



(22) Date de dépôt/Filing Date: 1992/10/29

(41) Mise à la disp. pub./Open to Public Insp.: 1993/05/01

(45) Date de délivrance/Issue Date: 2007/05/01

(30) Priorité/Priority: 1991/10/31 (US07/784,234)

(51) Cl.Int./Int.Cl. *C12N 15/62* (2006.01),
A61K 38/08 (2006.01), *A61K 38/10* (2006.01),
C07K 1/113 (2006.01), *C07K 14/245* (2006.01),
C07K 14/31 (2006.01), *C07K 19/00* (2006.01),
C07K 7/06 (2006.01), *C07K 7/08* (2006.01),
C12N 1/21 (2006.01), *C12N 15/52* (2006.01),
C12N 9/00 (2006.01), *C12P 21/02* (2006.01)

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(54) Titre : METHODE BIOSYNTHETIQUE DE PREPARATION DE COMPOSES CHIMIQUES

(54) Title: BIOSYNTHETIC PROCESS FOR THE PREPARATION OF LANTIBIOTICS

(57) **Abrégé/Abstract:**

A bacterial host is described which is transformed by a plasmid coding for a polypeptide precursor wherein the host comprises a multi-enzyme complex capable of reacting with the expressed polypeptide precursor to produce a polypeptide comprising at least one dehydroamino acid and/or at least one lanthione bridge. A process for producing a polypeptide comprising at least one dehydroamino acid and/or at least one lanthione bridge, such as gallidermin, is also described. A plasmid capable of transforming a bacterial host is additionally described. Also disclosed are recombinant DNA molecules which specify Epi B, Epi C, Epi D, Epi P and Epi Q, enzymes which are involved in the biosynthesis of lantibiotic epidermin.

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ABSTRACT

5 A bacterial host is described which is transformed by a plasmid coding for a polypeptide precursor wherein the host comprises a multi-enzyme complex capable of reacting with the expressed polypeptide precursor to produce a polypeptide comprising at least one dehydroamino acid and/or at least one lanthione bridge. A process for producing a polypeptide comprising at least one dehydroamino acid and/or at least one lanthione bridge, such as gallidermin, is also described. A plasmid capable of transforming a bacterial host is additionally described.

10 Also disclosed are recombinant DNA molecules which specify Epi B, Epi C, Epi D, Epi P and Epi Q, enzymes which are involved in the biosynthesis of lantibiotic epidermin.

A152-19.WP5

BIOSYNTHETIC PROCESS FOR THE PREPARATION
OF LANTIBIOTICS

Field of the Invention

This invention relates to the biosynthesis of chemical compounds, and in particular to the biosynthesis of chemical compounds containing
10 dehydroamino acid residues and/or thioether bridges. The invention also relates to the use of recombinant genetics to prepare enzymes involved in the biosynthesis of such chemical compounds.

Background of the Invention

Some polypeptide antibiotics such as nisin, subtilin, duramycin,
15 cinnamycin, ancovenin, Ro 09-0198 and epidermin contain dehydroamino acids and lanthionine bridges. These polypeptides are produced by various respective strains of microorganism. Nisin for example can be produced by cultivating strains of *Streptococcus lactis*, and subtilin by cultivation of *Bacillus subtilis*.

20 The genetic basis for the biosynthesis of these antibiotics has not, hitherto, been elucidated. Thus, it has not been known, for example, whether biosynthesis of such antibiotics and, in particular, the formation of the unusual amino acids found therein occurs via ribosomal synthesis or via multi-enzyme complexes.

27169-205

-2-

In addition it was not known whether the precursor proteins of such antibiotics were coded by distinct structural genes or were the degradation products of larger proteins.

5 In the course of work carried out to establish the structural gene of epiderm, we have been able to establish that surprisingly the above mentioned antibiotics, in particular epidermin, are each coded by a distinct structural gene, and that processing of a presequence
10 polypeptide is carried out by an enzymatic complex which effects formation of dehydroamino residues and/or thioether bridges.

Furthermore, the multi-enzyme complex may be involved in the secretion of the protein through the cell
15 membrane into the culture supernatant, as well as processing a prepolyptide. In this connection, such activity may be associated with a pre-sequence possessed by the prepolyptide, e.g., as in the case of the -30 to -1 sequence of pre-epidermin as described below.

20 Summary of the Invention

In one aspect, there is described a recombinant DNA molecule encoding the protein Epi B consisting of the amino acid sequence set forth in SEQ ID NO: 1.

In another aspect, there is described a
25 recombinant DNA molecule encoding the protein Epi C, consisting of the amino acid sequence set forth in SEQ ID NO: 2.

In another aspect, there is described a recombinant DNA molecule encoding the protein Epi D

271,69-205

-2a-

consisting of the amino acid sequence set forth in
SEQ ID NO: 3.

In another aspect, there is described a
recombinant DNA molecule encoding the protein Epi P
5 consisting of the amino acid sequence set forth in
SEQ ID NO: 5.

In another aspect, there is described a
recombinant DNA molecule encoding the protein Epi Q
consisting of the amino acid sequence set forth in
10 SEQ ID NO: 4.

In another aspect, there is described a
recombinant DNA molecule which is at least 85% identical to
SEQ ID NO: 6 from position 1593 to 4562 encoding Epi B
protein, wherein said DNA molecule codes for a protein
15 having Epi B enzymatic activity in the synthesis of
epidermin.

In another aspect, there is described a
recombinant DNA molecule which is at least 85% identical
with SEQ ID NO: 6 from position 4441 to 5805 encoding Epi C
20 protein, wherein said DNA molecule codes for a protein
having Epi C enzymatic activity in the synthesis of
epidermin.

In another aspect, there is described a
recombinant DNA molecule which is at least 85% identical to
25 SEQ ID NO: 6 from position 5824 to 6366 encoding Epi D
protein, wherein said DNA molecule codes for a protein
having Epi D enzymatic activity in the synthesis of
epidermin.

In another aspect, there is described a
30 recombinant DNA molecule which is at least 85% identical to

27169-205

-2b-

SEQ ID NO: 6 from position 6997 to 8379 of the complementary strand encoding Epi P protein, wherein said DNA molecule codes for a protein having Epi P enzymatic activity in the synthesis of epidermin.

5 In another aspect, there is described a recombinant DNA molecule which is at least 85% identical to SEQ ID NO: 6 from position 6369 to 6983 of the complementary strand encoding Epi Q protein, wherein said DNA molecule codes for a protein having Epi Q regulatory activity in the
10 synthesis of epidermin.

 In another aspect, there is described a recombinant protein encoded by the DNA molecule as described above.

 In another aspect, there is described a method of
15 preparing Epi B protein, the method comprising inserting the DNA molecule as described above into a plasmid vector such that the DNA molecule is under the control of a promoter regulator, inserting the resulting plasmid vector into a suitable host, culturing said host so that the protein is
20 expressed, and isolating the protein.

 In another aspect, there is described a method of producing epidermin, the method comprising inserting a DNA sequence coding for amino acids 31 to 52 of SEQ ID NO: 7 in a plasmid vector such that the DNA sequence is under the
25 control of a regulator promoter, transforming the resulting plasmid vector into a suitable host and cultivating the host so as to express the said DNA and isolating the encoded protein, wherein the host is also transformed by a DNA sequence or sequences comprising functionally operable genes
30 coding for Epi B as described above, Epi C as described above, Epi D as described above, Epi P as described above,

27169-205

-2c-

or Epi Q as described above, which genes are expressed during the cultivation of the host.

In another aspect, there is described a method of producing epidermin, the method comprising transforming into
5 a suitable host a plasmid vector comprising a DNA coding for amino acids 31 to 52 of SEQ ID NO: 7 under the control of a regulator promoter, and one or more functionally operable DNA selected from the group consisting of: DNA coding for Epi B as described above, DNA coding for Epi C as described
10 above, DNA coding for Epi D as described above, DNA coding for Epi P as described above, and DNA coding for Epi Q as described above, wherein the functionally operable DNA is expressed during cultivation of the host; and isolating the epidermin.

15 In another aspect, there is described an isolated Epi B protein consisting of the amino acid sequence set forth in SEQ ID NO: 1.

In another aspect, there is described an isolated Epi C protein consisting of the amino acid sequence set
20 forth in SEQ ID NO: 2.

In another aspect, there is described an isolated Epi D protein consisting of the amino acid sequence set forth in SEQ ID NO: 3.

In another aspect, there is described an isolated
25 Epi P protein consisting of the amino acid sequence set forth in SEQ ID NO: 5.

In another aspect, there is described an isolated Epi Q protein consisting of the amino acid sequence set forth in SEQ ID NO: 4.

27169-205

-2d-

In another aspect, there is described a host cell comprising the recombinant DNA molecule as described above.

Description of the Drawings

Figure 1 depicts the nucleotide sequence of the epidermin structural gene (Epi A) and the deduced amino acid sequence of pre-epidermin. A Shine-Dalgarno sequence is boxed and the proteolytic cleavage site at which the propeptide is processed is indicated by an arrow. Inverted repeats are underlined and potential stop codons are noted as am (amber) and oc (ochre).

Figure 2A depicts a prediction plot for pre-epidermin using a Hyron program, in which the respective bar charts show: (a) flexibility; (b) hydropathy; (c) hydrophilicity; (d) propensities for turn; (e) β -sheet; and (f) α -helix conformation.

Figure 2B depicts a helix wheel plot for pre-epidermin showing that the N-terminus may partially adopt an amphophilic α -helical conformation in an appropriate environment.

-3-

Figure 3 depicts a postulated naturation procedure for epidermin. The translated polypeptide (pre-epidermin) consists of 52-amino acid residues. Structure predictions indicate a partially α -helical N-terminus from which residues -30 to -10 may form an amphiphilic α -helix conformation. Water elimination occurs at the indicated Ser and Thr residues (a). With the exception of Thr⁺¹⁴, water elimination is followed by sulphide ring formation (b) and at the C-terminus, decarboxylation (c) and double bond formation (d) to produce pro-epidermin. The pro-epidermin structure is then processed by proteolytic cleavage to produce epidermin.

Figure 4 depicts the structure of epidermin. The ring structures are designated as A, B, C, D and E. The structures of the amino acids mesolanthione and threo-methyllanthione, are set forth.

Figure 5 depicts examples of unusual amino acids which are found in lanthione antibiotics and which can be formed in peptide products using the method of this invention.

Figure 6 depicts a schematic representation of the process for preparation of the pCUI plasmid from pCLP100 plasmid and pUC18 plasmid.

Figure 7A depicts the elution pattern of the isolated culture medium prepared in Example 2.

Figure 7B depicts the elution pattern of a standard containing gallidermin. Gallidermin is eluted at 7.54 minutes.

Figure 8 is a genetic analysis of episome pTü32 of *S. epidermis* plasmid pTü32, including

8A: a restriction map of episome pTü32, and

8B: a restriction map of the 13.5 kb BglIII fragment of pTü32.

The filled arrow corresponds to the epiA structural gene.

Open arrows represent reading frames epiB, C, D, P and Q.

8C: Southern hybridization of pTü32 digested with different restriction enzymes (EcoRI, EcoRV, BglIII, SphI) using a

-4-

15-mer oligonucleotide (5'CACATCCAGGAGTAC-3')
specific of epiA.

Figure 9 is a nucleotide sequence of the BglII/HpaII fragment of pTü32 containing reading frames epiA, B, C, D, P, Q, Y', and Y'' and the deduced amino acid sequences of the respective proteins. S/D sequences and termination structures are overlined. IR indicates inverted repeats. The start of the open reading frames of epiY, epiA, epiB, epiC, epiD, epiQ and epiP are indicated by bold letters. The N-terminal amino acid residues (possible translational start sites) are boxed.

Figure 10 shows the results of a Northern blot analysis of epiA (10A) and epiB (10B) expression in *S. epidermidis*, in which total RNA (40µg, lanes 1, 3, and 5, or 20 µg, lanes 2, 4, and 6) were separated on 1.2% agarose gels and hybridization was performed with an antisense RNA probe (SP6 transcript. Filters were washed with increasing stringency; lanes 1, 2:1xSSC, 0.1% SDS, exposition time, 4 h, lanes 3, 4:0.5xSSC, 0.1% SDS, exposition time 16 h; lanes 5,6:0.1x SSC, 0.1% SDS, exposition time, 3 days). The positions of 23S and 16S RNAs were used as a size standards.

Figure 11 shows sequence homologies between EpiP and different serine proteases at the active sites (SUBSI, subtilisin I168 precursor of *B. subtilis* (Terzaghi *et al.*, *Appl. Microbiol.* 29: 807-813 (1975); major intracellular serine protease from *B. subtilis* (Maniatis *et al.*, *Molecular Cloning. A Laboratory Manual*; 2nd ed. Cold Spring Harbour Laboratory Press (1990); SUMYTV, thermitase from *Thermoactinomyces vulgaris* (Stahl *et al.*, *J. Bacteriol* 158: 411-418 (1984)). The strongly conserved asparagine (asp), histidine (his), and serine (ser) residues are marked by asterisks. Similar amino acid residues are indicated by points and identical amino acid residues by colons.

Figure 12 shows sequence homologies between epiQ and PhoB (Makino *et al.*, *J. Mol. Biol.* 190:37-44 (1986)). Similar amino acid

residues are indicated by points and identical amino acid residues by colons.

Figure 13 is a HPLC elution profile of epidermin which was produced in *S. carnosus* TM300.

5 13A: Elution profile of epidermin standard substance (6.75 min, indicated by an arrow).

13B: Elution profile of epidermin standard substance (6.75 min, indicated by an arrow) isolated from culture filtrates of *S. carnosus* TM300 pTepi14. Culture filtrates were adsorbed to XAD 1180, eluted with methanol and finally concentrated by evaporation.

13C: Elution profile of untransformed *S. carnosus* TM300 culture filtrate treated as in 13B. The solid line indicates the elution region of epidermin.

15 Figure 14 shows the construction of pT181mcs. The PvuII³⁰⁹-PvuII⁶³¹ fragment of pUC19, part of lacZ and the multiple cloning site (mcs), was inserted into the single NdeI site within pre of pT181 (Gennaro *et al.*, *J. Bacteriol.* 169:2601-2610 (1987); Kahn *et al.*, *Plasmid* 10:251-259 (1983)) by blunt-end ligation. lacZ is in the opposite orientation to a *pre*. Black bar, interrupted *pre*; open bar, inserted pUC19 fragment.

