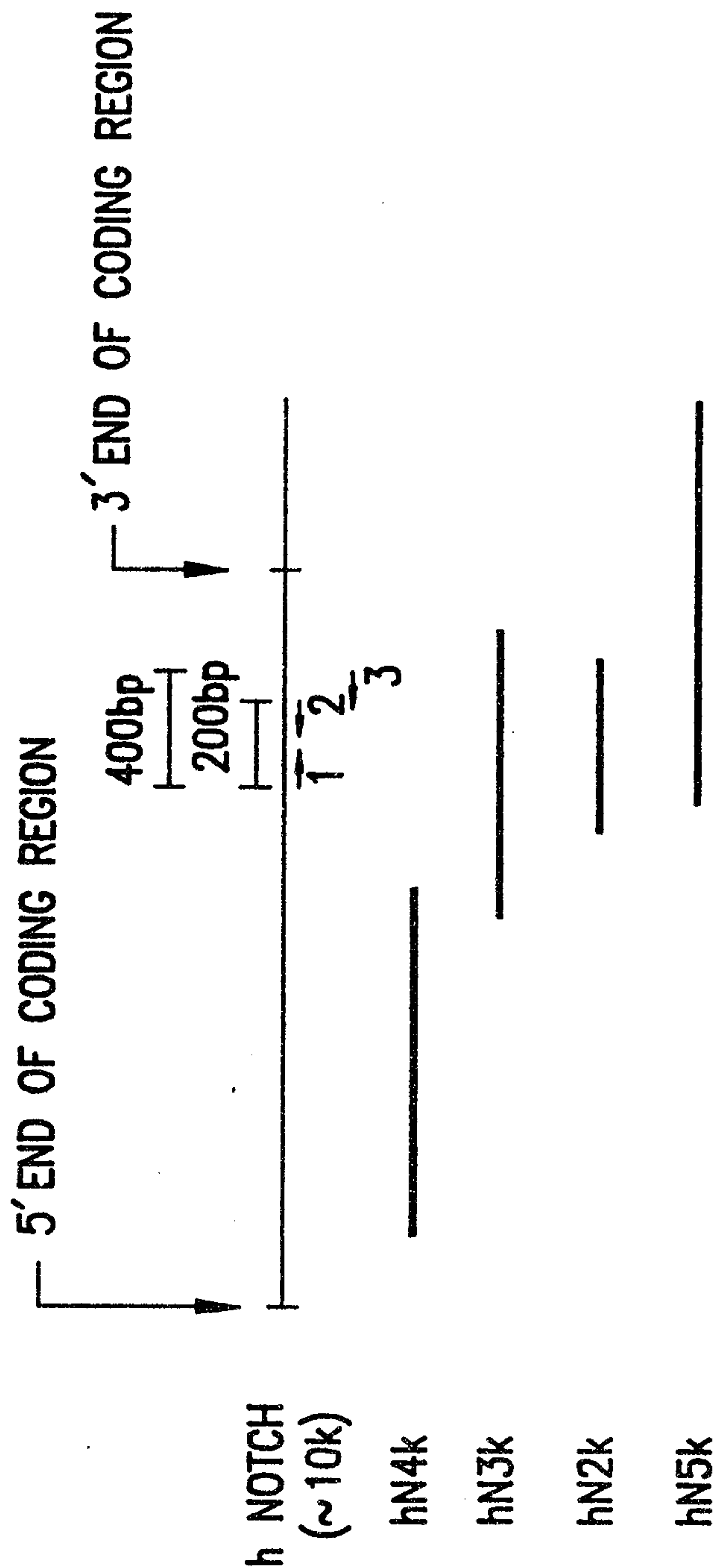
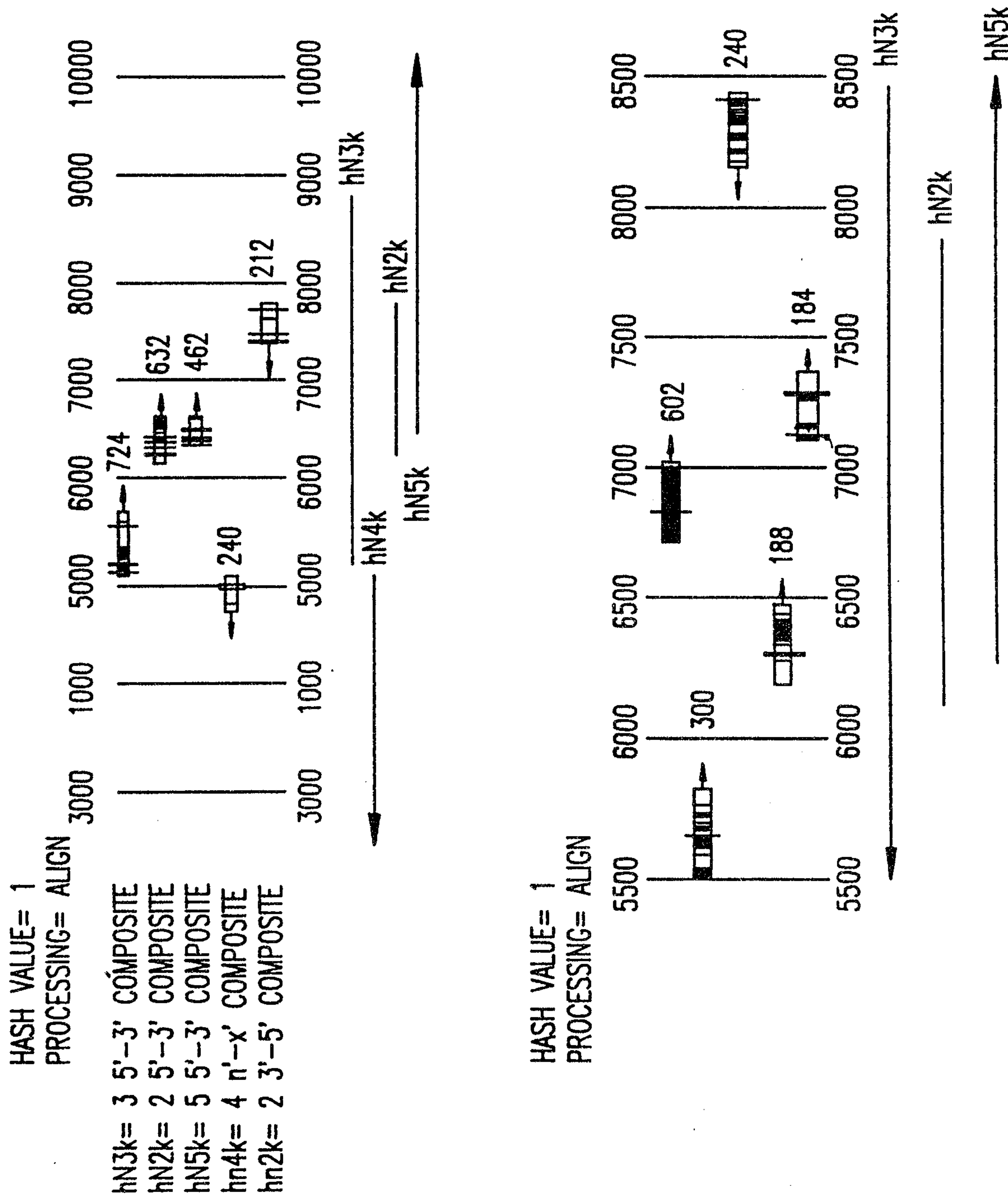


FIG.17

FIG. 18



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1 GAATTCGCT GGGAGAATGG TCTGAGCTAC CTGCCCCTCC TGCTGGGGCA TCAATGGCAA
61 GTGGGGAAAG CCACACTGGG CAAACGGGCC AGGCCATTTC TGGAAATGTGG TACATGGTGG
121 GCAGGGGGCC CGCAACAGCT GGAGGGCAGG TGGACTGAGG CTGGGGATCC CCCGCTGGTT
181 GGGCAATACT GCCTTTACCC ATGAGCTGGA AAGTCACAAT GGGGGGCAAG GGCTCCCGAG
241 GGTGGTTATG TGCTTCCTTC AGGTGGC

FIG.19A

1 GAATTCCTTC CATTATACGT GACTTTTCTG AAAGTGTAGC CACCCTAGTG TCTCTAACTC
61 CCTCTGGAGT TTGTCAGCTT TGGTCTTTTC AAAGAGCAGG CTCTCTTCAA GCTCCTTAAT
121 GCGGGCATGC TCCAGTTTGG TCTGCGTCTC AAGATCACCT TTGGTAATTG ATTCTTCTTC
181 AACCCGGAAC TGAAGGCTGG CTCTCACCCCT CTAGGCAGAG CAGGAATTCC GAGGTGGATG
241 TGTTAGATGT GAATGTCCGT GGCCCAGATG GCTGCACCCC ATTGATGTTG GCTTCTCTCC
301 GAGGAGGCAG CTCAGATTG AGTGATGAAG ATGAAGATGC AGAGGACTGT TCTGCTAACA
361 TCATCACAGA CTTGGTCTAC CAGGGTGCCA GCCTCCAGNC CAGACAGACC GGACTGGTGA
421 GATGGCCCTG CACCTTGCA G CCCGCTACTC ACGGGCTGAT GCTGCCAAGC GTCTCCTGGA
481 TGCAGGTGCA GATGCCAATG CCCAGGACAA CATGGGCCGC TGTCCACTCC ATGCTGCAGT
541 GGCACGTGAT GCCAAGGTGT ATTCAGATCT GTTA

FIG.19B

1 TCCAGATTCT GATTCGCAAC CGAGTAACTG ATCTAGATGC CAGGATGAAT GATGGTACTA
61 CACCCCTGAT CCTGGCTGCC CGCCTGGCTG TGGAGGGAAT GGTGGCAGAA CTGATCAACT
121 GCCAAGCGGA TGTGAATGCA GTGGATGACC ATGGAAAATC TGCTCTTCAC TGGGCAGCTG
181 CTGTCAATAA TGTGGAGGCA ACTCTTTTGT TGTGAAAAA TGGGGCCAAC CGAGACATGC
241 AGGACAACAA GGAAGAGACA CCTCTGTTTC TTGCTGCCCG GGAGGAGCTA TAAGC

FIG.19C

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1 GAATTCCCAT GAGTCGGGAG CTTCGATCAA AATTGATGAG CCTTTAGAAG GATCCGAAGA
61 TCGGATCATT ACCATTACAG GAACAGGCAC CTGTAGCTGG TGGCTGGGGG TGTGTGCCAC
121 AGGCGAGGAG TAGCTGTGCT GCGAGGGGGG CGTCAGGAAC TGGGCTGCGG TCACGGGTGG
181 GACCAGCGAG GATGGCAGCG ACGTGGGCAG GCGGGGGCTC TCCTGGGGCA GAATAGTGTG
241 CACCGCCAGG CTGCTGGGGC CCAGTACTGC ACGTCTGCCT GGCTCGGCTC TCCACTCAGG
301 AAGCTCCGGC CCAGGTGGCC GCTGGCTGCT GAG

FIG.20A

1 GAATTCCTGC CAGGAGGACG CGGGCAACAA GGTCTGCAGC CTGCAGTGCA ACAACCACGC
61 GTGCGGCTGG GACGGCGGTG ACTGCTCCCT CAACTTCACA ATGACCCCTG GAAGAACTGC
121 ACGCAGTCTC TGCAGTGCTG GAAGTACTTC AGTGACGGCC ACTGTGACAC CCAGTGCAAC
181 TCAGCCGGCT GCCTCTTCGA CGGCTTTGAC TGCCAGCGGC GGAAGGCCAG TTGCAACCCC
241 CTGTACGACC AGTACTGCAA GGACCACTTG AGCGACGGGC ACTGCGACCA GGGCTGCAAC
301 AGCGCGGAGT NCAGNTGGGA CGGGCTGGAC TGTGCGGCAG TGTACCCGAG AGCTGGCGGC
361 GCACGCTGGT GGTGGTGGTG CTGATGCCGC CGGAGCAGCT GCGCAACAGC TCCTTCCACT
421 TCCTGCGGGA CGTCAGCCGC GTGCTGCACA CCAACGTGTC TTCAAGCGTG ACGCACACGG
481 CCAGCAGATG ATGTTCCCTT ACTACGGCCG CGAGGAGGAG CTGCGCAAGC CCCATCAAGC
541 GTGCCGCCGA GGGCTGGGCC GCACCTGACG CCTGCTGGGC CA

FIG.20B

1 TCAGCCGAGT GCTGCACACC AACGTGTCTT CAAGCGTGAC GCACACGGCC AGCAGATGAT
61 GTTCCCCTAC TACGGCCGCG AGGAGGAGCT GCGCAAGCCC CATCAAGCGT GCCGCCGAGG
121 GCTGGGCCGC ACCTGACGCC TGCTGGGCCA

FIG.20C

1 TTACCATTAC AGGAACAGGC ACCTGTAGCT GGTGGCTGGG GGTGTTGTCC ACAGGCGAGG
61 AGTAGCTGTG CTGCGAGGGG GCGTCAGGA ACTGGGCTGC GGTACGGGT GGGACCAGCG
121 AGGATGGCAG CGACGTGGGC AGGGCGGGGC TCTCCTGGGG CAGAATAGTG TGCACCGCCA
181 GCTGCTGGGG CCCAGTGCTG CACGTCTGCC TGGCTCGGCT CTCCACTCAG GAAGCTCCGG
241 CCCAGGT

FIG.20D

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1 GAATTCCATT CAGGAGGAAA GGGTGGGGAG AGAAGCAGGC ACCCACTTTC CCGTGGCTGG
61 ACTCGTTCCC AGGTGGCTCC ACCGGCAGCT GTGACCGCCG CAGGTGGGGG CGGAGTGCCA
121 TTCAGAAAAT TCCAGAAAAG CCCTACCCCA ACTCGGACGG CAACGTCACA CCCGTGGGTA
181 GCAACTGGCA CACAAACAGC CAGCGTGTCT GGGGCACGGG GGGATGGCAC CCCCTGCAGG
241 CAGAGCTG

FIG.21A

1 CTAAAGGGAA CAAAAGCNGG AGCTCCACCG CGGGCGGCNC NGCTCTAGAA CTAGTGGANN
61 NCCCGGGCTG CAGGAATTCC GGCGGACTGG GCTCGGGCTC AGAGCGGCGC TGTGGAAGAG
121 ATTCTAGACC GGGAGAACAA GCGAATGGCT GACAGCTGGC CTCCAAAGTC ACCAGGCTCA
181 AATCGCTCGC CCTGGACATC GAGGGATGCA GAGGATCAGA ACCGGTACCT GGATGGCATG
241 ACTCGGATTT ACAAGCATGA CCAGCCTGCT TACAGGGAGC GTGANNTTTT CACATGCAGT
301 CGACAGACAC GAGCTCTATG CAT