25 Figure 15 shows the construction of pCU1. PCLP100 is a derivative of pC194 (Horinouchi *et al.*, *J. Bacteriol.* 150:815-825 (1982)) containing a single PstI site which was generated by opening pC194 at the HindIII site, deleting the ends with Ba131 (approximately 950 bp) and inserting a PstI-linker by blunt-end ligation. PCU1 was then generated by blunt-end ligation of pCPL100 and pUC19 (Vieira *et al.*, *Gene* 19:259-268 (1982)) via the single PstI and NdeI sites, respectively. The multiple cloning site (mcs) in front of lacZ was used for cloning various epi gene-containing fragments. This shuttle vector replicates both in staphylococci and *E. coli*.

Figure 16 shows:

- 5 A) the generation of pTepi14 by cloning the 14 kb BglII fragment of pTü32 in pT181 mcs. This fragment containing the entire genetic information necessary for epidermin production in *S. carnosus*. The indicated ORFs and their transcriptional directions (indicated by arrows) are deduced from the DNA sequence. *epiA*, the structural gene, is presented by the black arrow.
- 10 B) various pTepi14 DNA fragments subcloned into pT181mcs (pT...) or pCU1 (pCU...). The respective plasmids were used to complement the *S. epidermidis* Epi⁻ mutants. The complete ORFs represent in the plasmid are indicated.

Figure 17 shows the construction of pPS4epiA and pPS4epiB. pPS4 is a derivative of pLipPS1 (Liebl *et al.*, *Mol. Gen. Genet.* 204:166-173 (1986)). A single BamHI site was inserted after a strong staphylococcal promoter. Cloning of genes into the BamHI site under the control of the ORF2 promoter normally leads to good expression in staphylococci. *epiA* was PCR-amplified and contained flanking BamHI sites. The 3.2 kb BstNI fragment containing *epiB* was inserted into the BamHI site by blunt-end ligation. The respective EMS-mutants were complemented only when *epiA* and *epiB* were under the control of the ORF2 promoter. *lip*, lipase gene; *cat*, chloramphenicol acetyl transferase gene; ORF2, *S. carnosus*-specific truncated ORF.

25 Figure 18 shows the complementation of epidermin production in *S. carnosus* (pTepiABCDQ) by flanking DNA fragments. The fragments were subcloned into the compatible plasmid pCA44.

Description of the Preferred Embodiments

Broadly speaking the present invention provides in one aspect a bacterial host containing a plasmid, wherein said plasmid codes for a polypeptide which is not normally produced by said host, and wherein said
5 host during cultivation provides a multi-enzyme complex whereby a polypeptide is produced which contains at least one dehydroamino acid and/or at least one lanthionine bridge, said produced polypeptide being foreign to said host.

A suitable multi enzyme complex is one which is capable of
10 effecting at least one of the following operations, namely water elimination and sulphide bridge formation; the complex may also effect decarboxylation and double bond formation.

Suitable hosts for carrying out the process of the present invention are those which, without modification of their genetic material, are
15 capable of producing polypeptides containing a dehydroamino acid residue and/or lanthionine bridge and/or a methyl lanthionine bridge. Examples of such hosts are *Streptococcus lactis*, *Bacillus subtilis*, *Streptomyces cinnamoneus*, *Streptomyces sp.* *Streptoverticillum griseoverticillum*, *Staphylococcus epidermis*, *Staphylococcus epidermin* strain 5, *Staphylococcus*
20 *gallinarum* and mutant strains thereof, e.g., a mutant strain of *S. epidermin* DSM 3095 which is incapable of producing epidermin.

Strains which are of special interest are *Staphylococcus gallinarum* (F16/P57) Tü 3928 which has been deposited with the Deutsche Sammlung von Microorganismen under the terms of the Budapest Treaty
25 on 18 May 1988 and has received the depository number Tü 3928 in DSM 4616 and *Staphylococcus epidermis* DSM 3095 which was deposited by the present applicants with the Deutsche Sammlung von Microorganismen under the terms of the Budapest Treaty on 26th October 1984.

In order to transform a suitable host, a suitable plasmid may be
30 modified by known genetic engineering techniques.

Desirably a plasmid from a host which produces a polypeptide containing at least one dehydroamino acid residue and/or at least one sulfide bridge is treated by modifying or replacing the gene coding for a pre-polypeptide to provide a plasmid coding for a polypeptide foreign to
5 said host and then transforming said host with the altered plasmid.

Any of a variety of methods may be used to replace or modify a gene coding for the pre-polypeptide.

DNA coding for the pre-polypeptide sequence of the desired compound can be prepared by chemical synthesis. Suitable chemical
10 syntheses have been disclosed in *Anal. Biochem.* 121, 365 (1982). The known techniques allow the preparation of polynucleotides, e.g., of up to 60 to 100 bases to be prepared.

Suitable protected nucleotides can be linked by the phosphotriester method Agarwal *et al.*, (*Agnew, Chem.* 84, 489 (1972)),
15 the phosphotriester method (Reesem., *Tetrahedron* 39, 3, (1983)) or the phosphitetriester method (Letsinger *et al.*, *J. Am. Chem. Soc.* 98, 3655 (1976)) or the phosphoramidite method. The solid phase method allows for simplification of the synthesis of the polynucleotides.

The double stranded DNA can be constructed enzymatically from
20 chemically prepared short but overlapping segments.

For example, overlapping polynucleotide sequences from both DNA strands can be used, which are held together in the correct conformation by base pairing and are then chemically linked by the enzyme DNA ligase (Khorana *et al.*, *J. Biol. Chem.* 251, 565 (1976)).

25 Another possibility comprises incubating in each case one polynucleotide sequence from the two DNA stands with a short overlapping segment in the presence of the four required deoxynucleoside triphosphates with a DNA-polymerase, for example, DNA-polymerase I, the Klenow fragment of polymerase I or T4 DNA-polymerase, or with
30 reverse transcriptase. The two polynucleotide sequences are thereby held together in the correct arrangement by base pairing and are supplemented

with the required nucleotides by the enzyme to give a complete double-strand DNA (Narany *et al.*, *Anal. Biochem.* 121, 365 (1982)).

Another suitable method for obtaining the DNA coding for a polypeptide comprises isolating the DNA from the genomic DNA of a tissue or cell culture or microorganism, lysing the cells e.g. with SDS or proteinase K, or if desired mechanically, and deproteinising the DNA by repeated extraction with phenol.

The RNA can be preferably digested with RNase. The obtained raw DNA is partially digested with suitable restriction enzymes e.g. HaeIII and AluI and fragments isolated and multiplied in a suitable phage or cosmid, e.g. in charon 4A or EMBL-3 phage and assayed for the desired sequences e.g. with a radioactively labelled DNA probe.

The DNA coding for a desired polypeptide can also be obtained by reverse transcription of isolated mRNA into cDNA. This may be the preferred method if the DNA structure is not known. In this method the DNA is obtained from genomic DNA in a cDNA library via the mRNA. The cDNA library comprises the genetic information which is complementary to the mRNA isolated from cells.

To obtain a cDNA library, the mRNA is isolated from cells expressing the desired basic (possibly unmodified) protein. This mRNA is converted into double stranded cDNA.

Standard methods well known in the art are applied in the preparation of mRNA. The cell membrane is broken and the cell content released from which the mRNA is isolated. The cell membrane is preferably broken by physical methods or lysis with detergents such as SDS, guanidine thiocyanate, definite salt conditions or homogenization, preferably by mixing. The mRNA is isolated by the standard methods of phenol extraction, ethanol precipitation, centrifugation and chromatography, preferably a combination of several methods. Centrifugation is preferably done over gradients, for example over a CsCl

gradient. For chromatography, preferably columns are used, especially oligo-dT columns.

The total mRNA can be converted directly into Ds-cDNA following the methods of the art. Preferably the mRNA coding for a
5 desired polypeptide is further enriched using several techniques, such as electrophoresis, chromatography and centrifugation, preferably sucrose gradient centrifugation.

Fractions containing mRNA coding for a desired polypeptide can be detected by various methods, such as *in vivo* or *in vitro* translations,
10 followed by detection of a relevant activity or, when the nucleotide sequence is known, by hybridization with an oligonucleotide probe.

In vivo translation systems can be prokaryotic or eukaryotic systems. A preferred *in vivo* translation system is the *Xenopus laevis* oocyte system (see Maniatis *et al.*, *Molecular Cloning, A Laboratory*
15 *Manual*, Cold Spring Harbor Laboratory (1982)). *In vitro* systems are, for example, wheat germ and rabbit reticulocyte lysates, both of which are commercially available.

From any pool of mRNA derived from unfractionated or fractionated mRNA, ds-cDNA can be obtained by the well known
20 methods of the art (preferred general methods are described in Maniatis *et al.* (*supra*), Okayam and Berg, *Molecular and Cell Biology* 2, 161-170 (1982) and Heidecker, *Nucleic Acid Research* 11, 4891-4906 (1983)). In general, the mRNA is converted first to ss-cDNA using reverse transcriptase or DNA-polymerase I (Klenow fragment). Two methods are
25 alternatively used for priming the synthesis of the ds-cDNA. The first method was the natural loop formation of the ss-cDNA. The second method is that of tailing the ss-cDNA with a homopolymeric tail such as poly-dC or poly-DT.

The mRNA fraction of which the corresponding polypeptide shows
30 the highest activity in the detection system is transcribed into the complementary cDNA by methods well known in the art. The mRNA

and oligo-dT as a primer are mixed, dNTPs are then added as starting material and the synthesis of the cDNA-mRNA hybrid molecule is realized by the enzyme reverse transcriptase. The RNA molecules are degraded by addition of NaOH. DNA polymerase is admixed, preferably
5 the Klenow fragment of the DNA polymerase I, and the mixture is incubated at a suitable temperature, preferably 12-15°C. The mixture is incubated with nuclease S1 and the ds-cDNA corresponding to the mRNA coding for a desired polypeptide is obtained.

For amplification the obtained ds-cDNA can be spliced into
10 suitable vector e.g. the plasmid pUC-KO and the obtained hybrid vector multiplied by use of a suitable host, e.g. *E. Coli* HB101. Reisolation of the hybrid vectors, and recovering the isolated cDNA therefrom allows a structure determination of the DNA coding for a desired polypeptide.

Preparation of a Hybrid Vector

15 A hybrid vector of the invention can be prepared by splicing a DNA coding for a polypeptide of the desired sequence into a suitable vector.

Suitable vectors are carriers for integrated passenger DNA, which can be used to transform a host microorganism.

20 Suitable as vectors are plasmids derived from microorganisms which in an untransformed state produce polypeptides which contain dehydroamino and/or sulfide groups. Suitable vectors carry the insert DNA at a defined position.

In general, such vectors may contain a replicon and a control sequence, i.e. a promoter, which are derived from the host cell or a
25 species compatible with the host cell in which they are used. The vector ordinarily carries a replicon site and may contain sequences (marker genes) which are capable of providing phenotype selection in transformed cells. Suitable marker genes may provide antibiotic resistance or resistance to heavy metals or they may complement a genetic defect of the

host. Further useful sequences in such vectors are enhancer and activator sequences.

One suitable starting vector is a 54 kbp plasmid pEpi32 from the strain *Staphylococcus epidermis* DSM 3095 which is identical to plasmid pTü32. This plasmid, which is characterized below, contains the *epiA* gene encoding for a 52-prepeptide, which is processed to a tetracyclic 21-peptide amide antibiotic. A vector carrying a passenger DNA is designated a hybrid vector.

10 The desired DNA is spliced into the starting vector by conventional methods.

A starting plasmid for example can first be linearised by a suitable restriction enzymes, e.g. the plasmid pEpi32 by HindIII, BamHI and EcoRI, then d/G-tailed in the presence of dGTP and the terminal deoxynucleotidyl transferase. The double stranded cDNA insert is dC-tailed in the presence of dCTP and terminal deoxynucleotidyl transferase. Combining both cDNA and vector results in the hybrid vector. Bacteriophages, such as lambda, are preferred for constructing genomic libraries. The lambda cloning systems are described by Maniatis (supra). The
20 suitable vector DNA is digested to completion with the appropriate restriction enzyme, and the left and right arms are separated from the central fragments by velocity gradient centrifugation or gel electrophoresis. Another method is to digest parts of the stuffer fragments with restriction enzymes which lack recognition sites in the left and right arms. The isolated genomic DNA can be partially digested to fragments of 13-20kb in length. Afterwards the arms are ligated with the fragments of foreign DNA having termini compatible with those of

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the arms.

The appropriate DNA insert is recloned from the original vector used for the original cloning, into a suitable expression vector. To this end appropriate restriction enzymes are used, possibly in combination with oxonucleones, to produce the desired DNA fragments.

The DNA insert may be subcloned into a multiple site of a suitable well known plasmid vector e.g. derivatives of pC194, pTI81 and pUB110 at the restriction sites HindIII/BamHI/EcoRI.

5 The method of the invention can thus be used to prepare derivatives of known peptides and hormones, in which a cystein residue in the unmodified peptide is replaced by sulfide-bridged amino acids and serine and thiamine are replaced by corresponding dehydroamino acid residues.

10 These fragments are integrated into an appropriate expression vector by using the cohesive ends directly or by the addition of appropriate chemically synthesized oligonucleotide bridges. For the modification of the ends for example HindIII and BgLII can be used. The method is not limited to any special restriction enzymes. Any desired link can be made between the expression vector and the DNA insert using
15 suitable restriction enzymes in combination with chemically synthesized oligonucleotides.

Appropriate DNA inserts can also be obtained which code for polypeptide having site directed mutagenesis.

20 A variety of methods may be used to induce mutations of underlying DNA so as to prepare the desired mutants.

One method may comprise first inserting a fragment of a native or basic gene, containing sequences coding for the region to be mutated, into the replicative form of a phage, e.g. phage MI3mp8 to form MI3mp8PA. A synthetic oligonucleotide, complementary to the inserted sequences but
25 containing one or more nucleotidetriplets which code for the amino acid to be substituted, is then annealed to the single stranded form of MI3mp8A to form a double stranded region. This region serves as a primer for DNA polymerase I synthesis of the remaining complementary strand. After replication and identification, the mutant sequence may be
30 further modified or used to construct a suitable vector for expressing the mutated polypeptide.