FIG.21B

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1 GAATTCCGAG GTGGATGTGT TAGATGTGAA TGTCCGTGGC CCAGATGGCT GCACCCCAT
61 GATGTTGGCT TCTCTCCGAG GAGGCAGCTC AGATTTGAGT GATGAAGATG AAGATGCAGA
121 GGA CTCTTCT GCTAACATCA TCACAGACTT GGTCTTACCA GGGTGCCAGC CTTCCAGGCC
181 CAAGAACAGA CCGGACTTGG TGAGATGGCC CTGCACCTTG CAGCCCGCTA CTACGGGCTG
241 ATGCTGCCAA GGTTCCTGGAT GCAGGTGCAG ATGCCAATGC CCAGGACAAC ATGGGCCGCT
301 GTCCACTCCA TGCTGCAGTG GCACTGATGC

FIG.22A

1 CAGAGGATGG TGAGGGTCCA TGCAGATAGG TTCTCCCCAT CCTGTGAATA ATAAATGGGT
61 GCAAGGGCAG AGAGTCACCA TTTAGAATGA TAAAATGTTT GCACACTATG AAAGAGGCTG
121 ACAGAATGTT GCCACATGGA GAGATAAAGC AGAGAATGAA CAAACTT

FIG.22B

1 AGGATGAATG ATGGTACTAC ACCCCTGATC CTGGCTGCCC GCCTGGCTGT GGAGGGAATG
61 GTGGCAGAAC TGATCAACTG CCAAGCGGAT GTGAATGCAG TGGATGACCA TGGAAAATCT
121 GCTCTTCACT GGGCAGCTGC TGTCAATAAT GTGGAGGCAA CTCTTTTGTT GTTGAAAAAT
181 GGGGCCAACC GAGACATGCA GGACAACAAG GAAGAGACAC CTCTG

FIG.22C

1 AATAATAAAT GGGTGCAAGG GCAGAGAGTC ACCATTTAGA ATGATAAAAT GTTTGCACAC
61 TATGAAAGAG GCTGACAGAA TGTTGCCACA TGGAGAGATA AAGCAGAGAA TGAACAAACT
121 T

FIG.22D

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10	20	30	40
* * * *	* * * *	* * * *	* * * *
TGC CAG GAG GAC GCG GGC AAC AAG GTC TGC AGC CTG CAG TGC AAC AAC			
C Q E D A G N K V C S L Q C N N>			
50	60	70	80
* * * *	* * * *	* * * *	* * * *
CAC GCG TGC GGC TGG GAC GGC GGT GAC TGC TCC CTC AAC TTC AAT GAC			
H A C G W D G G D C S L N F N D>			
100	110	120	130
* * * *	* * * *	* * * *	* * * *
CCC TGG AAG AAC TGC ACG CAG TCT CTG CAG TGC TGC TGG AAG TAC TTC AGT			
P W K N C T Q S L Q C C W K Y F S>			
150	160	170	180
* * * *	* * * *	* * * *	* * * *
GAC GGC CAC TGT GAC AGC CAG TGC AAC TCA GCC GGC TGC CTC TTC GAC			
D G H C D S Q C N S A G C L F D>			

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FIG. 23 A

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200	210	220	230	240
* GGC TTT GAC TGC CAG CGT GCG GAA GGC CAG TGC AAC CCC CTG TAC GAC	* * * * *			
G F D C Q R A E G Q C N P L Y D> -				
250	260	270	280	
* CAG TAC TGC AAG GAC CAC TTC AGC GAC GGC CAC TGC GAC CAG GGC TGC	* * * * *			
Q Y C K D H F S D G H C D Q G C>				
290	300	310	320	330
* AAC AGC GCG GAG TGC GAG TGG GAC GGC CTG GAC TGT GCG GAG CAT GTA	* * * * *			
N S A E C E W D G L D C A E H V>				
340	350	360	370	380
* CCC GAG AGG CTG GCG GCC GCG ACG CTG GTG GTG GTG CTG ATG CCG	* * * * *			
P E R L A A G T L V V V V L M P>				

FIG.23B

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390	400	410	420	430
* * *	* * *	* * *	* * *	* * *
CCG GAG CAG CTG CGC AAC AGC TCC TTC CAC TTC CTG CGG GAG CTC AGC				
P E Q L R N S S F H F L R E L S>				
440	450	460	470	480
* * *	* * *	* * *	* * *	* * *
CGC GTG CTG CAC ACC AAC GTG GTC TTC AAG CGT GAC GCA CAC GGC CAG				
R V L H T N V F K R D A H G Q>				
490	500	510	520	
* * *	* * *	* * *	* * *	
CAG ATG ATC TTC CCC TAC TAC GGC CGC GAG GAG GAG CTG CGC AAG CAC				
Q M I F P Y Y G R E E L R K H>				
530	540	550	560	570
* * *	* * *	* * *	* * *	* * *
CCC ATC AAG CGT GCC GGC GAG GGC TGG GCC GCA CCT GAC GCC CTG CTG				
P I K R A A E G W A A P D A L L>				

FIG.23C

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580	*					590				600				610		620	
	*		*	*	*		*	*	*		*	*	*		*	*	
GGC	CAG	GTG	AAG	GCC	TCG	CTG	CTC	CCT	GGT	GGC	AGC	GAG	GGT	GGG	CGG		
G	Q	V	K	A	S	L	L	P	G	G	S	E	G	G	R>		
630	*					640				650				660		670	
	*	*	*	*	*		*	*	*		*	*	*		*	*	
CGG	CGG	AGG	GAG	CTG	GAC	CCC	ATG	GAC	GTC	CGC	GGC	TCC	ATC	GTC	TAC		
R	R	E	L	D	P	M	D	V	R	G	S	I	V	Y>			
680	*					690				700				710		720	
	*	*	*	*	*		*	*	*		*	*	*		*	*	
CTG	GAG	ATT	GAC	AAC	CGG	CAG	TGT	GTG	CAG	GCC	TCC	TCG	CAG	TGC	TTC		
L	E	I	D	N	R	Q	C	V	Q	A	S	S	Q	C	F>		
730	*					740				750				760			
	*	*	*	*	*		*	*	*		*	*	*		*		
CAG	AGT	GCC	ACC	GAC	GTG	GCC	GCA	TTC	CTG	GGA	GCG	CTC	GCC	TCG	CTG		
Q	S	A	T	D	V	A	A	F	L	G	A	L	A	S	L>		

FIG.23D

770	*					790		800		810	*
	*		*	*	*		*	*	*	*	*
		GGC AGC CTC AAC ATC CCC TAC AAG ATC GAG GCC GTG CAG AGT GAG ACC									
		G S L N I P Y K I E A V Q S E T>-									
820	*					840		850		860	*
	*		*	*	*		*	*	*	*	*
		GTG GAG CCG CCC CCG CCG GCG CAG CTG CAC TTC ATG TAC GTG GCG GCG									
		V E P P P A Q L H F M Y V A A>									
870	*					890		900		910	*
	*		*	*	*		*	*	*	*	*
		GCC GCC TTT GTG CTT CTG TTC TTC GTG GGC TGC GGG GTG CTG CTG TCC									
		A A F V L L F F V G C G V L L S>									
920	*					940		950		960	*
	*		*	*	*		*	*	*	*	*
		CGC AAG CGC CGG CAG CAT GGC CAG CTC TGG TTC CCT GAG GGC TTC									
		R K R R Q H G Q L W F P E G F>									