In the work carried out on epidermin a wobbled DNA probe 5'-GTG(A)CAT(G/A)ATG(A)AAT(C)TT-3' deduced from a suitable pentapeptide segment of the proposed pre-sequence of epidermin LysPheIleCylThr was prepared. This DNA probe was hybridized against
5 plasmid DNA from *S. epidermin* DSM 3095.

Restriction analysis of the isolated plasmid reveals seven DNA fragments with EcoRI (16, 11, 10, 6.5, 5.5, 3.5 and 2.5 kbp), nine DNA fragments with HindIII (17, 14, 10, 5.3, 2.8, 1.8, 0.8, 0.6 and 0.5 kbp) and five DNA fragments with BamHI (20, 19, 10, 3 and 1 kbp).

10 A 5.4 kbp HindIII fragment was subcloned and subjected to rehybridization whereby the structure gene *epiA* was located within a 2.2 kbp EcoRI/BglII fragment.

As a mixture of 24 different 14-mers was used as a hybridization probe. The probe was applied in a 30-fold excess as a sequencing primer
15 in accordance with the techniques described in Novick *et al.* *Ann. N.Y. Acad. Sci.* 182, 279-294 (1971), Southern, *J. Molec. Biol.* 98, 503-517 (1975) and Heinrich *et al.*, *Molecul. gen. Genet.* 209, 563-569 (1987). The peptide sequence of epidermin allowed identification of the open reading frame. A single methionine codon is in appropriate distance to a Shine-
20 Dalgarno sequence. The structural gene of pre-epidermin terminates at the TAA stop codon, hence pre-epidermin consists of 52 amino acids (Figure 1) and it is processed to the epidermin between Arg⁻¹ and Ile⁺¹. Thus, as can clearly be seen, pre-epidermin is not a degradation product of a larger protein but is coded by a distinct structural gene.

25 Thus, it is apparent that, unexpectedly, the precursor protein of the antibiotics are coded by distinct structural genes.

A combination of prediction profiles for secondary structure (α , β , turns), flexibility, hydropathy, hydrophilicity (Figure 2A) and helix wheel plot were made using a Hycon program (Figure 2B). A high α -helix
30 probability is predicted for pre-epidermin -30 to -8 whereas the C-terminal part 1-22 which corresponds to pro-epidermin exhibits very high turn

probability. Moreover, the prediction plot shows clearly, that the N-terminus -30 to -1 highly hydrophilic, whereas the C-terminal part is more lipophilic. The N-terminal part -30 to -8 seems to fold partially into an amphophilic α -helix.

5 The N-terminal segment of pre-epidermin -30 to -1 does not contain any cysteine residues, whereas the C-terminal segment 1-22 contains the four cysteine residues, involved in sulphide bridge formation. Sequence -30 to -1 included many cleavage sites for endoproteases whereas even in the pre-epidermin state, sequence 1-22 is highly resistant
10 to proteolytic degradation.

The mature antibiotic can only be attacked by trypsin at Lys in position 13. The processing site Arg¹-Ile⁺¹ is hydrophilic and accessible, due to the turn forming Pro² residue.

15 The various enzymatic reactions which occur in the production of the antibiotics such as epidermin include modifications of the polypeptide part 1-22; cleavage of the N-terminal prepeptide fragment -30 to -1 and secretion of the matured antibiotic (see Figures 3 and 4).

20 The enzymatic modifications occur before cleavage of the prepeptide fragment. Enzymatic modification includes the elimination of water from Ser and Thr residues in position 5, 16, 19 and 8, 14 respectively to form dehydroalanine and dehydrobutyrine residues. Addition of thiol groups of Cys residues in position 2, 11, 21 and 22 to the C=C double bonds, also occurs, yielding the meso-lanthionine or (2S 3S, 6R) -3-methyl-lanthionine bridges. In addition, decarboxylation of residue
25 22 and double bond formation yields the C-terminal S-(2-aminovinyl)-D-cysteine. The reaction of C-terminally situated cysteine thiol groups with N-terminally located dehydroamino acids occurs with complete stereospecificity in epidermin, nisin and subtilin. Accordingly, during modification these elimination-addition reaction imply a reversal of
30 configuration of the C α carbon atoms at pre-epidermin residues L-Ser and

L-Thr to give D-configured C α atoms. On the other hand, the L-configuration of the cysteine halves is still maintained.

5 The four sulphide rings are also formed, subsequently at the same catalytic site, which is supported by the interaction with the N-terminal amphophilic α -helix. Only Thr⁺¹⁴ dehydrates without finding a cysteine. This position (Lys⁺¹³-Dhb⁺¹⁴) constitutes the enzymatic cleavage site at which trypsin inactivates the antibiotic epidermin. During sulphide ring formation C-terminal rigidity and hydrophobicity increases and may favor interaction of pro-epidermin with the lipid bilayer and may induce
10 translocation.

Finally, the hydrophilic α -helical N-terminus -30 to -1 is cleaved by a specific protease at the characteristic cleavage site described above.

Using the techniques described above plasmids coding for lantibiotics can be modified either by mutation of the gene coding for the
15 respective polypeptide or by replacement of such a gene by a gene coding for a different polypeptide and used to transform the original host or a different host, provided such host also, in its native state, is capable of expressing a lantibiotic.

Generally speaking, where the original functional gene codes for
20 a pre-sequence, as discussed above for example in the case of epidermin, the DNA sequence coding for such a pre-sequence may be retained in the modified plasmid; in this case the DNA-sequence for the new, or mutated pro-polypeptide will be positioned directly upstream of the pre-sequence DNA similarly to the original pro-polypeptide sequence.

25 Cultivation of a bacterial host according to the present invention may be carried out under conventionally used cultivation conditions as described for instance in our co-pending British Patent Application No. 8811760.1 which was filed on 18th May 1988 and in European Patent Application Publication No. 0 181 578. Purification and isolation of the
30 desired protein may also be carried out using the techniques or suitable modifications thereof described in the foregoing patent applications for

epidermin and gallidermin, including the use of adsorbents, ion-exchange resins and if desired HPLC.

5 The process of the invention can be applied to the formation of novel compounds for experimental purposes, or to the formation of known compounds or derivatives of known compounds in new hosts. For instance a plasmid containing the gene coding for epidermin can be used to transform the species *Streptococcus lactis* to produce epidermin from that host, or the gene coding for Gallidermin (see our co-pending British Patent Application referred to above) can be used to replace the gene
10 coding for the pro-polypeptide for epidermin in e.g. plasmid pEpi32 and used to transform *Staphylococcus epidermis* DSM 3095 to produce gallidermin from this host. Similarly other biologically active peptide derivatives containing dehydroamino acid residues and/or lanthionine bridges and/or methyllanthionine bridges can be produced, such as
15 derivatives of hormones such as human insulin, oxytocin, vasopressin, peptide antibiotics, hormone inhibitors such as elastase inhibitor and fibrinolytically active agents such as human tissue plasminogen activator. Such derivatives, as well as retaining biological activity of the parent compound can have increased stability and improved half-lives.

20 Ideally the DNA coding for the desired pro-polypeptide should include codons for cystein and serine and/or for cysteine and threonine for the formation of thioether bridges.

For relatively short chain polypeptides these respective codons should normally be no more than eight and preferably no more than six
25 codons apart, inclusive, although it is envisaged that, depending upon the steric conformation of the final polypeptide molecule much greater spacing is possible.

In respect of the formation of dehydroamino acids these will usually be derived from serine and threonine and, accordingly the DNA
30 coding for the desired pro-polypeptide will include codons for such amino acids.

Amongst the unusual amino acids which may be present in a polypeptide produced according to the present invention are, dehydroalanine, 2,3-dehydro-2-aminobutyric acid, meso-lanthionine, (2S, 3S, 6R)-3methyl-lanthionine, S-(2-(Z)-aminovinyl)-D-cystein, lysinoalanine and β -hydroxyaspartic acid; the structure of these residues are shown in Figure 5.

We have unexpectedly found that the multi enzyme complex responsible for the posttranslational modification of pre-epidermin is located on the 54kb plasmid pTü32 of *Staphylococcus epidermis* Tü 3298/DSM 3095.

The six genes (ORFs) responsible for the production of epidermin are designated herein epi A, B, C, D, Q and P and are clustered within 8kb and the proteins for which they code are designated Epi A, B, C, D, Q and P respectively; epi A encodes the 52 amino acid-long pre-epidermin. As described below, epi B, C and D are involved in the four enzymatic modification reactions (i) water elimination by a serine/threonine dehydratase, (ii) sulfur addition by a lanthionine synthase, (iii) C-terminal decarboxylation by a cysteine decarboxylase and (iv) double bond formation. Epi P protein is believed to be responsible for cleaving the mature epidermin from the N-terminal leader peptide, based on its striking homologies with the essential domain of serine proteases (Koide *et al.*, *J. Bacteriol.* 167:110-116 (1986); Meloun *et al.*, *FEBS Lett.* 183:195-200 (1985); and Stahl *et al.*, *J. Bacteriol.* 158:411-418 (1984)) whilst Epi Q is believed to be a regulatory protein regulating epidermin biosynthesis, based on its distinct homology to the pho B gene of *E. coli* (Makino *et al.*, *J. Mol. Biol.* 190:37-44 (1986)), the fact that both proteins are of a similar size with 205 (epi Q) and 229 (pho B) amino acid residues, the observed homology of 24.2% extending over the 153 C-terminal amino acid residues and the hydrophilicity plots of both proteins.

As a result of the unexpected finding of the entire genetic information for the epidermin biosynthesis and the elucidation of the genes for the proteins epi B, C, D, Q and P, it is now possible to obtain the isolated DNA coding for the proteins, and to construct plasmids
5 containing one or more of these genes so that upon cultivation of a host containing such plasmids one of these proteins alone or predetermined combinations of the proteins may be expressed and subsequently isolated.

The present invention therefore includes DNA sequences encoding respectively for the protein Epi B or Epi C, or Epi D, or Epi P or Epi Q.
10 These sequences may be isolated DNA either single or double stranded, obtained by cleavage of and isolation from pTü32 in known manner or obtained by chemical synthesis or any other conventional procedure. The DNA may also be integrated in a plasmid, suitably an expression plasmid and under the control of a promoter regulator; such constructs when
15 transformed into a suitable host which is then cultivated will express the protein Epi B, Epi C, Epi D, Epi P or Epi Q or combination of these proteins according to which DNAs were ligated into the plasmid. Alternatively plasmid pTü32 may be treated with suitable restriction nucleases to excise one or other of the DNA sequences, followed by
20 religation after any necessary modification of the free ends of the digested plasmid, so as to create a modified plasmid containing DNA sequences coding for predetermined ones of epi B, C, D, P and Q.

A further variant comprises the substitution of the gene coding for epidermin in pTü32 with a DNA sequence coding for a predetermined
25 amino acid sequence whereby cultivation of a suitable host with the modified plasmid will result in expression of a protein different from epidermin.

It is thus possible to substitute a DNA sequence encoding for gallidermin or mutant epidermin or other lantibiotic or other protein, for
30 the epidermin coding sequence in pTü32 whereby the resulting plasmid can be transformed into a suitable host which may be a host normally

27169-205

-20-

incapable of producing a lantibiotic or any of the proteins Epi B, C, D, P or Q and to cultivate the host under conditions whereby the substituted DNA sequence and the genes epi B, C, D, P and Q are expressed, so as to obtain a protein which is gallidermin, mutant epidermin or other
5 protein containing at least one structural feature of a lantibiotic.

Alternatively the genes coding for the proteins Epi B, C, D, P or Q may be inserted into a suitable vector, together with a DNA sequence encoding a predetermined amino acid sequence, the genes coding for the Epi proteins and the predetermined amino acid sequence being operably
10 connected with suitable promoter regulator functions, the resulting plasmid being transformed into a suitable host which may be a host normally incapable of producing a lantibiotic or any of the proteins Epi B, C, D, P or Q, and the host cultivated so that the inserted genes cause the expression of a protein derived from said predetermined amino acid
15 sequence but containing a lantibiotic structural feature, which protein may be gallidermin, epidermin, mutant epidermin, or another protein.

The present invention thus also includes within its scope DNA sequences capable of hybridizing, preferably under stringent conditions, with the DNA sequences described herein and coding for proteins having
20 substantially the activity of the proteins Epi B, C, D, P or Q. Stringent hybridization conditions select for DNA sequences of greater than 85% or, more preferably, greater than about 90% identity. Screening of the cDNA library may be carried out under highly stringent conditions according to the method described in European Patent Application No.
25 88 119 602.9 and Kashima *et al.* (*Nature* 313:402-404 (1985)). The DNA sequences capable of hybridizing under stringent conditions with the DNA sequences disclosed in the present application may be, for example, allelic variants of the disclosed DNA sequences, may be naturally present in the particular microorganism but related to the disclosed DNA sequences, or
30 may derived from other sources. General techniques of nucleic acid hybridization are disclosed by Maniatis, T. *et al.*, *In: Molecular Cloning*.

a Laboratory Manual, Cold Spring Harbor, NY (1982), and by Haymes, B.D. et al., In: Nucleic Acid Hybridization, a Practical Approach, IRL Press, Washington, DC (1985), which references are herein incorporated by reference.

5 The proteins Epi B, C, D, P and Q are valuable and interesting new reagents potentially useful in the preparation of novel proteins or other substances containing structural features such as dehydroalanine, dehydrobutynine, meso-lanthionine, 3-methyl-lanthione, and S-(2-aminovinyl)-D-cysteine.

10 As such, they may be utilized as isolated proteins, or as chemical catalytic reagents in chemical synthesis procedures to investigate the extracellular processing of proteins by such enzymes.

The invention also relates to the proteins Epi B, C, D, P and Q in substantially pure form. By the term "substantially pure" is intended that the protein is free of the impurities that are naturally associated therewith. Substantial purity may be evidenced by a single band by
15 electrophoresis.