FIG. 23E

	970	980	990	1000
AAA	GTG	TCT	GAG	GCC
	TCT	GAG	GCC	AGC
	GAG	GCC	AGC	AAG
	GCC	AGC	AAG	AAG
	AGC	AAG	AAG	CGG
	CGG	CGG	CGG	GAG
	GAG	GAG	GAG	CCC
	CCC	CCC	CCC	CTC
	CTC	CTC	CTC	GGC
	GGC	GGC	GGC	GAG
K	V	S	E	A
	S	E	A	S
	E	A	S	K
	A	S	K	K
	S	K	K	R
	R	R	R	E
	E	E	E	P
	P	P	P	L
	L	L	L	G
	G	G	G	E
	E	E	E	>

[illegible]

1060	1070	1080	1090	1100
ATG GAC GAC AAC CAG AAT GAG TGG GGG GAC GAC CTG GAG ACC AAG				
M D D N Q N E W G D D E L E T K>				

	1110	1120	1130	1140	1150
*	*	*	*	*	*
AAG TTC CGG TTC GAG GAG CCC GTG GTT CTG CCT GAC CTG GAC GAC CAG					
K F R F E E P V L P D L D Q>					

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FIG. 23F

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1160 * 1170 * 1180 * 1190 * 1200 *

ACA GAC CAC CGG CAG TGG ACT CAG CAG CAC CTG GAT GCC GCT GAC CTG
T D H R Q W T Q Q H L D A D L>

1210 1220 1230 1240
* * * *
CGC ATG TCT GCC ATG GCC CCC ACA CCG CCC CAG GGT GAG GTT GAC GCC
R M S A M A P T P P Q G E V D A>

1250 1260 1270 1280 1290
* * * * *
GAC TGC ATG GAC GTC AAT GTC CGC GGG CCT GAT GGC TTC ACC CCG CTC
D C M D V N V R G P D G F T P L>

1300 1310 1320 1330 1340
* * * * *
ATG ATC GCC TCC TGC AGC GGG GGC GGC CTG GAG ACG GGC AAC AGC GAG
M I A S C G G G L E T G N S E>

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FIG. 23G

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1350	1360	1370	1380	1390
* GAA GAG GAG GAC GCG CCG GCC GTC ATC TCC GAC TTC ATC TAC CAG GGC				*
E E E D A P A V I S D F I Y Q G>				
1400	1410	1420	1430	1440
* GCC AGC CTG CAC AAC CAG ACA GAC CGC ACG GCC GAG ACC GCC TTG CAC				*
A S L H N Q T D R T G E T A L H>				
1450	1460	1470	1480	
* CTG GCC GCC CGC TAC TCA CGC TCT GAT GCC GCC AAG CGC CTG CTG GAG				*
L A A R Y S R S D A A K R L L E>				
1490	1500	1510	1520	1530
* GCC AGC GCA GAT GCC AAC ATC CAG GAC AAC ATG GGC CGC ACC CCG CTG				*
A S A D A N I Q D N M G R T P L>				

FIG. 23H

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1540 1550 1560 1570 1580
* * * * *
CAT GCG GCT GTG TCT GCC GAC GCA CAA GGT GTC TTC CAG ATC CTG ATC
H A A V S A D A Q G V F Q I L I>

1590 1600 1610 1620 1630
* * * * *
CGG AAC CGA GCC ACA GAC CTG GAT GCC CGC ATG CAT GAT GGC ACG ACG
R N R A T D L D A R M H D G T T>

1640 1650 1660 1670 1680
* * * * *
CCA CTG ATC CTG GCT GCC CGC CTG GCC GTG GAG GGC ATG CTG GAG GAC
P L I L A A R L A V E G M L E D>

1690 1700 1710 1720
* * * *
CTC ATC AAC TCA CAC GCC GAC GTC AAC GCC GTA GAT GAC CTG GGC AAG
L I N S H A D V N A V D D L G K>

1730 1740 1750 1760 1770
* * * * *
TCC GCC CTG CAC TGG GCC GCC GCG AAC AAT GTG GAT GCC GCA GTT
S A L H W A A A V N V D A A V>

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FIG. 231

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1780	1790	1800	1810	1820
* GTG CTC CTG AAG AAC GGG GCT AAC AAA GAT ATG CAG AAC AAC AGG GAG	* * * *	* * *	* * *	* * *
V L L K N G A N K D M Q N R E>				
1830	1840	1850	1860	1870
* * * *	* * *	* * *	* * *	* * *
GAG ACA CCC CTG TTT CTG GCC GCC CGG GAG GGC AGC TAC GAG ACC GCC				
E T P L F L A A R E G S Y E T A>				
1880	1890	1900	1910	1920
* * * *	* * *	* * *	* * *	* * *
AAG GTG CTG CTG GAC CAC TTT GCC AAC CGG GAC ATC ACG GAT CAT ATG				
K V L L D H F A N R D I T D H M>				
1930	1940	1950	1960	
* * * *	* * *	* * *	* * *	
GAC CGC CTG CCG CGC GAC ATC GCA CAG GAG CGC ATG CAT CAC GAC ATC				
D R L P R D I A Q E R M H D I>				

FIG.23J

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1970	1980	1990	2000	2010	
* GTG AGG CTG CTG GAC GAG TAC AAC CTG GTG CGC AGC CCG CAG CTG CAC	* * * * *				
V R L L D E Y N L V R S P Q L H>					
2020	2030	2040	2050	2060	
* * * * *					
GGA GCC CCG CTG GGG GGC ACG CCC ACC CTG TCG CCC CCG CTC TGC TCG					
G A P L G G T P T L S P L C S>					
2070	2080	2090	2100	2110	
* * * * *					
CCC AAC GGC TAC CTG GGC AGC CTC AAG CCC GGC GTG CAG GGC AAG AAG					
P N G Y L L G S L K P G V Q G K K>					
2120	2130	2140	2150	2160	
* * * * *					
GTC CGC AAG CCC AGC AGC AAA GGC CTG GCC TGT GGA AGC AAG GAG GCC					
V R K P S S K G L A C G S K E A>					

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FIG.23K

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2170 2180 2190 2200
 * * * *
 AAG GAC CTC AAG GCA CGG AGG AAG AAG TCC CAG GAT GGC AAG GGC TCC
 K D L K A R R K R K S Q D G K G C>

2210 2220 2230 2240 2250
 * * * * *
 CTG CTG GAC AGC TCC GGC ATG CTC TCG CCC GTG GAC TCC CTG GAG TCA
 L L D S S G M L S P V D S L E S>

2260 2270 2280 2290 2300
 * * * * *
 CCC CAT GGC TAC CTG TCA GAC GTG GCC TCG CCG CCA CTG CTG CCC TCC
 P H G Y L S D V A S P P L L P S>

2310 2320 2330 2340 2350
 * * * * *
 CCG TTC CAG CAG TCT CCG TCC GTG CCC CTC AAC CAC CTG CCT GGG ATG
 P F Q Q S S P S V P L N H L P G M>

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FIG. 23L

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2360	2370	2380	2390	2400
* CCC GAC ACC CAC CTG GGC ATC GGG CAC CTG AAC GTG GCG GCC AAG CCC	* P D T H L G I G H L N V A A K P>	* *	* *	* *
2410	2420	2430	2440	
* GAG ATG GCG GCG CTG GGT GGC GGC GGC CTG GCC TTT GAG ACT GGC	* E M A A L G G G G R L A F E T G>	* *	* *	
2450	2460	2470	2480	2490
* CCA CCT CGT CTC TCC CAC CTG CCT GTC GGC TCT GGC ACC AGC ACC GTC	* P P R L S H L P V A S G T S T V>	* *	* *	* *
2500	2510	2520	2530	2540
* CTG GGC TCC AGC AGC GGA GGG GCC CTG AAT TTC ACT GTG GGC GGC TCC	* L G S S G G A L N F T V G G S>	* *	* *	* *