The polypeptides of the invention may be isolated and purified from the above-described recombinant molecules in accordance with conventional methods, such as extraction, precipitation, chromatography,
20 affinity chromatography, electrophoresis, or the like. Preferably, the polypeptides are produced as part of a fusion protein which further comprises an auxiliary protein. Such auxiliary which facilitates the isolation and purification of the polypeptide of interest. Such auxiliary proteins include, for example, typical secretion signals, the maltose
25 binding protein from *E. coli*, or protein A. Methods for preparing fusion proteins comprising protein A, the purification thereof by immunoaffinity chromatography, and the cleavage thereof to release the protein of interest is taught, for example, in PCT Application Publication No. WO84/03103 (1984).

30 A necessary condition to permit cleavage of the fusion protein is that it contains a unique cleavage site which may be recognized and

-22-

cleaved by suitable means. Such a cleavage site may be a unique amino acid sequence recognizable by chemical or enzymatic means and located between the desired protein and the auxiliary protein. Such a specific amino acid sequence must not occur within the desired protein or auxiliary protein. Examples of enzymatic reagents include proteases such as collagenase which may recognize the amino acid sequence $\text{NH}_2\text{-Pro-X-Gly-Pro-COOH}$, wherein X is an arbitrary amino acid residue, e.g. leucine; chymosin (rennin) which cleaves the Met-Phe bond; kallikrein B which cleaves on the carboxyl side of Arg in X-Phe-Arg-Y; enterokinase which recognizes the sequence $\text{X-(Asp)}_n\text{-Lys-Y}$, wherein $n=2-4$, and cleaves it on the carboxyl side of Lys; thrombin which cleaves at specific arginyl bonds. Examples of chemical agents which may be used to cleave the fusion proteins include cyanogen bromide which cleaves after Met; hydroxylamine which cleaves the Asn-Z bond wherein Z may be Gly, Leu or Ala; formic acid which in high concentration ($\sim 70\%$) specifically cleaves Asp-Pro.

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, utilize the present invention to its fullest extent. The following preferred specific embodiments are, therefore, to be construed as merely illustrative, and not limitative of the remainder of the disclosure in any way whatsoever.

EXAMPLES

Example 1

1. Overproduction of gallidermin

A DNA fragment containing the open reading frame of gallidermin can be cloned in *Staphylococcus epidermidis* DSM 3095, the epidermin producing strain by using a medium copy plasmid such as pC194, pE194,

pUB110, pT181 or pMK148 gallidermin. An increase of the gene doses usually correlates with an increase of product production; the correlation is not necessarily linear. High copy number plasmid derivatives of pC194 or pT181 can be used as cloning vehicles too.

5 2. Exchange of leader sequence

The leader-sequence of epidermin corresponding to amino acids -1 to -30, is involved in the secretion of epidermin. The sequence can be used to secrete other peptides in *S. epidermidis* such as gallidermin.

10 The leader-sequence DNA can be made portable by inserting respective linkers at the beginning and at the end of its sequence. Thus the leader sequence DNA can be isolated in large amounts from the plasmid and can be inserted at respective positions of other peptides and proteins. The leader-sequence DNA can also be produced by chemical synthesis.

15 Example 2

Production of Gallidermin using *S. epidermis* as host

1. Preparation of plasmid (see Figure 6)

20 a) Plasmid pCUI was prepared by ligating PstI digested pCLP100 and NdeI digested pUC18 using Klenow as described in the thesis "Molekular genetische Untersuchungen zur plasmidkodierten Arsenit und Arsenatrestistent bei Staphylococcen", by Dr. Ralf Rosenstein (available from the Technische Universitat, Munich, West Germany). The resulting plasmid was then
25 digested with EcoRI.

- b) Chromosomal DNA was isolated from *S. gallinarum* (DMS 4616) and was digested with EcoR1. A 4.7 kb fragment containing the gallidermin structural gene in a 2.4 kb long sequence between HindIII and EcoR1 restriction sites was isolated using as a primer the sequence.

5' CAC ATC CAG GAG TAC 3'

- c) The 4.7 kb Fragment was then ligated into the EcoR1 site of the digested pCUI plasmid from step a) to give a plasmid designated pCUgdm1.

10 2. Preparation of a *S. epidermis* host

In this example a mutant strain of *S. epidermis* DSM 3095 incapable of producing epidermin was isolated.

The mutagenesis was carried out on a strain which was characterized by chromosomally coded Rifampicin resistance (20 ug/ml).

15 *S. epidermis* DSM 3095 grown on Agar plates was used to inoculate 30 ml basic broth medium which was cultivated overnight. 0.5 ml of the overnight cultivation was then used to inoculate 50 ml of production medium which was shake cultivated at 37°C for three hours.

20 Cells were removed from the cultivation medium and suspended in 4.5 ml pre-warmed TM-Buffer (30 mM Tris-Maleate pH 6.5 (the resulting solution is designated Solution A)).

The solution A was checked for spontaneous mutations and for cell count (1.25×10^{10} cells/ml).

25 4 ml of solution A was thoroughly shaken with 1 ml ethyl methyl sulphonate (final concentration 47 µg/ml) and then maintained under shaking at 37°C for one hour.

-25-

Cells were then extracted from the cultivation broth, washed twice in TM-Buffer and resuspended in 5 ml TM-Buffer (the resulting solution was designated Solution B and contained mutated cells).

5 Solution B was found to contain 2×10^8 cells/ml which corresponds to survival rate of 1.6%.

50 ml of solution B was added to 5 ml production medium and grown overnight at 37°C (phenotypic expression). The resulting solution was designated Solution C. A cell count showed 7.3×10^8 cells/ml.

10 The solution was plated on BM-Agar plates and individual colonies were picked out. These were used to inoculate test plates (consisting of BM-Agar to which *Micrococcus luteus* has been laid on the surface). Those colonies which had no inhibitory effect on *M. luteus* were selected as non-producers of Epidermin.

BM Agar contains per liter:

15 10 gm Peptone No. 140
5 gm Yeast extract
1 mg Glucose
5 mg NaCl
1 mg K_2HPO_4
20 pH 7.5

A mutation rate of about 3% was noted.

The 45 non-producers which were found were sub-cloned 20 times to yield 16 stable non-producers.

25 All stable non-producers were found to contain the wild type plasmid pEpi32. From the restriction pattern this is identified as identical to the plasmid in the wild type strain.

Transformation of non-producing *S. epidermis*

750 ml of BM-medium was inoculated with 5 ml of medium obtained by overnight cultivation of a stable non-producing strain, and the inoculated medium was shake cultivated in a 2 liter flask at 37°C with a
5 shake speed of 120 rpm.

The initial optical density of the inoculated BM-medium was 0.03-0.04. When the optical density had reached 0.45-0.55 the cells were removed by centrifugation in a GS.-3-Rotor at 8500 rpm for 15 minutes at 4°C. The isolated cells were then washed successively in 750, 350, 40
10 and 10 ml of 10% glycerin, suspended in 2-3 ml 10% glycerin, and frozen in 110 ml portions in ERGs at -70°C. The cell count amounted to $1-5 \times 10^{10}/\text{ml}$.

The frozen cells were thawed at room temperature for 5 minutes, then 50 μl of cell suspension was incubated in an ERG with 2 μl plasmid
15 pCUgdm1 in TE-Buffer for 30 minutes at room temperature.

The mixture was then introduced into an electroporation cuvette having a 0.2 cm electrode gap and immediately electroporated. Thereafter the cells were rapidly resuspended in 950 μl SMMP50-medium, transferred into a 2.5 ml ERG and shaken for 90 minutes at 37°C. The
20 ERGs were inclined at 45° in order to provide for a good aeration of the medium.

SMMP50-medium contains pro 100 ml, 55 ml 2SMM, 40 ml 4 PAB and 5 ml 5% BSA. The 2SMM contains 1 mol saccharose, 0.04 mol maleic acid, 0.04 mol MgCl_2 and NaOH to pH 6.5. 4 PAB is a solution
25 of 7 g/100 ml of Gibco antibiotic medium 3.

The cell suspension is diluted and spread on a BM-Agar containing gallidermin which is incubated for 20 hours at 37°C.

Testing of growing strains which produce gallidermin was carried out by selection of colonies from a *M. luteus* test plate and by cultivating

-27-

the respective selected colonies and determining the presence of gallidermin by HPLC.

Three pCUgdm1 transformed mutants capable of producing gallidermin were located.

5 Determination of the presence of gallidermin produced by pCUgdm1 transformed *S. epidermin*

a) Bio assay

10 FP-Agar was inoculated with *M. luteus* ATCC 9341 and incubated at 37°C for 18 hours. Half of the produced culture was removed with a loop and suspended in 100 ml FP-medium and was cultivated for 8 hours at 36°C. The cultivation was stopped when the optical density reached 1.0. FP-Agar was inoculated with 0.5% of this suspension, each 10 ml was poured into a Petri dish and stored for 3 weeks at 4°C.

15 The Plate diffusion test was carried out as described in Zähler and Maas, "Biology of Antibiotics", Springer Verlag, Berlin 1972. 10 ul of culture filtrate from cultivation of the transformed *S. epidermin* was captured on a filter paper and dried. The paper was placed on the test plate which was then incubated for 24 hours at 37°C.

b) HPLC

20 The selected transformed strain was cultivated for 26 hours in the production medium. The culture broth was centrifuged for 10 minutes at 13.000 rpm.

25 The isolated culture liquid was then subject to HPLC on a SP 8.700 liquid chromatography apparatus (Spectra Physics, Darmstadt, FRG) using as the mobile phase A) H₂O with 0.5% 70% perchloric acid and B) Acetonitrile. Column packings were Nucleosil -100 C-18 of grain size 7

-28-

um and column sizes 125 mm x 4.6 mm I.D. and 20 mm x 4.6 mm ID for the pre-column.

Gradients were as follows:

	time (min.)	A [%]	B [%]
5	0	77.5	22.5
	8	63.0	37.0
	8.5	0	100
	9.5	0	100
	10	77.5	22.5
10	14	77.5	22.5

The resulting chromatogram is shown in Figure 7A. A standard curve is shown in Figure 7B showing that gallidermin elutes at 7.54 minutes.

The following were used as culture medium.

1. FP-Agar

Meat extract	4 g
Peptone	10 g
NaCl	3 g
Na ₂ HPO ₄	5 g
Glucose	10 g
Complex agar	15 g
Water	1 liter
pH	7.2

2. FP-Medium

Meat extract	4 g
Peptone	10 g
NaCl	3 g
Na ₂ HPO ₄	5 g
Glucose	10 g
Water	1 liter
pH	7.2

3. Production medium

Meat extract	33 g
Malt extract	30 g
NaCl	40 g
Calcium Hydroxide	3.8 g
Water	1 liter
pH	6.5

5 Example 3Plasmid Isolation

Plasmid DNA from *S. epidermis* Tü3298 was isolated according to a modified procedure of Norick *et al.*, *Ann. NY-Acad. Sci.* 182:279-294 (1971). *S. epidermis* was grown on BM-media (1% peptone 140, Gibco, Neu-Isenburg, F.R.G., 0.5% yeast extract, Difco, Detroit, USA, 0.1% glucose, 0.5% NaCl and 0.1% K₂HPO₄ x 2H₂O) until stationary phase. Cells were centrifuged and washed twice with 0.5 M EDTA. The pellet was resuspended in 80 ml NaCl buffer (50 mM Tris/HCl, pH 7, 50 mM

EDTA, 2.5 M NaCl), 1.5 ml lysostaphin solution (0.5 mg/ml, Sigma, Heidelberg, F.R.G.) was added and the suspension was incubated at 37°C for 20 min. Cells were lysed by the addition of 80 ml lysis buffer (50 mM Tris/HCl, pH 8, 300 mM EDTA, 500 mM Brij., 40 mM sodium deoxycholate and kept on ice for 1 h. The lysate was centrifuged (30 min, 13,000 rpm, 4°C) and the supernatant was mixed with one quarter of its volume with 50% solution of PEG-6000. Plasmid DNA was precipitated at 4°C overnight. The DNA suspension was centrifuged (20 min, 13,000 rpm, 4°C), resuspended in 8 ml TE buffer and 50 µl of proteinase K solution (20 mg/ml) was added. After incubation at 37°C for 15 min the DNA was precipitated with ethanol and further purified by CsCl centrifugation (1 g CsCl/ml, 40,000 rpm, 40 h, 20°C).

RNA isolation and electrophoreses

S. epidermin was grown on SMS minimum medium (Terzaghi *et al.*, *Appl. Microbiol.* 29:807-813 (1975)) and RNA isolated therefrom, using a modified procedure similar to that described for *Bacillus subtilis* RNA (Ulmanen *et al.*, *J. Bacteriol.* 162:176-182 (1985)). Cells were lysed with lysostaphin (0.1 mg/ml) in protoplasting buffer and incubation was performed at 37°C. Total RNA was glyoxylated (McMaster *et al.*, *Proc. Natl. Acad. Sci. USA* 74:4835-4839 (1977)) and separated on a 1.2% agarose gel using 10 mM Na₂P0₄, pH 7, as electrophoresis buffer. RNA was stained with ethidium bromide and blotted to a nitrocellulose membrane (Scheider and Schuell, Dassel, F.R.G.) by capillary transfer with 20xSSC buffer (0.15 M NaCl, 0.015 M tri sodium citrate, pH 9). 23SrRNA and 16SrRNA were used as size standards.

In vitro transcription

Single stranded RNA probes were obtained by cloning the respective fragment in a pSPT18/19 vector system (Boehringer Mannheim, Mannheim, F.R.G.). The plasmids were linearized with EcoRI or HindIII to get a linear DNA template. For transcription the protocol in Melton
5 *et al.*, *Nucl. Acid Res.* 12:7035-7056 (1984), was modified according to the instructions of the commercial supplier. T7-RNA polymerase or SP6-RNA polymerase was used in the presence of $\alpha^{32}\text{P}$ -CTP (800 Ci/mMol). Unincorporated ribonucleotides were separated from labeled RNA by
10 Sephadex G50 chromatography.

Northern hybridization

RNA was transferred after electrophoresis according to Thomas, P.S., *Proc. Natl. Acad. Sci. USA* 77: 5201-5205 (1980). After 2 h incubation at 80°C the filter was shortly incubated in 20 Tris/HCl, pH 8, at 100°C to reverse glyoxylation. Afterwards filters were prehybridized at
15 42°C in 50% formamide, 5xSSC (0.15 M NaCl, 0.015 M tri sodium citrate, pH 9), 50 NaPO₄, pH 6.5, 0.1% ficoll 400 (Pharmazia, Freiburg, F.R.G.), 0.1% polyvinylpyrrolidone, 0.1% bovine serum albumin and 0.25 mg/ml denatured salmon sperm DNA for 2h. After probe addition hybridization
20 was performed in the same buffer at 42°C for 12 h. Filters were washed once in 1xSSC, 0.1% SDS at 42°C for 15 min and exposed to Kodak-X Omat films at -70°C for 4 h. Thereafter filters were washed twice with 0.5 SSC, 0.1% SDS at 70°C for 15 min and autoradiograms were exposed at -70°C for 16 h. Next day washing was continued with 0.1xSSC, 0.1%
25 SDS at 70°C for 30-60 min and afterwards again exposed to Kodak-X Omat films at -70°C for 3 days.

Southern hybridization

For southern hybridization (Southern, E.M., *J. Mol. Biol.* 98:503-517 (1975)) 5' labeled oligonucleotides were used as probes at 23°C. Oligonucleotides were labeled with gamma³²P-ATP using 4T polynucleotide kinase (Boehringer Mannheim, Mannheim, F.R.G.).
5 Oligonucleotides and primers were synthesized on a 391 DNA synthesizer (Applied Biosystems, Weiterstadt, F.R.G.) and used without further purification.

DNA sequencing

10 DNA was sequenced radioactively and non-radioactively by the chain termination method (Sanger *et al.*, *Proc. Natl. Acad. Sci. USA* 74:5463-5467 (1977)) using T7-DNA polymerase (Pharmazia, Freiburg, F.R.G.). Radioactive plasmid sequencing was performed as described in Hattori *et al.*, *Anal. Biochem.* 152:232-238 (1984) with appropriate primers.
15 The 3.6 kb BamHI/PstI fragment was sequenced non-radioactively on an Applied 373A DNA sequenator (Applied Biosystems, Weiterstadt, F.R.G.). The respective fragment was cloned in phagemid pBSK-/+. The construction was digested with BamHI and SacI and the linearized DNA was unidirectionally digested from the 5' end with exonuclease III
20 (Boehringer Mannheim, Mannheim, F.R.G.) to obtain a set of nested deletions which were treated with mung bean nuclease (Boehringer Mannheim, Mannheim, F.R.G.) to receive blunt ends. After electrophoresis (1% agarose gel) fragments of appropriate size were isolated from the gel, religated and transformed into *E. coli* strain XL-1
25 Blue. Single stranded DNA was isolated by using helper phage CSM13 and sequenced with Taq Polymerase (Promega, Freiburg, F.R.G.) according to the protocol of the commercial supplier.

Plasmid Construction

The staphylococcal tetracycline resistance plasmid pT181 has been sequenced (Kahn *et al.*, *Plasmid* 10:251-259 (1983)) and found to contain a single NdeI site within the pre-gene which is not necessary for plasmid replication (Gennaro *et al.*, *J. Bacteriol.* 169:2601-2610 (1987)). The multiple cloning site (mcs) of the *E. coli* vector pUC19 (Yanisch-Perron *et al.*, *Gene* 33:103-119 (1985)) was inserted into the NdeI site to form pT18lmcs (see Figure 14).

A staphylococcus-*E. coli* shuttle vector, pCUI (Figure 10) was constructed from pCLP100, a derivative of the staphylococcal chloramphenicol resistance plasmid pC194 (Horinouchi *et al.*, *J. Bacteriol.* 150:815-825 (1982)) and the *E. coli* vector pUC19. PCUI is stably maintained in both hosts with an insert size up to approximately 6 kb. pT18lmcs and pCUI are compatible in staphylococci and were used to subclone DNA fragments from pTü32.

A HindIII fragment of pTü32 was cloned in pUC19 and used as a probe in Southern hybridization to identify further restriction sites near the HindIII fragment (Figure 8C).

The 13.5 kbp BglII fragment of the 54 kbp episomal element pTü32 from *S. epidermis* was subcloned in pT18lmcs to yield pTepil4 (Figure 8A). For DNA sequencing subclones were made in the *E. coli* vector pUC19 (Yanisch-Perron *et al.*, *Gene* 33:103-119 (1985)) and pBluescript II^R (Stratagene, Heidelberg, F.R.G.). Single stranded RNA probes were obtained from DNA cloned in vector pSPT18/19 (Boehringer Mannheim, Mannheim, F.R.G.).

Gene Analysis

Sequencing the DNA region adjacent to the epidermin structural gene, epi A, revealed five additional complete open reading frames epi B, C, D, P and Q inside the 13.5kbp BglII fragment of pTü32.

5 As can be seen in Figure 9, directly adjacent to the sequence encoding for EpiA separated by only 50 nucleotides from the epiA ochre codon there is a large open reading frame preceded by a S/D sequence which spans 2,970 bp. A TTG codon for leucine which can also act as a translation start codon in staphylococci is in appropriate distance (86p) to
10 a S/D sequence. This open reading frame is designated epiB and as described herein can successfully be used for the complementation of epidermin biosynthesis mutants and an essential role in epidermin biosynthesis.

The protein coded for by epiB, starting from the TTG (Leu) has
15 a molecular weight of about 115kDa, a net charge of -3 at pH7, and is moderately hydrophobic (41% hydrophobic residues) as may also be predicted from a hydrophilicity plot according to Kyte *et al.*, *J. Mol. Biol.* 157:105-132 (1982).

At the 3' end of epiB no palindromine structure characteristic of
20 transcription termination can be seen. There is, however, a 122bp overlap with an other reading frame epiC, shifted by -1 base pair also to be seen in Figure 9.

We have established this to be no artefact by independently cloning and sequencing the respective 47 kbp HindIII-fragment twice from two
25 independent plasmid isolations. This was also confirmed by mutant complementation with an epiC containing fragment as described herein.

Inside the overlapping region of epiB and epiC reading frames the first TTG codon (Leu) which is only 36bp 3' to an AGGA element serves as a translational start codon, indicating that both reading frames overlap
30 by about 40 codons. The actual amino-terminus of the EpiC protein was

determined by N-terminal sequencing. Reading frame epiC encodes a protein with 445 amino acid residues commencing with starting codon TTG (Leu). The reading frame epiD directly follows 3' to epiC with a start ATG 86p 3' to a AGGAGG S/D sequence. 3' to epiD is a classical rho dependent transcription terminator structure; epiD encodes a protein of 181 amino acid residues with ATG (Met) on start codon.

None of the proteins EpiB, C, D, P and Q show any similarity with protein sequences filed in the protein data bases Swiss Prot and Gene Bank, and thus represent unknown types of enzymes and regulatory proteins.

Transcription of the biosynthetic genes

Single stranded RNA probes were obtained by cloning the desired fragment in a pSPT 18/19 vector system (Boehringer Mannheim, Mannheim, F.R.G.) as described above.

Two transcripts differing considerably in size were obtained as illustrated in Figure 10. A hybridization probe specific of epiA identified a small transcript of about 300bp. Transcripts of similar size were also found for the lantibiotics nisin (Buchmann *et al.*, *J. Biol. Chem.* 263:16260-16266 (1988)) and subtilin (Banerjee *et al.*, *J. Biol. Chem.* 263:9508-9514 (1988)). Additionally a large transcript of approximately 5kb can be identified with a hybridization probe specific for epiB. As there were no *E. coli*-like promoter sequences in front of epiB, whereas appropriate sequences were located 5' to epiA it can be seen that the epiA promoter acts as a promoter for a polycistronic mRNA.

Downstream open reading frames

The open reading frames epiP and epiQ are located on the opposite DNA to epiB, C and D with epiQ sharing a termination structure with epiD a perfect hairpin with a 6bp loop.

5 Exactly within this loop structure the TAA stop codons for both reading frames epiD and epiQ share two of three nucleotides.

The epiP reading frame starts with an ATG codon which is in appropriate distance (6 bp) to a S/D sequence. Taking the ATG codon as the translational start of epiP a protein of 461 amino acid residues with
10 molecular weight of 51.8kD. epiP shares characteristic homologies with the conserved amino acid motives of serine proteases (see Figure 11) indicating that epiP is implicated in cleaving the mature lantibiotic from the modified prepeptide.

The epiQ reading frame also starts with an ATG codon and
15 encodes 205 amino acid residues (Figure 9). A S/D sequence is present 6 bp distance to the ATG codon and a molecular weight of 243 kD can be deduced from the DNA sequence. The epiQ protein shares characteristic homologies with PhoB (see Figure 12) which is a positive regulatory factor for the phosphate regulatory of *E. coli* so that epiQ is
20 implicated as a regulatory factor in lantibiotic synthesis.

Preceding epiP is an *E. coli*-like -10 region (5'-TATAAA) 12bp in front of the S/D sequence which may serve as a promoter in staphylococci. The distance between the epiP stop codon and the ATG start codon of epiQ is only 10 nucleotides and the epiQ S/D sequence overlaps with the
25 epiP termination codon as shown in Figure 9.

5' to epiA, B, C, D a further reading frame with opposite orientation can be seen which potentially encodes a maximum of 148 amino acids. A characteristic S/D sequence is present but none of the previously described start codons for staphylococci (ATG, TTG, GTG).

With a -1 frame shift a further reading frame follows which exceeds the isolated BglII fragment illustrated in Figure 9.

These two reading frames are homologous to a single open reading frame, gdmY, identified adjacent to the structural gene of gallidermin (Schnell, N., *Biosynthese der Peptid-Antibiotika Epidermin und Gallidermin*; Doctoral Thesis, University of Tübingen, F.R.G. (1989)). The homologous reading frames on the *S. epidermis* plasmid are designated epiY' and epiY''.

Example 4

10 *S. carnosus* TM300 was transformed with the plasmid pTepil4, prepared as described above, using standard techniques. The transformed strain was then grown on BM-media (see above).

15 The resulting transformants were found to be capable of inhibiting the epidermin sensitive tester strain *Micrococcus luteus* ATCC9341. In this assay 1 ml of an overnight culture of *M. luteus* (adjusted to an OD₅₇₈ of 1.0) was added to 500 ml molten BM-Agar. Petri dishes usually contained 10 ml of this agar. Dilutions of *S. epidermis* cultures were spread on the agar surface. Epidermin positive colonies were detected as a zone of growth inhibition of *M. luteus* around the colonies.

20 Cells were grown on 3% meat extract, 3.8% malt extract, 0.6% CaCl₂·2H₂O and 4.6% NaCl, pH6.5. According to the transformation used, tetracycline or chloramphenicol was added. After 24 h incubation (37°C, 160 rpm) in 500 ml Erlenmeyer flasks with one extension containing 100 ml medium, the culture both was centrifuged at 10,000 rpm
25 in a Servall centrifuge for 10 min.

Supernatants of liquid transformant cultures were purified by adsorption chromatography (XAD1180, impurities eluted with water/methanol (1:1) and epidermin eluted with methanol/0.1N HCl (9:1); after evaporation the eluate was adjusted with 3N NaOH to pH 3.5 and

filled up with water to 10 ml) and detected by HPLC chromatography. The inhibitory activity co-migrated with mature epidermin at 6.75/6.76 min (see Figures 13A and 13B). Untransformed *S. carnosus* culture media treated similarly had no peak in this elution region (6.72 to 6.79 min, Figure 13C). These results clearly confirmed the heterologous epidermin biosynthesis in *S. carnosus* and demonstrated that pTepil4 contains all information necessary for epidermin biosynthesis.

As pTepil4 contains the 13.5kbp BglII fragment this indicates that the epiY' and epiY'' reading frames are not necessary for the production of epidermin in this system as epiY' lacks a translational start codon and epiY'' is incomplete on this fragment.

Example 5

A number of epi' mutants of *S. epidermin* Tü3298 were prepared by ethylmethane sulfonate (EMS) mutagenesis. This procedure was carried out according to Miller, J.H., *Experiments in molecular genetics*, Cold Spring Harbor Laboratory; Cold Spring Harbor, N.Y. (1972). The mutants were screened for epidermin production, or lack of epidermin production using the *M. luteus* assay described above. Epi' mutants were transferred several times to test their stability. Of the 40 epi' mutants isolated, only 10 were stable; the unstable mutants produced epidermin again after several transfers. All stable epi' mutants still contained plasmid pTü32 which suffered no deletions or rearrangements as tested by restriction endonuclease analysis. The 10 epi' mutants were used for complementation studies.

Various restriction fragments of plasmid pTü32 were cloned in *S. carnosus* to test for heterologous epidermin production. The fragments were inserted into plasmid vectors T181mcs and pCU1 as described above and the various ORFs which were subcloned as shown in Figure 16B.

Cloning was first carried out in *S. carnosus* (by protoplast transformation (Gotz *et al.*, *FEMS Microbiol. Lett.* 40:285-288 (1987)) or *E. coli* (using CaCl_2 ; Cohen *et al.*, *Proc. Nat. Acad. Sci. USA* 69:2110-2114 (1972)) and then the recombinant plasmids were isolated and transferred
5 into the various *S. epidermis* epi mutants by electroporation (Augustin *et al.*, *FEMS Microbiol. Lett.* 66:203-208 (1990)). Enzymes used for molecular cloning were obtained from Boehringer Mannheim (Mannheim, F.R.G.), BRL (Eggenstein, F.R.G.) or Pharmacia (Sweden). This indirect transformation method was necessary since transformation of *S. epidermin*
10 strains was only successful with circular covalently closed (ccc) plasmids; when ligation products were used, transformants could only be isolated occasionally.

The results of the complementation studies are summarized in Table 1.