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FIG.23 M

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2550	2560	2570	2580	2590
* ACC AGT TTG AAT GGT CAA TGC GAG TGG CTG TCC CGG CTG CAG AGC GGC T S L N G Q C E W L S R L Q S G>	* 2600	* 2610	* 2620	* 2630
* ATG GTG CCG AAC CAA TAC AAC CCT CTG CCG GGG AGT GTG GCA CCA GGC M V P N Q Y N P L R G S V A P G>	* 2650	* 2660	* 2670	* 2680
* CCC CTG AGC ACA CAG GCC CCC TCC CTG CAG CAT GGC ATG GTA GGC CCG P L S T Q A P S L Q H G M V G P>	* 2690	* 2700	* 2710	* 2720
* CTG CAC AGT AGC CTT GCT GCC AGC GCC CTG TCC CAG ATG ATG AGC TAC L H S S L A A S A L S Q M M S Y>				

FIG.23N

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2740 * * * * * 2750 2760 2770 2780
 CAG GGC CTG CCC AGC ACC CGG CTG GCC ACC CAG CCT CAC CTG GTG CAG
 Q G L P S T R L A T Q P H L V Q>

2790 * * * * * 2800 2810 2820 2830
 ACC CAG CAG GTG CAG CCA AAC TTA CAG ATG CAG CAG AAC CTG
 T Q Q V Q P Q N L Q M Q Q N L>

2840 * * * * * 2850 2860 2870 2880
 CAG CCA GCA AAC ATC CAG CAG CAA AGC CTG CAG CCG CCA CCA CCA
 Q P A N I Q Q Q S L Q P P P>

2890 * * * * * 2900 2910 2920
 CCA CCA CAG CCG CAC CTT GGC GTG AGC TCA GCA GCC AGC GGC CAC CTG
 P P Q P H L G V S S A S G H L>

2930 * * * * * 2940 2950 2960 2970
 GGC CGG AGC TTC CTG AGT GGA GAG CCG AGC CAG GCA GAC GTG CAG CCA

G R S F L S G E P S Q A D V Q P>

FIG.23 0

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2980	2990	3000	3010	3020
* CTG GGC CCC AGC AGC CTG GCG GTG CAC ACT ATT CTG CCC CAG GAG AGC	* * * * *	* * * * *	* * * * *	* * * * *
L G P S S L A V H T I L P Q E S>				
3030	3040	3050	3060	3070
* * * * *	* * * * *	* * * * *	* * * * *	* * * * *
CCC GCC CTG CCC ACG TCG CTG CCA TCC TCG CTG GTC CCA CCC GTG ACC				
P A L P T S L P S S L V P P V T>				
3080	3090	3100	3110	3120
* * * * *	* * * * *	* * * * *	* * * * *	* * * * *
GCA GCC CAG TTC CTG ACG CCC CCC TCG CAG CAC AGC TAC TCC TCG CCT				
A A Q F L T P P S Q H S Y S P>				

FIG.23P

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3130	3140	3150	3160
* GTG GAC AAC ACC CCC AGC CAC CAG CTA CAG GTG CCT GTT CCT GTA ATG	* * * *		
V D N T P S H Q L Q V P V M>			
3170	3180	3190	3200
* * * *			
GTA ATG ATC CGA TCT TCG GAT CCT TCT AAA GGC TCA ATT TTG ATC			
V M I R S S D P S K G S I L I>			
3220	3230		
* * *			
GAA GCT CCC GAC TCA TGG			
E A P D S W>			

FIG.23Q

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G GAG GTG GAT GTG TTA GAT GTG AAT GTC CGT GGC CCA GAT GGC TGC 46
 Glu Val Asp Val Leu Asp Val Asn Val Arg Gly Pro Asp Gly Cys
 1 5 10 15

ACC CCA TTG ATG TTG GCT TCT CTC CGA GGA GGC AGC TCA GAT TTG AGT 94
 Thr Pro Leu Met Leu Ala Ser Leu Arg Gly Gly Ser Ser Asp Leu Ser
 20 25 30

GAT GAA GAT GAA GAT GCA GAG GAC TCT TCT GCT AAC ATC ATC ACA GAC 142
 Asp Glu Asp Glu Asp Ala Glu Asp Ser Ser Ala Asn Ile Ile Thr Asp
 35 40 45

TTG GTC TAC CAG GGT GCC AGC CTC CAG GCC CAG ACA GAC CGG ACT GGT 190
 Leu Val Tyr Gln Gly Ala Ser Leu Gln Ala Gln Thr Asp Arg Thr Gly
 50 55 60

GAG ATG GCC CTG CAC CTT GCA GCC CGC TAC TCA CGG GCT GAT GCT GCC 238
 Glu Met Ala Leu His Leu Ala Ala Arg Tyr Ser Arg Ala Asp Ala Ala
 65 70 75

AAG CGT CTC CTG GAT GCA GGT GCA GAT GCC AAT GCC CAG GAC AAC ATG 286
 Lys Arg Leu Leu Asp Ala Gly Ala Asp Ala Asn Ala Gln Asp Asn Met
 80 85 90 95

GGC CGC TGT CCA CTC CAT GCT GCA GTG GCA GCT GAT GCC CAA GGT GTC 334
 Gly Arg Cys Pro Leu His Ala Ala Val Ala Ala Asp Ala Gln Gly Val
 100 105 110

TTC CAG ATT CTG ATT CGC AAC CGA GTA ACT GAT CTA GAT GCC AGG ATG 382
 Phe Gln Ile Leu Ile Arg Asn Arg Val Thr Asp Leu Asp Ala Arg Met
 115 120 125

AAT GAT GGT ACT ACA CCC CTG ATC CTG GCT GCC CGC CTG GCT GTG GAG 430
 Asn Asp Gly Thr Thr Pro Leu Ile Leu Ala Ala Arg Leu Ala Val Glu
 130 135 140

FIG.24A

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GGA ATG GTG GCA GAA CTG ATC AAC TGC CAA GCG GAT GTG AAT GCA GTG	478
Gly Met Val Ala Glu Leu Ile Asn Cys Gln Ala Asp Val Asn Ala Val	
145 150 155	
GAT GAC CAT GGA AAA TCT GCT CTT CAC TGG GCA GCT GCT GTC AAT AAT	526
Asp Asp His Gly Lys Ser Ala Leu His Trp Ala Ala Ala Val Asn Asn	
160 165 170 175	
GTG GAG GCA ACT CTT TTG TTG TTG AAA AAT GGG GCC AAC CGA GAC ATG	574
Val Glu Ala Thr Leu Leu Leu Leu Lys Asn Gly Ala Asn Arg Asp Met	
180 185 190	
CAG GAC AAC AAG GAA GAG ACA CCT CTG TTT CTT GCT GCC CGG GAG GGG	622
Gln Asp Asn Lys Glu Glu Thr Pro Leu Phe Leu Ala Ala Arg Glu Gly	
195 200 205	
AGC TAT GAA GCA GCC AAG ATC CTG TTA GAC CAT TTT GCC AAT CGA GAC	670
Ser Tyr Glu Ala Ala Lys Ile Leu Leu Asp His Phe Ala Asn Arg Asp	
210 215 220	
ATC ACA GAC CAT ATC GAT CGT CTT CCC CGG GAT GTG GCT CGG GAT CGC	718
Ile Thr Asp His Met Asp Arg Leu Pro Arg Asp Val Ala Arg Asp Arg	
225 230 235	
ATG CAC CAT GAC ATT GTG CGC CTT CTG GAT GAA TAC AAT GTG ACC CCA	766
Met His His Asp Ile Val Arg Leu Leu Asp Glu Tyr Asn Val Thr Pro	
240 245 250 255	
AGC CCT CCA GGC ACC GTG TTG ACT TCT GCT CTC TCA CCT GTC ATC TGT	814
Ser Pro Pro Gly Thr Val Leu Thr Ser Ala Leu Ser Pro Val Ile Cys	
260 265 270	
GGG CCC AAC AGA TCT TTC CTC AGC CTG AAG CAC ACC CCA ATG GGC AAG	862
Gly Pro Asn Arg Ser Phe Leu Ser Leu Lys His Thr Pro Met Gly Lys	
275 280 285	

FIG.24B

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AAG TCT AGA CGG CCC AGT GCC AAG	AGT ACC ATG CCT ACT AGC CTC CCT	910
Lys Ser Arg Arg Pro Ser Ala Lys	Ser Thr Met Pro Thr Ser Leu Pro	
290	295 300	
AAC CTT GCC AAG GAG GCA AAG GAT GCC AAG GGT AGT AGG AGG AAG AAG	958	
Asn Leu Ala Lys Glu Ala Lys Asp Ala Lys Gly Ser Arg Arg Lys Lys		
305	310 315	
TCT CTG AGT GAG AAG GTC CAA CTG TCT GAG AGT TCA GTA ACT TTA TCC	1006	
Ser Leu Ser Glu Lys Val Gln Leu Ser Glu Ser Ser Val Thr Leu Ser		
320	325 330 335	
CCT GTT GAT TCC CTA GAA TCT CCT CAC ACG TAT GTT TCC GAC ACC ACA	1054	
Pro Val Asp Ser Leu Glu Ser Pro His Thr Tyr Val Ser Asp Thr Thr		
340	345 350	
TCC TCT CCA ATG ATT ACA TCC CCT GGG ATC TTA CAG GCC TCA CCC AAC	1102	
Ser Ser Pro Met Ile Thr Ser Pro Gly Ile Leu Gln Ala Ser Pro Asn		
355	360 365	
CCT ATG TTG GCC ACT GCC GCC CCT CCT GCC CCA GTC CAT GCC CAG CAT	1150	
Pro Met Leu Ala Thr Ala Ala Pro Pro Ala Pro Val His Ala Gln His		
370	375 380	
GCA CTA TCT TTT TCT AAC CTT CAT GAA ATG CAG CCT TTG GCA CAT GGG	1198	
Ala Leu Ser Phe Ser Asn Leu His Glu Met Gln Pro Leu Ala His Gly		
385	390 395	
GCC AGC ACT GTG CTT CCC TCA GTG AGC CAG TTG CTA TCC CAC CAC CAC	1246	
Ala Ser Thr Val Leu Pro Ser Val Ser Gln Leu Leu Ser His His His		
400	405 410 415	
ATT GTG TCT CCA GGC AGT GGC AGT GCT GGA AGC TTG AGT AGG CTC CAT	1294	
Ile Val Ser Pro Gly Ser Gly Ser Ala Gly Ser Leu Ser Arg Leu His		
420	425 430	
CCA GTC CCA GTC CCA GCA GAT TGG ATG AAC CGC ATG GAG GTG AAT GAG	1342	
Pro Val Pro Val Pro Ala Asp Trp Met Asn Arg Met Glu Val Asn Glu		
435	440 445	

FIG.24C
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ACC CAG TAC AAT GAG ATG TTT GGT ATG GTC CTG GCT CCA GCT GAG GGC 1390
 Thr Gln Tyr Asn Glu Met Phe Gly Met Val Leu Ala Pro Ala Glu Gly
 450 455 460

ACC CAT CCT GGC ATA GCT CCC CAG AGC AGG CCA CCT GAA GGG AAG CAC 1438
 Thr His Pro Gly Ile Ala Pro Gln Ser Arg Pro Pro Glu Gly Lys His
 465 470 475

ATA ACC ACC CCT CGG GAG CCC TTG CCC CCC ATT GTG ACT TTC CAG CTC 1486
 Ile Thr Thr Pro Arg Glu Pro Leu Pro Pro Ile Val Thr Phe Gln Leu
 480 485 490 495

ATC CCT AAA GGC AGT ATT GCC CAA CCA GCG GGG GCT CCC CAG CCT CAG 1534
 Ile Pro Lys Gly Ser Ile Ala Gln Pro Ala Gly Ala Pro Gln Pro Gln
 500 505 510

TCC ACC TGC CCT CCA GCT GTT GCG GGC CCC CTG CCC ACC ATG TAC CAG 1582
 Ser Thr Cys Pro Pro Ala Val Ala Gly Pro Leu Pro Thr Met Tyr Gln
 515 520 525

ATT CCA GAA ATG GCC CGT TTG CCC AGT GTG GCT TTC CCC ACT GCC ATG 1630
 Ile Pro Glu Met Ala Arg Leu Pro Ser Val Ala Phe Pro Thr Ala Met
 530 535 540

ATG CCC CAG CAG GAC GGG CAG GTA GCT CAG ACC ATT CTC CCA GCC TAT 1678
 Met Pro Gln Gln Asp Gly Gln Val Ala Gln Thr Ile Leu Pro Ala Tyr
 545 550 555

CAT CCT TTC CCA GCC TCT GTG GGC AAG TAC CCC ACA CCC CCT TCA CAG 1726
 His Pro Phe Pro Ala Ser Val Gly Lys Tyr Pro Thr Pro Pro Ser Gln
 560 565 570 575

CAC AGT TAT GCT TCC TCA AAT GCT GCT GAG CGA ACA CCC AGT CAC AGT 1774
 His Ser Tyr Ala Ser Ser Asn Ala Ala Glu Arg Thr Pro Ser His Ser
 580 585 590

GGT CAC CTC CAG GGT GAG CAT CCC TAC CTG ACA CCA TCC CCA GAG TCT 1822
 Gly His Leu Gln Gly Glu His Pro Tyr Leu Thr Pro Ser Pro Glu Ser
 595 600 605

FIG.24D

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CCT GAC CAG TGG TCA AGT TCA TCA CCC CAC TCT GCT TCT GAC TGG TCA 1870
Pro Asp Gln Trp Ser Ser Ser Ser Pro His Ser Ala Ser Asp Trp Ser
610 615 620

GAT GTG ACC ACC AGC CCT ACC CCT GGG GGT GCT GGA GGA GGT CAG CGG 1918
Asp Val Thr Thr Ser Pro Thr Pro Gly Gly Ala Gly Gly Gly Gln Arg
625 630 635

GGA CCT GGG ACA CAC ATG TCT GAG CCA CCA CAC AAC AAC ATG CAG GTT 1966
Gly Pro Gly Thr His Met Ser Glu Pro Pro His Asn Asn Met Gln Val
640 645 650 655