Table 1. Epidermin production by non-producing <u>S. epidermidis</u> mutants after transformatin with various pTep14 DNA fragments												
Mutant	Complementation with										Mutation locus	
	pTep1 14	pTep1 ABCDQ	pCUep1 ABC	pTep1 AB	pCUep1 A1	pCUep1 A2	pCUep1 CDQ	pCUep1 DQ	pCUep1 Q	pCUep1 B		
EMS 5	+	+	+	+	+	-	-	-	-	-	<u>ep1A</u>	
EMS 6	+	+	+	+	+	-	-	-	-	-	<u>ep1A</u>	
EMS 11	+	+	-	-	-	-	+	+	-	-	<u>ep1D</u>	
EMS 12	+	+	+	-	-	-	+	-	-	-	<u>ep1C</u>	
EMS 13	+	+	+	-	-	-	+	-	-	-	<u>ep1C</u>	
EMS 18	+	+	+	+	-	-	-	-	-	-	<u>ep1B</u>	
EMS 19	+	+	+	-	-	-	+	-	-	-	<u>ep1C</u>	
EMS 33	+	+	+	+	-	-	-	-	-	-	<u>ep1B</u>	
EMS 39	+	+	+	-	-	-	+	-	-	-	<u>ep1C</u>	
EMS 45	+	+	+	+	-	-	-	-	-	-	<u>ep1B</u>	
pCU: Fragments cloned in pCU1; pT: Fragments cloned in pT181mcs. + complementation (epidermin production; - no complementation)												

A series of plasmids were constructed which carry various epi genes (A, B, C, D, P and Q) (Figure 16B). Two plasmids pTepi4 and pTepiABCDQ were able to complement all epimutants. The other constructed plasmids pCUepiABC, pTepiAB, pCUepiCDQ, pCUepiB, 5 pCUepiA₁, pCUepiA₂, pCUepiDQ and pCUepiQ contained the indicated genes.

The various plasmids were able to complement only certain classes of mutants which are classified herein as follows:

- EMS 5 and 6 - epiA mutants,
- 10 EMS 18, 33 and 45 - epiB mutants,
- EMS 12, 13, 19 and 39 - epiC mutants,
- EMS 11 - epiD mutant.

The results as shown below indicate at least that the four ORFs epiA, B, C and D are required for epidermin biosynthesis.

- 15 The plasmid pCUepiA₁ carries the structural gene epiA as the only complete ORF and an additional 1400bp upstream and 602bp downstream, the latter encoding 190 amino acids of the epiB N-terminus. Transformation using pCUepiA₁ resulted in the complementation of the epidermin mutants EMS 5 and 6 identifying them as epiA mutants. The 20 smaller epiA-containing Scal fragment cloned in both orientations in pCUepiA₂ failed to complement the epimutants as the epiA promoter was cut by this enzyme.

- 25 pCUepiB carries a BstN1 fragment containing the complete epiB and an upstream region of 100bp which includes 75bp of the 3' terminus of epiA; the epiA promoter is missing. Transformation with pCUepiB failed to complement any *S. epidermis* mutant to epidermin production, indicating that epiB lacks its own promoter and is very likely co-transcribed from the epiA promoter.

- 30 This is in agreement with the results obtained with pTepiAB (Figure 16B; Table 1) which contains epiA promoter and the complete

epiA and B genes and the use of which complements both the epiA and epiB mutants.

Plasmid pCUepiCDQ was able to complement both epiC and epiD mutants and plasmid pCUepiDQ was only able to complement the epiD mutant (Table 1). The complementation was independent of the orientation of the cloned DNA fragment. These results show that both epiC and epiD possess their own promoters.

Example 6

The epiA mutated pTü32 derivatives were isolated from EMS 5 and 6 and the respective epiA ORFs were sequenced. Both plasmids had point mutations within epiA; in the EMS 5 plasmid the codon AGT (Ser³) was changed to AAT (Asn³) and in the EMS 6 plasmid the codon GGA (Gly¹⁰) was changed to GAA (Gln¹⁰); both these mutations were located at crucial sites within the unmodified epidermin.

Example 7

An epiB (on a BstN1-fragment) was put under the control of the promoter on plasmid pPS4 (Figure 17). The resulting plasmid pPS4epiB was able to complement the epiB mutants EMS 18, 33 and 45. A plasmid containing epiB in the opposite orientation did not complement the mutations. This also establishes that pCUepiB was unable to complement any of the EMS mutants, because the epiA promoter is missing.

Example 8

As described above, the presence of pTepi4 (Figure 16A) resulted in epidermin biosynthesis in *S. carnosus*; however, the presence of pTepiABCDQ did not. The minimum size of DNA required which leads

to heterologous epidermin expression in *S. carnosus* was determined by complementing *S. carnosus* (pTepiABCDQ) with distally located DNA fragments (Figure 18). Transformation of *S. carnosus* (pTepiABCDQ) with plasmids pCA44-90, pCA44-91 and pCA44-92 led to epidermin production, pCA44-92 containing the complete epiQ and epiP ORFs consisted of the smallest DNA fragment able to complement epidermin production. These results indicate that the epidermin biosynthetic genes are clustered within an 8kb DNA fragment containing the six ORFs; epiA, B, C, D, Q and P and that no other genes are involved in epidermin biosynthesis.

In these examples staphylococcal plasmid DNA was prepared by the cleaved lysate method (Makino *et al.*, *J. Mol. Biol.* 190:37-44 (1986)). Cells were lysed by the addition of lysostaphin (8 μ g/ml) and the DNA was isolated by CsCl-centrifugation. *E. coli* supercoiled plasmid DNA was prepared by the modified alkaline lysis method (Birnboim *et al.*, *Nucl. Acid Res.* 7:1513-1518 (1979)).

The DNA sequence of the PCR-amplified epiA-containing fragment and the two mutated epiA regions of the *S. epidermis* mutants, EMS 5 and 6, was determined by double-stranded DNA sequencing using the dideoxy procedure (McMaster *et al.*, *Proc. Natl. Acad. Sci. USA* 74:4835-4839 (1977)), the "sequence" list of Pharmacia and (α -³⁵S)-dATP from Amersham. Primers used for DNA sequencing and PCR amplification were synthesized using the DNA-synthesizer of Applied Biosystems. The sequences of the two primers for PCR amplification of epiA are as follows:

- a) 5'-GGGTTT**T**AGG(TA)ATCCTTTT**T**AATAAATTTT**T**AGGAG-3'
- b) 5'-CCTCAA**A**ATTAAGACG(A)GAT(G)CCTCTATTGAAGCCC-3'

Primer a) binds in front of the RBS of epiA and primer b) after the epiA stop codon. These bases indicated by bold letters represent

(shown in brackets) used to create BamHI sites in front and at the end of *epiA*; the *epiA* promoter is absent in the amplified DNA fragment.

For the determination of the DNA sequence of the mutated *epiA* in the mutants EMS 5 and 6, plasmid pTü32 was isolated and the DNA region was amplified by PCR using another set of DNA primers binding upstream of the postulated *epiA* promoter region (5'-GGTTTGGTTATTTTCC-3') and downstream of the stop codon (5'-CCTCAAAATTAAGACAGAGCCTC-3'); the DNA sequence of *epiA* is also shown in Schnell et al., Nature (Lond.) 333:276-278 (1988).

Example 9

The *epiD* gene was isolated from the plasmid pTepil4, multiplied by PCR amplification and cloned into the StuI-restriction site of vector pIH902 (New England, Biolabs) by "blunt end" ligation, with the result that the *epiD* gene is fused without any intervening base pairs immediately at the Factor Xa-cleavage site of vector pIH902, which was then transformed into *E. coli*.

Cultivation of the *E. coli* resulted in expression of the enzyme *epiD* fused to the Maltose binding protein of *E. coli*. The resulting fusion protein was purified by affinity chromatography on Amylose column material.

It was found that the enzyme *epiD* could be cleaved from the fusion protein in low yield by means of Factor Xa. A modification of the amino acid sequence at the cleavage region will enable the cleavage rate to be improved.

The fusion protein was sequenced at the DNA level from

the fusion position to the 3' end of *epiD*. The *epiD* sequence corresponded to the wild type sequence of *S. epidermis*.

Plasmid pCA44 is deposited in *Staphylococcus carnosus* TM 300 at the DSM Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH, Mascheroder Weg 1b, D-3000 Braunschweig, Germany, under No. 6863, the deposit being dated 23rd December 1991.

Plasmid pPS4 is deposited in *Staphylococcus carnosus* TM 300 under No. 6864 at the same depositary, deposit being dated 23rd December 1991.

10

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions.

SEQUENCE LISTING

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 Ser Asp Asn Ile Asp Tyr Asp Leu Ile Leu Gln Asn Asp Ile Phe Lys
 35 40 45
 Glu Ser Ile Met Thr Thr Thr Tyr Asn Leu Tyr Gln Ser Ile Gly Lys
 50 55 60
 Ile Asp Trp Glu Lys Asp Asn Lys Lys Thr Arg Asn Val Lys Glu Ser
 65 70 75 80
 Leu Leu Lys Tyr Leu Ile Arg Met Ser Thr Arg Ser Thr Pro Tyr Gly
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 Met Leu Ser Gly Val Ala Leu Gly Glu Phe Ser Glu Asn Asn Asn Ile
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 Lys Ile Lys Asp Ser Ser Phe His Lys Lys Asp Val Lys Ile Asp Gly
 115 120 125
 Gln Trp Leu Tyr Lys Leu Val His Tyr Leu Glu Ser Asp Tyr Thr Tyr
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 Tyr Lys Asp Ser Phe Val Ile Trp Asn Gln Gln Asn Tyr Ile Tyr Asn
 145 150 155 160

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				165					170					175		
Asn	Asp	Val	Leu	Ser	Val	Lys	Tyr	Asn	Ser	Ile	Leu	Val	Phe	Ile	His	
			180					185					190			
Glu	Asn	Ser	Lys	Lys	Asn	Ile	Thr	Tyr	Glu	Glu	Leu	Val	Gln	Leu	Ile	
		195					200					205				
Ser	Ser	Lys	Tyr	Ser	Ile	Glu	Asn	Lys	Glu	Glu	Val	Lys	Val	Phe	Val	
	210					215					220					
Gln	Glu	Leu	Ile	Asn	Lys	Glu	Ile	Ile	Phe	Ser	Asp	Leu	Arg	Pro	Thr	
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Leu	Glu	Asn	Lys	Asn	Pro	Leu	Asp	Tyr	Ile	Ile	Asn	Ser	Leu	Asn	Pro	
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Lys	Asn	Ser	Leu	Val	Gly	Thr	Leu	Ile	Asn	Ile	Ser	Asn	Glu	Ile	Thr	
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Lys	Tyr	Ser	Lys	Met	Pro	Leu	Gly	Lys	Gly	Glu	Tyr	Lys	Tyr	Leu	Asp	
		275					280					285				
Ile	Val	Asn	Leu	Met	Ser	Gln	Leu	Phe	Val	Ser	Lys	Asn	Tyr	Leu	Gln	
	290					295					300					
Ile	Asp	Thr	Tyr	Ile	Asp	Tyr	Ser	Arg	Asn	Glu	Leu	Lys	Gln	Ser	Leu	
305					310					315					320	
Ala	Asp	Asn	Ile	Ser	Glu	Ala	Ala	Tyr	Ile	Leu	Trp	Leu	Leu	Ser	Pro	
				325					330					335		
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Asn	Asn	Thr	Val	Ser	Lys	Ile	Asn	Ala	Pro	Val	Ser	Thr	Glu	Ile	Tyr	
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Ser	Glu	Ile	Tyr	Phe	Gly	Asn	Ser	Ile	Lys	Gly	Tyr	Glu	Asp	Phe	Ala	
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Val	Ile	Ser	Pro	Ile	Leu	Gly	Ser	Phe	Asn	Ala	Gly	Ala	Thr	Phe	Gly	
	450					455					460					
Arg	Phe	Thr	Gly	Asn	Phe	Asn	Ile	Lys	Lys	Lys	Asn	Gln	Leu	Gln	Lys	
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Glu	Ile	Val	His	His	Tyr	Asn	Asn	Tyr	Met	Asn	Glu	Asn	Gly	Leu	Glu	
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Leu	Tyr	Leu	Tyr	Ser	Glu	Lys	His	Asp	Ser	Arg	Ile	Val	Phe	Val	Ser	
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Asn	Ser	Met	Phe	Asn	Tyr	Glu	Phe	Gly	Ser	Glu	Leu	Tyr	Lys	Phe	Leu	
			565						570					575		
Arg	Glu	Ile	Ser	Phe	Glu	Lys	Thr	Lys	Phe	Ile	Gln	Pro	Ile	Thr	Glu	
			580					585					590			
Glu	Gly	Ile	Asp	Ser	Leu	Pro	Phe	Cys	Pro	Arg	Ile	Ile	Tyr	Lys	Asn	
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Ile	Ile	Leu	Lys	Pro	Ala	Thr	Trp	Lys	Ile	Asn	Ser	Glu	Met	Phe	Ser	
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Glu	Thr	Glu	Asn	Trp	Leu	Asn	Arg	Phe	Ala	Thr	Ile	Arg	Glu	Lys	Trp	
625					630					635					640	
His	Ile	Pro	Lys	Asp	Val	Ile	Ile	Ala	Phe	Gly	Asp	Asn	Arg	Leu	Leu	
			645					650						655		
Leu	Asn	Leu	Leu	Asn	Asp	Lys	His	Leu	Ile	Ile	Leu	Lys	Lys	Glu	Leu	
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Lys	Lys	His	Gly	Arg	Ile	Arg	Ile	Leu	Glu	Ser	Phe	Ile	Asn	Glu	Ser	
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Asn	Asn	Glu	Arg	Met	Leu	Glu	Ile	Val	Thr	Pro	Leu	Tyr	Lys	Lys	Thr	
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Ser	Leu	Lys	Glu	Gln	Ser	Phe	Ile	Ile	Pro	Lys	Asn	Arg	Asn	Lys	His	
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Phe	Asn	Asn	Leu	Lys	Asp	Trp	Phe	Ser	Ile	His	Leu	Ser	Ile	Pro	Lys	
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Thr	Tyr	Gln	Asp	Asn	Phe	Ile	Gln	Asp	Tyr	Leu	Leu	Pro	Phe	Ile	Thr	
			740					745					750			
Glu	Leu	Lys	Val	Asn	Asn	Phe	Ile	Asn	Lys	Phe	Phe	Tyr	Ile	Lys	Phe	
		755					760					765				
Lys	Glu	Asp	Glu	Asp	Phe	Ile	Lys	Leu	Arg	Leu	Leu	Arg	Glu	Asp	Glu	
	770					775					780					
Asp	Tyr	Ser	Gln	Ile	Tyr	Ser	Phe	Ile	Lys	Asn	Trp	Lys	Asp	Tyr	Cys	
785					790					795					800	

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 Phe Phe Met Tyr Asp Ser Leu Leu Ser Ile Asn Ile Ile Gln Ser Glu
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 Leu Asp Tyr Leu Glu Ile Asn Lys Ser Glu Lys Glu Glu Ile Leu Ile
 865 870 875 880
 Asn Asn Ala Glu Asp Leu Tyr Arg Ser Asn Asp Ile Arg Glu Tyr Lys
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 Thr Ser Leu Ala Ala Pro Lys Val Ser Gly Ala Leu Ala Leu Glu Ile
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 Asp Lys Tyr Gln Leu Lys Asp Gln Pro Glu Thr Ala Ile Glu Leu Phe
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 atcttttcca tacttatcta aaagtttata agaacctcct atcgtcatta aatctataaa 7320
 attatttcca taattagaaa actcagaaat ataatcatta tcatcgatgg atcctacagt 7380
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 atcaactttt tcatcatctc ttaatttttt tttattttga ttatctttaa ttaaataatt 7620
 tcctaaacta acgttgatta catcattgtc atcatttgct gcatcaataa ttcctttaga 7680
 tacccaaagc atttcacttt tctttgagcc aaatactcgg tatacattca tctctactcc 7740
 agggtttaca ccttttaaat taccgtttgc tcctatttgt cctgctacta atgtaccatg 7800
 attcaattta tcttcttcaa aattttttatt tcctgattca tcgttttcgc tacctctaaa 7860
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 tgatttgcta gttttaattt gtgctgtatg tagttcagga attttataag ttaactcgat 8220
 atttttttgt ttaatggatt ctttaaaagt ttttgcatta tcatattcaa cactataata 8280
 acttaattct tcatttagtg aacttccaaa agcatactca ttttgcaaaa aaactaatga 8340
 caatattaaa aaaacaatga aaaatttaaa tttgttcata tagcacctct aacatattat 8400
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 aatgttctgt tgcaagatga aaaatacgag gtatcaaagt accgatacag cgagtattac 8520
 actcaattaa ttaaaaataa aatatgttgt gattaaaatt tattttataa aagtatgggc 8580
 aatttattat tattcaagtt aaaacaaaga gtccgggaca taaagtttca gcctcttcgt 8640
 cctaattacc aaaaaactta ctccaaaatc cttttttaga ttgggttttt ctaatttttt 8700

<210> 7
 <211> 52

15

<212> PRT

<213> S.epidermidis

<220>

<221> misc_feature

<223> Epi A

<400> 7

Met	Glu	Ala	Val	Lys	Glu	Lys	Asn	Asp	Leu	Phe	Asn	Leu	Asp	Val	Lys
1				5					10					15	

Val	Asn	Ala	Lys	Glu	Ser	Asn	Asp	Ser	Gly	Ala	Glu	Pro	Arg	Ile	Ala
			20					25						30	

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

Ser	Tyr	Cys	Cys
	50		

27169-205

-46-

CLAIMS:

1. A recombinant DNA molecule encoding the protein Epi B consisting of the amino acid sequence set forth in SEQ ID NO: 1.
- 5 2. A recombinant DNA molecule encoding the protein Epi C, consisting of the amino acid sequence set forth in SEQ ID NO: 2.
3. A recombinant DNA molecule encoding the protein Epi D consisting of the amino acid sequence set forth in
10 SEQ ID NO: 3.
4. A recombinant DNA molecule encoding the protein Epi P consisting of the amino acid sequence set forth in SEQ ID NO: 5.
5. A recombinant DNA molecule encoding the protein
15 Epi Q consisting of the amino acid sequence set forth in SEQ ID NO: 4.
6. A recombinant DNA molecule which is at least 85% identical to SEQ ID NO: 6 from position 1593 to 4562 encoding Epi B protein, wherein said DNA molecule codes for
20 a protein having Epi B enzymatic activity in the synthesis of epidermin.
7. A recombinant DNA molecule which is at least 85% identical with SEQ ID NO: 6 from position 4441 to 5805 encoding Epi C protein, wherein said DNA molecule codes for
25 a protein having Epi C enzymatic activity in the synthesis of epidermin.
8. A recombinant DNA molecule which is at least 85% identical to SEQ ID NO: 6 from position 5824 to 6366 encoding Epi D protein, wherein said DNA molecule codes for

27169-205

-47-

a protein having Epi D enzymatic activity in the synthesis of epidermin.

9. A recombinant DNA molecule which is at least 85% identical to SEQ ID NO: 6 from position 6997 to 8379 of the
5 complementary strand encoding Epi P protein, wherein said DNA molecule codes for a protein having Epi P enzymatic activity in the synthesis of epidermin.

10. A recombinant DNA molecule which is at least 85% identical to SEQ ID NO: 6 from position 6369 to 6983 of the
10 complementary strand encoding Epi Q protein, wherein said DNA molecule codes for a protein having Epi Q regulatory activity in the synthesis of epidermin.

11. A plasmid comprising the DNA molecule according to claim 1 or claim 6 under the control of a promoter regulator
15 sequence wherein at least one DNA molecule selected from the group consisting of:

(a) the recombinant DNA molecule according to claim 2;

(b) the recombinant DNA molecule according to
20 claim 3;

(c) the recombinant DNA molecule according to claim 4;

(d) the recombinant DNA molecule according to claim 5; and

25 (e) a recombinant DNA molecule encoding an Epi A protein having the amino acid sequence set forth in SEQ ID NO: 7;

is absent.

27169-205

-48-

12. A plasmid comprising the DNA molecule according to claim 1 or claim 6 under the control of a promoter regulator sequence wherein:

(a) the recombinant DNA molecule according to
5 claim 2;

(b) the recombinant DNA molecule according to
claim 3;

(c) the recombinant DNA molecule according to
claim 4;

10 (d) the recombinant DNA molecule according to
claim 5; and

(e) a recombinant DNA molecule encoding an Epi A
protein having the amino acid sequence set forth in
SEQ ID NO: 7;

15 are absent.

13. A plasmid comprising the DNA molecule according to claim 1 or claim 6 under the control of a promoter regulator sequence wherein at least one DNA molecule selected from the group consisting of:

20 (a) the recombinant DNA molecule according to
claim 7;

(b) the recombinant DNA molecule according to
claim 8;

(c) the recombinant DNA molecule according to
25 claim 9;

(d) the recombinant DNA molecule according to
claim 10; and

27169-205

-49-

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

is absent.

14. A plasmid comprising the DNA molecule according to claim 1 or claim 6 under the control of a promoter regulator sequence wherein:

(a) the recombinant DNA molecule according to claim 7;

10 (b) the recombinant DNA molecule according to claim 8;

(c) the recombinant DNA molecule according to claim 9;

(d) the recombinant DNA molecule according to claim 10; and

15 (e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

are absent.

15. A plasmid comprising the DNA molecule according to claim 2 or claim 7, under the control of a promoter regulator sequence, wherein at least one DNA molecule selected from the group consisting of:

(a) the recombinant DNA molecule according to claim 1;

25 (b) the recombinant DNA molecule according to claim 3;

(c) the recombinant DNA molecule according to claim 4;

27169-205

-50-

(d) the recombinant DNA molecule according to claim 5; and

(e) a recombinant DNA molecule encoding an Epi A protein having the amino acid sequence set forth in
5 SEQ ID NO: 7;

is absent.

16. A plasmid comprising the DNA molecule according to claim 2 or claim 7, under the control of a promoter regulator sequence, wherein:

10 (a) the recombinant DNA molecule according to claim 1;

(b) the recombinant DNA molecule according to claim 3;

(c) the recombinant DNA molecule according to
15 claim 4;

(d) the recombinant DNA molecule according to claim 5; and

(e) a recombinant DNA molecule encoding an Epi A protein having the amino acid sequence set forth in
20 SEQ ID NO: 7;

are absent.

17. A plasmid comprising the DNA molecule according to claim 2 or claim 7, under the control of a promoter regulator sequence, wherein at least one DNA molecule
25 selected from the group consisting of:

(a) the recombinant DNA molecule according to claim 6;

27169-205

-51-

(b) the recombinant DNA molecule according to claim 8;

(c) the recombinant DNA molecule according to claim 9;

5 (d) the recombinant DNA molecule according to claim 10; and

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

is absent.

10 18. A plasmid comprising the DNA molecule according to claim 2 or claim 7, under the control of a promoter regulator sequence, wherein:

(a) the recombinant DNA molecule according to claim 6;

15 (b) the recombinant DNA molecule according to claim 8;

(c) the recombinant DNA molecule according to claim 9;

(d) the recombinant DNA molecule according to
20 claim 10; and

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

are absent.

19. A plasmid comprising the DNA molecule according to
25 claim 3 or claim 8, under the control of a promoter regulator sequence, wherein at least one DNA molecule selected from the group consisting of:

27169-205

-52-

(a) the recombinant DNA molecule according to claim 2;

(b) the recombinant DNA molecule according to claim 1;

5 (c) the recombinant DNA molecule according to claim 4;

(d) the recombinant DNA molecule according to claim 5; and

(e) a recombinant DNA molecule encoding an Epi A
10 protein having the amino acid sequence set forth in
SEQ ID NO: 7;

is absent.

20. A plasmid comprising the DNA molecule according to
claim 3 or claim 8, under the control of a promoter
15 regulator sequence, wherein:

(a) the recombinant DNA molecule according to claim 2;

(b) the recombinant DNA molecule according to claim 1;

20 (c) the recombinant DNA molecule according to claim 4;

(d) the recombinant DNA molecule according to claim 5; and

(e) a recombinant DNA molecule encoding an Epi A
25 protein having the amino acid sequence set forth in
SEQ ID NO: 7;

are absent.

27169-205

-53-

21. A plasmid comprising the DNA molecule according to claim 3 or claim 8, under the control of a promoter regulator sequence, wherein at least one DNA molecule selected from the group consisting of:

5 (a) the recombinant DNA molecule according to claim 7;

(b) the recombinant DNA molecule according to claim 6;

10 (c) the recombinant DNA molecule according to claim 9;

(d) the recombinant DNA molecule according to claim 10; and

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

15 is absent.

22. A plasmid comprising the DNA molecule according to claim 3 or claim 8, under the control of a promoter regulator sequence, wherein:

20 (a) the recombinant DNA molecule according to claim 7;

(b) the recombinant DNA molecule according to claim 6;

(c) the recombinant DNA molecule according to claim 9;

25 (d) the recombinant DNA molecule according to claim 10; and

27169-205

-54-

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

are absent.

23. A plasmid comprising the DNA molecule according to
5 claim 4 or claim 9, under the control of a promoter regulator sequence, wherein at least one DNA molecule selected from the group consisting of:

(a) the recombinant DNA molecule according to claim 2;

10 (b) the recombinant DNA molecule according to claim 3;

(c) the recombinant DNA molecule according to claim 1;

(d) the recombinant DNA molecule according to
15 claim 5; and

(e) a recombinant DNA molecule encoding an Epi A protein having the amino acid sequence set forth in SEQ ID NO: 7;

is absent.

20 24. A plasmid comprising the DNA molecule according to claim 4 or claim 9, under the control of a promoter regulator sequence, wherein:

(a) the recombinant DNA molecule according to claim 2;

25 (b) the recombinant DNA molecule according to claim 3;

27169-205

-55-

(c) the recombinant DNA molecule according to claim 1;

(d) the recombinant DNA molecule according to claim 5; and

5 (e) a recombinant DNA molecule encoding an Epi A protein having the amino acid sequence set forth in SEQ ID NO: 7;

are absent.

25. A plasmid comprising the DNA molecule according to
10 claim 4 or claim 9, under the control of a promoter regulator sequence, wherein at least one DNA molecule selected from the group consisting of:

(a) the recombinant DNA molecule according to claim 7;

15 (b) the recombinant DNA molecule according to claim 8;

(c) the recombinant DNA molecule according to claim 6;

(d) the recombinant DNA molecule according to
20 claim 10; and

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;

is absent.

26. A plasmid comprising the DNA molecule according to
25 claim 4 or claim 9, under the control of a promoter regulator sequence, wherein:

27169-205

-56-

(a) the recombinant DNA molecule according to claim 7;

(b) the recombinant DNA molecule according to claim 8;

5 (c) the recombinant DNA molecule according to claim 6;

(d) the recombinant DNA molecule according to claim 10; and

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;
are absent.

27. A plasmid comprising the DNA molecule according to claim 5 or claim 10, under the control of a promoter regulator sequence, wherein at least one DNA molecule
15 selected from the group consisting of:

(a) the recombinant DNA molecule according to claim 2;

(b) the recombinant DNA molecule according to claim 3;

20 (c) the recombinant DNA molecule according to claim 4;

(d) the recombinant DNA molecule according to claim 1; and

(e) a recombinant DNA molecule encoding an Epi A
25 protein having the amino acid sequence set forth in SEQ ID NO: 7;

is absent.

27169-205

-57-

28. A plasmid comprising the DNA molecule according to claim 5 or claim 10, under the control of a promoter regulator sequence, wherein:

(a) the recombinant DNA molecule according to
5 claim 2;

(b) the recombinant DNA molecule according to
claim 3;

(c) the recombinant DNA molecule according to
claim 4;

10 (d) the recombinant DNA molecule according to
claim 1; and

(e) a recombinant DNA molecule encoding an Epi A
protein having the amino acid sequence set forth in
SEQ ID NO: 7;

15 are absent.

29. A plasmid comprising the DNA molecule according to claim 5 or claim 10, under the control of a promoter regulator sequence, wherein at least one DNA molecule selected from the group consisting of:

20 (a) the recombinant DNA molecule according to
claim 7;

(b) the recombinant DNA molecule according to
claim 8;

(c) the recombinant DNA molecule according to
25 claim 9;

(d) the recombinant DNA molecule according to
claim 6; and

27169-205

-58-

(e) a recombinant DNA molecule having the amino acid sequence set forth in SEQ ID NO: 7;
is absent.

30. A plasmid comprising the DNA molecule according to
5 claim 5 or claim 10, under the control of a promoter
regulator sequence, wherein:

(a) the recombinant DNA molecule according to
claim 7;

(b) the recombinant DNA molecule according to
10 claim 8;

(c) the recombinant DNA molecule according to
claim 9;

(d) the recombinant DNA molecule according to
claim 6; and

15 (e) a recombinant DNA molecule having the amino
acid sequence set forth in SEQ ID NO: 7;
are absent.