TAT GCG TGAGAGAGTC CACCTCCAGT GTAGAGACAT AACTGACTTT TGTAATGCT 2022
Tyr Ala

GCTGAGGAAC AAATGAAGGT CATCCGGGAG AGAAATGAAG AAATCTCTGG AGCCAGCTTC 2082

TAGAGGTAGG AAAGAGAAGA TGTTCTTATT CAGATAATGC AAGAGAAGCA ATTCGTCAGT 2142

TTCACTGGGT ATCTGCAAGG CTTATTGATT ATTCTAATCT AATAAGACAA GTTTGTGGAA 2202

ATGCAAGATG AATACAAGCC TTGGGTCCAT GTTTACTCTC TTCTATTTGG AGAATAAGAT 2262

GGATGCTTAT TGAAGCCCAG ACATTCTTGC AGCTTGGACT GCATTTTAAG CCCTGCAGGC 2322

TTCTGCCATA TCCATGAGAA GATTCTACAC TAGCGTCCTG TTGGGAATTA TGCCCTGGAA 2382

TTCTGCCTGA ATTGACCTAC GCATCTCCTC CTCCTTGGAC ATTCTTTTGT CTTCAATTGG 2442

TGCTTTTGGT TTTGCACCTC TCCGTGATTG TAGCCCTACC AGCATGTTAT AGGGCAAGAC 2502

CTTTGTGCTT TTGATCATTG TGGCCCATGA AAGCAACTTT GGTCTCCTTT CCCCTCCTGT 2562

CTTCCCGGTA TCCCTTGGAG TCTCACAAGG TTTACTTTGG TATGGTTCTC AGCACAACCC 2622

TTTCAAGTAT GTTGTTTCTT TGGAAAATGG ACATACTGTA TTGTGTTCTC CTGCATATAT 2682

CATTCTGGA GAGAGAAGGG GAGAAGAATA CTTTCTTCA ACAAATTTTG GGGGCAGGAG 2742

ATCCCTTCAA GAGGCTGCAC CTTAATTTTT CTTGTCTGTG TGCAGGTCTT CATATAAAT 2802

FIG.24E

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TTACCAGGAA GAAGGGTGTG AGTTTGTTGT TTTTCTGTGT ATGGGCCTGG TCAGTGTA	2862
TTAA GTTTTATCCT TGATAGTCTA GTTACTATGA CCCTCCCCAC TTTTAA	2922
TTAA GTTTGGAATG TTGGAATGAC CAAGAGACAA GTTAACTCGT GCAAGAGCCA GTTACCCACC	2982
TTAA CACAGGTCCC CCTACTTCCT GCCAAGCATT CCATTGACTG CCTGTATGGA ACACATTTGT	3042
TTAA CCCAGATCTG AGCATTCTAG GCCTGTTTCA CTCACTCACC CAGCATATGA AACTAGTCTT	3102
TTAA AACTGTTGAG CCTTTCCTTT CATATCCACA GAAGACACTG TCTCAAATGT TGTACCCTTG	3162
TTAA CCATTTAGGA CTGAACTTTC CTTAGCCCAA GGGACCCAGT GACAGTTGTC TTCCGTTTGT	3222
TTAA CAGATGATCA GTCTCTACTG ATTATCTTGC TGCTTAAAGG CCTGCTCACC AATCTTTCTT	3282
TTAA TCACACCGTG TGGTCCGTGT TACTGGTATA CCCAGTATGT TCTCACTGAA GACATGGACT	3342
TTAA TTATATGTTT AAGTGCAGGA ATTGGAAAGT TGGACTTGTT TTCTATGATC CAAAACAGCC	3402
TTAA CTATAAGAAG GTTGGAAAAG GAGGAACTAT ATAGCAGCCT TTGCTATTTT CTGCTACCAT	3462
TTAA TTCTTTTCCT CTGAAGCGGC CATGACATTC CCTTTGGCAA CTAACGTAGA AACTCAACAG	3522

FIG.24F

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AACATTTTCC TTTCTAGAG TCACCTTTTA GATGATAATG GACAACTATA GACTTGCTCA	3582
TTGTTGAGAC TGATTGCCCC TCACCTGAAT CCACTCTCTG TATTCATGCT CTTGGCAATT	3642
TCTTTGACTT TCTTTTAAGG GCAGAAGCAT TTTAGTTAAT TGTAGATAAA GAATAGTTTT	3702
CTTCCTCTTC TCCTTGGGCC AGTTAATAAT TGGTCCATGG CTACACTGCA ACTTCCGTCC	3762
AGTGCTGTGA TGCCCATGAC ACCTGCAAAA TAAGTTCTGC CTGGGCATTT TGTAGATATT	3822
AACAGGTGAA TTCCCGACTC TTTTGGTTTG AATGACAGTT CTCATTCTT CTATGGCTGC	3882
AAGTATGCAT CAGTGCTTCC CACTTACCTG ATTTGTCTGT CGGTGGCCCC ATATGGAAAC	3942
CCTGCGTGTG TGTGGCATA ATAGTTTACA AATGGTTTTT TCAGTCCTAT CCAAATTTAT	4002
TGAACCAACA AAAATAATTA CTTCTGCCCT GAGATAAGCA GATTAAGTTT GTTCATTCTC	4062
TGCTTTATTC TCTCCATGTG GCAACATTCT GTCAGCCTCT TTCATAGTGT GCAAACATTT	4122
TATCATTCTA AATGGTGACT CTCTGCCCTT GGACCCATTT ATTATTCACA GATGGGGAGA	4182
ACCTATCTGC ATGGACCCTC ACCATCCTCT GTGCAGCACA CACAGTGCAG GGAGCCAGTG	4242
GCGATGGCGA TGACTTTCTT CCCCTG	4268

FIG.24G

SUBSTITUTE SHEET

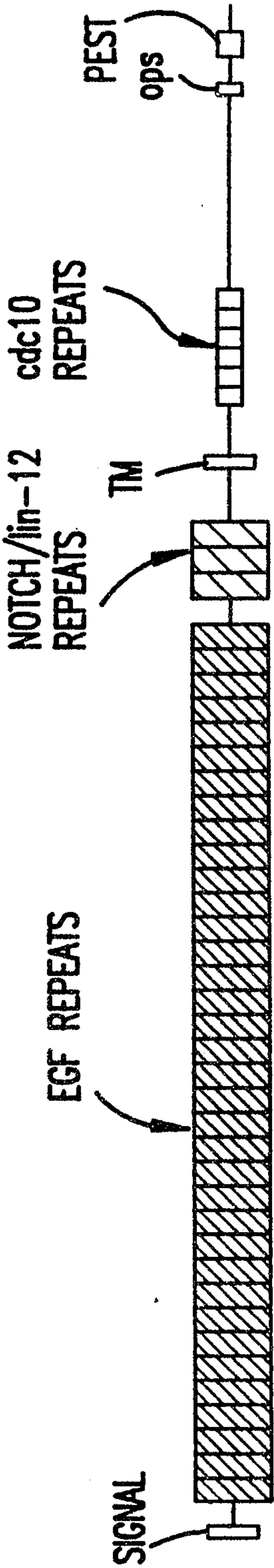
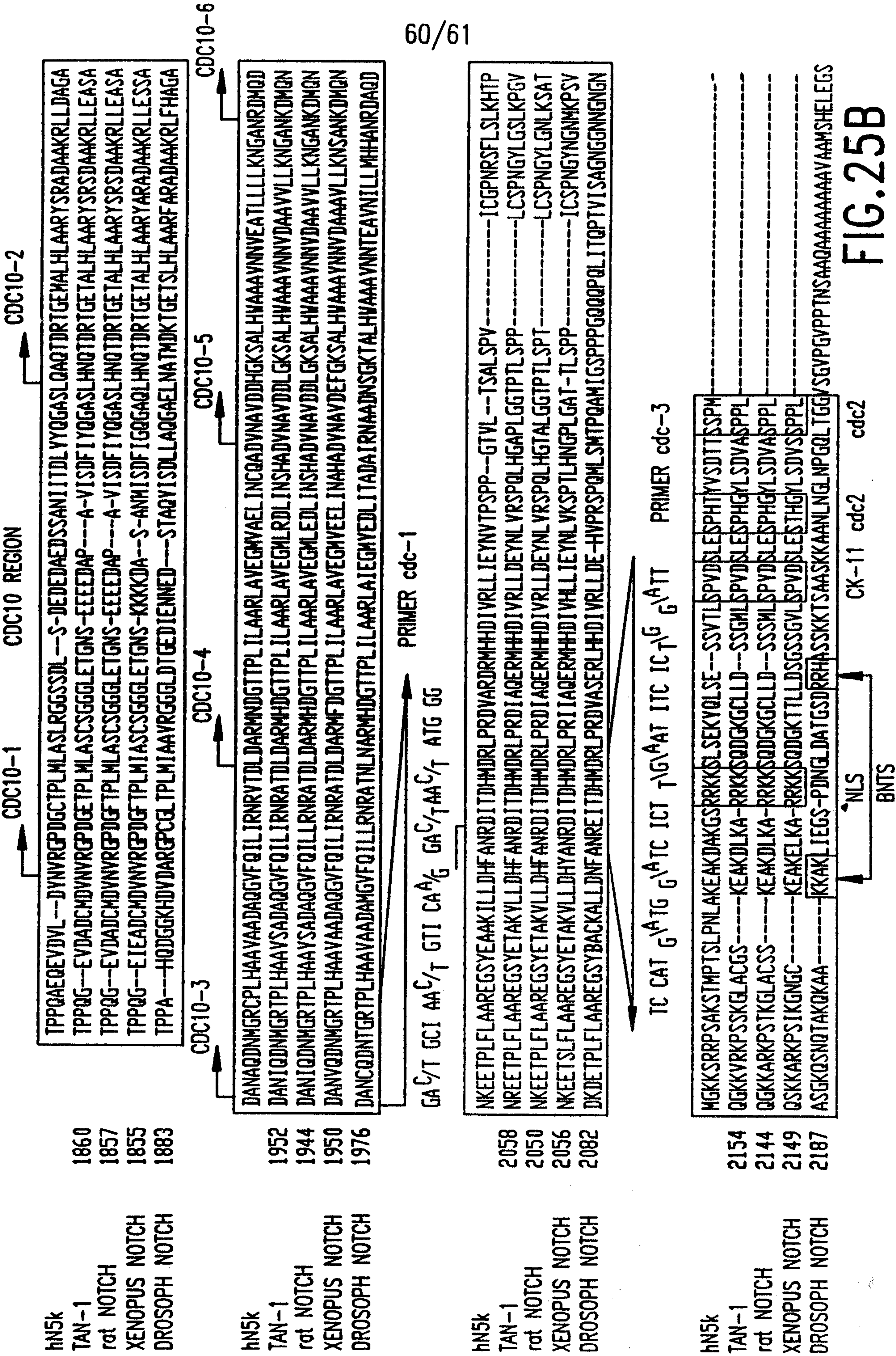


FIG. 25A



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hN5k
TAN-1 2218
rat NOTCH 2209
XENOPUS NOTCH 2214
DROSOPH NOTCH 2285

-----ITSGGDDASPNML--ATAAPPYHAQHALSF
-----LRSPR--DQSPVPLNHLPGMPDTHLGIGHLNVA
-----LRSPR--DQSPSHPLSHLPGMPDTHLGISHLNVA
-----MTSPR--DQSPSHPLNHLTSMPESQLGMNHINMA
-----DQELLNGGGLGMNGNGQRNGVGPGVLP

CK-11

hN5k
TAN-1 2250
rat NOTCH 2242
XENOPUS NOTCH 2247
DROSOPH NOTCH 2390

-----SNLHEHQ-----PLAHGASTVLPVSQLLSHHIIYSPGS--GSAGLSRLHPYVPADV--MNRMEVNETQYNEFMGYLAPAEG--THPGI
A-KPEMAALGGGRLAFETGPPRLSHLPVASTSTVLGSSSGGALNFTVGGSTSLNGQCEVLSRLQSGHVPNQYNPLRGSVAPGPLSTQAPSLQHG--MYGPLHSSL
A-KPEMAALAGGRLAFETGPPRLSHLPVASSASTVLSTNGTGAMNFTVGAPASLNGQCEVLPRLONGMVPSQYNPLRPGVTPGTLSTQAGLQHGMM--SPIHSSL
T-KQEMAA--GSNRMAFDAMVPRLTHL--NASSPNTIMS---NGSMHFTVGGAPTMSQCDNLARLQNGHVQNYDP IRNGIQQGN--AQQAQALQHGLMTS--LHNLGL
GGLCGMGGLSGAGNGNSHEQGLSPYS--NQSPPHSVQSSALSPHAYLGSPSPAKSRPSLPTSPTHIQAMRHA TQKQFGGSNLNSLLGGANGGVVGGGGGGGGV

hN5k
TAN-1 2354
rat NOTCH 2344
XENOPUS NOTCH 2343
DROSOPH NOTCH 2495

-----APQSRPPEGK-----HITPREPLP-IV-TFQIPKGSIAQPAG-----APQDQSTCPPAYAGPLPTMYQIP-----EMARL-P
AASALQMMMS-----YQGLPSTRLATQPHLYQTQQYQPNLQMQQQNLQPANIQQQQLQPPPPPPQPHLGVSSAASGHLGRSFLSGEPSQADYQPLGP
STNLSPII-----YQGLPNTRLATQPHLYQTQQYQPNLQIQPN-----LQPPS---QPHLSVSSAANGHLGRSFLSGEPSQADYQPLGP
PATTLSQMMT-----YQAMPNTRLANQPHLMQAGQMQQQN-----LQLHQSMQQQHN--SSTTSTHINSFPCSSDISQTDLQQM--
VGQGPQNSPVSLGIISPTGSDMGIMLAPQSSKNSAIMQTI SPQQQQQQQQQQQQQQQQQQQQQQQQQQQQQLGGLFSGAGLDLNG--FCGSPDSFHSQGMNPP

hN5k
TAN-1 2448
rat NOTCH 2423
XENOPUS NOTCH 2416
DROSOPH NOTCH 2599

SVAFPTAMPQQQQQVAQTILPAYHPFPASVGKYHTPPSQHSYASSNAARTPSHSHLQGEHPYLTPSPESPDQVSSSSPHSA--SDWSDVTTSTPT
SSLAVHTILPQ--ESPALPTSLPSSLYPPVTAAGFLTPPSQHSY--SS-PYENTPSHQLQVP--EHPFLTPSPESPDQVSSSSPHSNVSDWSEGVSSPPT
SSLPVHTILPQ--ESQALPTSLPSSMVPMTTITQFLTPPSQHSY--SSSPVINTPSHQLQVP--EHPFLTPSPESPDQVSSSSSRHSNISDWSEGISPPT
SSNNIHSVMPQ--DTQIFAASLPSNL TQSMTTAGFLTPPSQHSY--SS-PMDNTPSHQLQVP--DHPFLTPSPESPDQVSSSSPHSNMDSWSEGISPPT
S---IQSSMSG--SSPSTNMLSPSSQHNQAFYQYLTPSSQHS-----GGHTPQHLVQTL-D-SYPTSPSPESPGHVVSSSSPSRN--SDWSEGVQSPAA

PEST-CONTAINING REGION

FIG. 25C