31. A recombinant protein encoded by the DNA molecule
according to claim 6.

20 32. A recombinant protein encoded by the DNA molecule
according to claim 7.

33. A recombinant protein encoded by the DNA molecule
according to claim 8.

34. A recombinant protein encoded by the DNA molecule
25 according to claim 9.

27169-205

-59-

35. A recombinant protein encoded by the DNA molecule according to claim 10.

36. A method of preparing Epi B protein, the method comprising inserting the DNA molecule as defined in
5 claim 1 or 6 into a plasmid vector such that the DNA molecule is under the control of a promoter regulator, inserting the resulting plasmid vector into a suitable host, culturing said host so that the protein is expressed, and isolating the protein.

10 37. A method of preparing Epi C protein, the method comprising inserting the DNA molecule as defined in claim 2 or 7 into a plasmid vector such that the DNA molecule is under the control of a promoter regulator,
15 inserting the resulting plasmid vector into a suitable host, culturing said host so that the Epi C protein is expressed, and isolating the Epi C protein.

38. A method of preparing Epi D protein, the method comprising inserting the DNA molecule as defined in
20 claim 3 or 8 into a plasmid vector such that the DNA molecule is under the control of a promoter regulator, inserting the resulting plasmid vector into a suitable host, culturing said host so that the Epi D protein is expressed, and isolating the Epi D protein.

39. A method of preparing Epi P protein, the method
25 comprising inserting the DNA molecule as defined in claim 4 or 9 into a plasmid vector such that the DNA molecule is under the control of a promoter regulator, inserting the resulting plasmid vector into a suitable host, culturing said host so that the Epi P protein is expressed,
30 and isolating the Epi P protein.

27169-205

-60-

40. A method of preparing Epi Q protein, the method comprising inserting the DNA molecule as defined in claim 5 or 10 into a plasmid vector such that the DNA molecule is under the control of a promoter regulator,
5 inserting the resulting plasmid vector into a suitable host, culturing said host so that the Epi Q protein is expressed, and isolating the Epi Q protein.

41. A fusion protein comprising an auxiliary protein other than epidermin and a protein selected from the group
10 consisting of:

- (a) the recombinant protein according to claim 31;
- (b) the recombinant protein according to claim 32;
- (c) the recombinant protein according to claim 33;
- (d) the recombinant protein according to claim 34;

15 and

- (e) the recombinant protein according to claim 35.

42. A fusion protein wherein an auxiliary protein other than epidermin is fused to an Epi protein selected from the group consisting of:

- 20
- (a) the recombinant protein according to claim 31;
 - (b) the recombinant protein according to claim 32;
 - (c) the recombinant protein according to claim 33;
 - (d) the recombinant protein according to claim 34;

and

- 25
- (e) the recombinant protein according to claim 35.

27169-205

-61-

43. The fusion protein according to claim 41 or 42, wherein said auxiliary protein facilitates secretion of the fusion protein from a selected host.

44. The fusion protein according to claim 41 or 42, wherein the auxiliary protein facilitates purification by affinity chromatography.

45. The fusion protein according to claim 41 or 42 in which the auxiliary protein is the Maltose binding protein from *E. coli*.

10 46. A DNA encoding the fusion protein according to any one of claims 41 to 45.

47. A method of producing epidermin, the method comprising inserting a DNA sequence coding for amino acids 31 to 52 of SEQ ID NO: 7 in a plasmid vector such that
15 the DNA sequence is under the control of a regulator promoter, transforming the resulting plasmid vector into a suitable host and cultivating the host so as to express the said DNA and isolating the encoded protein, wherein the host is also transformed by a DNA sequence or sequences
20 comprising functionally operable genes coding for Epi B according to claim 31, Epi C according to claim 32, Epi D according to claim 33, Epi P according to claim 34, or Epi Q according to claim 35, which genes are expressed during the cultivation of the host.

25 48. A method of producing epidermin, the method comprising

transforming into a suitable host a plasmid vector comprising a DNA coding for amino acids 31 to 52 of SEQ ID NO: 7 under the control of a regulator promoter, and
30 one or more functionally operable DNA selected from the

27169-205

-62-

group consisting of: DNA coding for Epi B as defined in claim 6, DNA coding for Epi C as defined in claim 7, DNA coding for Epi D as defined in claim 8, DNA coding for Epi P as defined in claim 9, and DNA coding for Epi Q as defined in claim 10, wherein the functionally operable DNA is expressed during cultivation of the host; and

isolating the epidermin.

49. The method according to claim 48 wherein the plasmid vector further comprises DNA coding for the pre-peptide sequence of pre-epidermin operably linked to the DNA coding for amino acids 31 to 52 of SEQ ID NO: 7, wherein the pre-peptide sequence of pre-epidermin is set forth as amino acids 1 to 30 of SEQ ID NO: 7.

50. An isolated Epi B protein consisting of the amino acid sequence set forth in SEQ ID NO: 1.

51. An isolated Epi C protein consisting of the amino acid sequence set forth in SEQ ID NO: 2.

52. An isolated Epi D protein consisting of the amino acid sequence set forth in SEQ ID NO: 3.

53. An isolated Epi P protein consisting of the amino acid sequence set forth in SEQ ID NO: 5.

54. An isolated Epi Q protein consisting of the amino acid sequence set forth in SEQ ID NO: 4.

55. A host cell comprising the recombinant DNA molecule of any one of claims 1 to 10.

56. A host cell comprising the plasmid of any one of claims 11 to 30.

FIG. 1

1
|
TTTAAACTTTATATCATTAATATGTTTAGGAAAGTAGAAGAAATTACACTTTTGTAAATTTTCTGAATATACATA
am

100
|
GTATTATTGCGGAGTACTAAATAATTAATTGAAAGGGTTTATAATCCTTTTAAATAAATTTTJAGGAGJGTTT

200
|
AAA ATG GAA GCA GTA AAA GAA AAA AAT GAT CTT TTT AAT CTT GAT GTT AAA GTT AAT GCA
M E A V K E K N D L L F N L D V K V N A
-30
|
-20

2/32

FIG. 1

AAA GAA TCT AAC GAT TCA GGA GCT GAA CCA AGA ATT GCT AGT AAA TTT ATA TGT ACT CCT
K E S N D S G A E P R I A S K F I C T P
-10 -1 +1
300
GGA TGT GCA AAA ACA GGT AGT TTT AAC AGT TAT TGT TGT TAATTCAGAAGAATTAGATTGGCAGG
G C A K T G S F N S Y C C OC
+10 +20
400
CTTCAATAGAGGCTCTGTCTTAATTTCAGGTCGAAATAGCAATTGGATTAATATATTTGTTCCATCGAATATATATGCT
am am

3/32

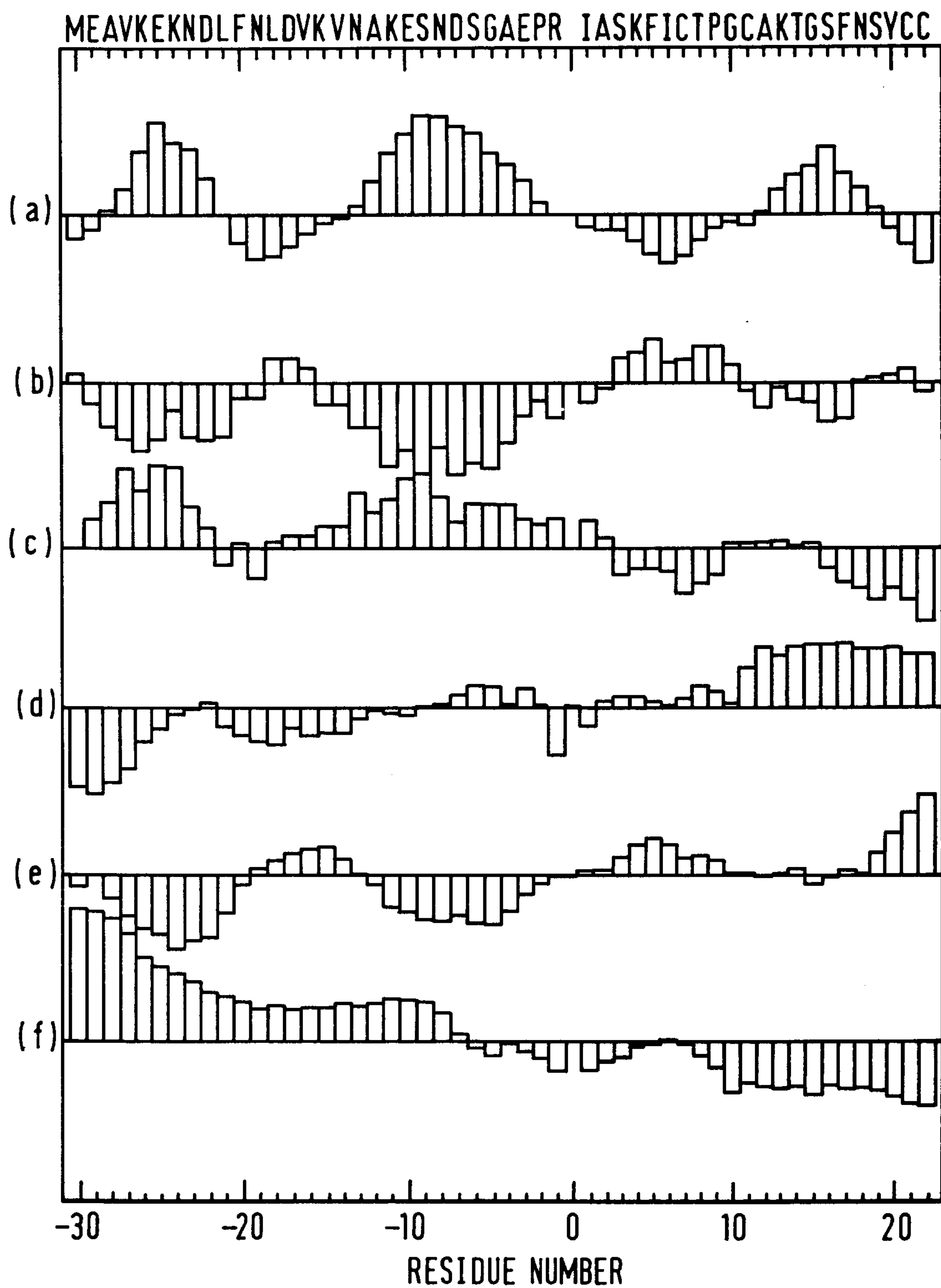
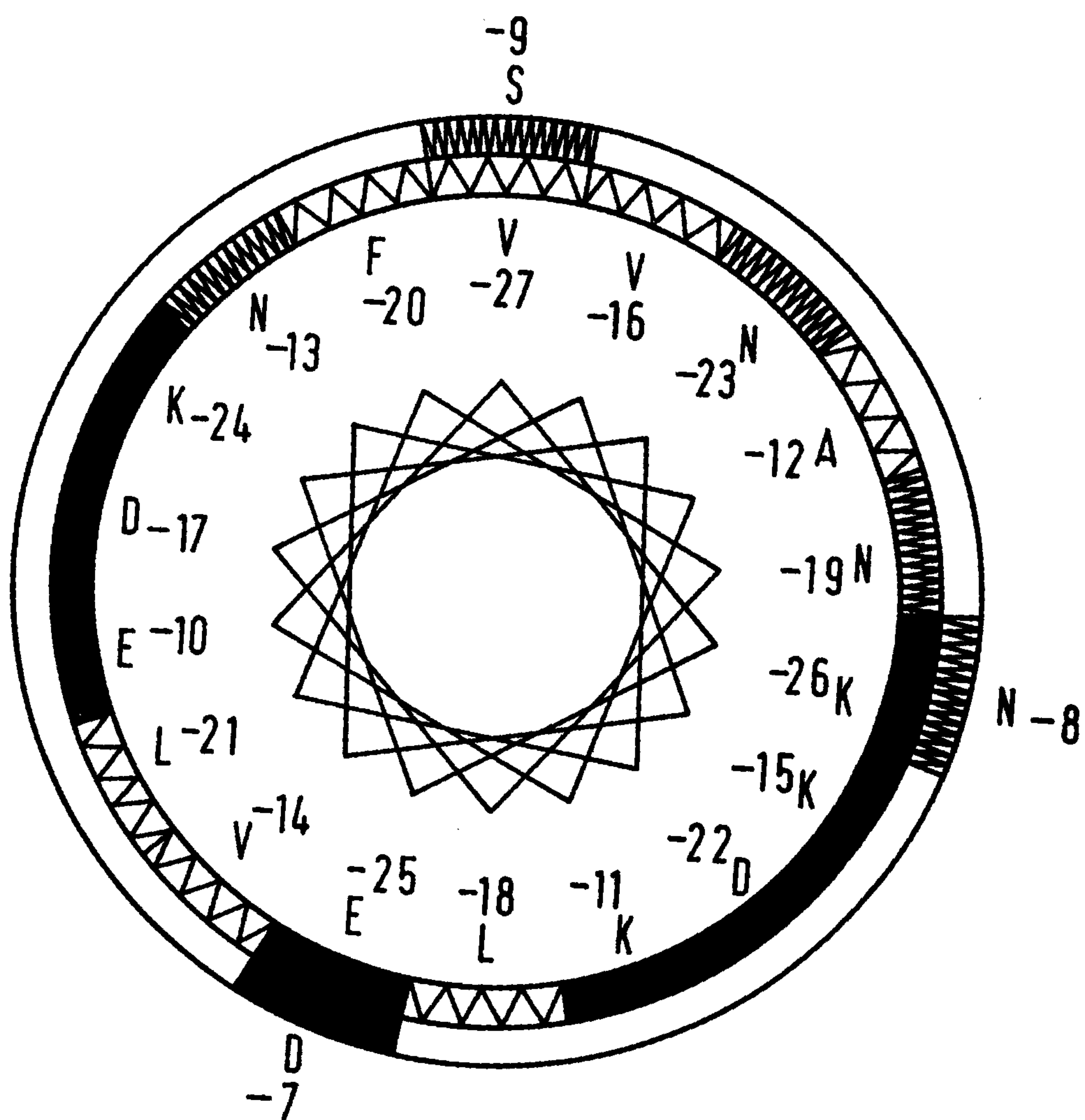
FIG. 2A

FIG. 2B

5/32

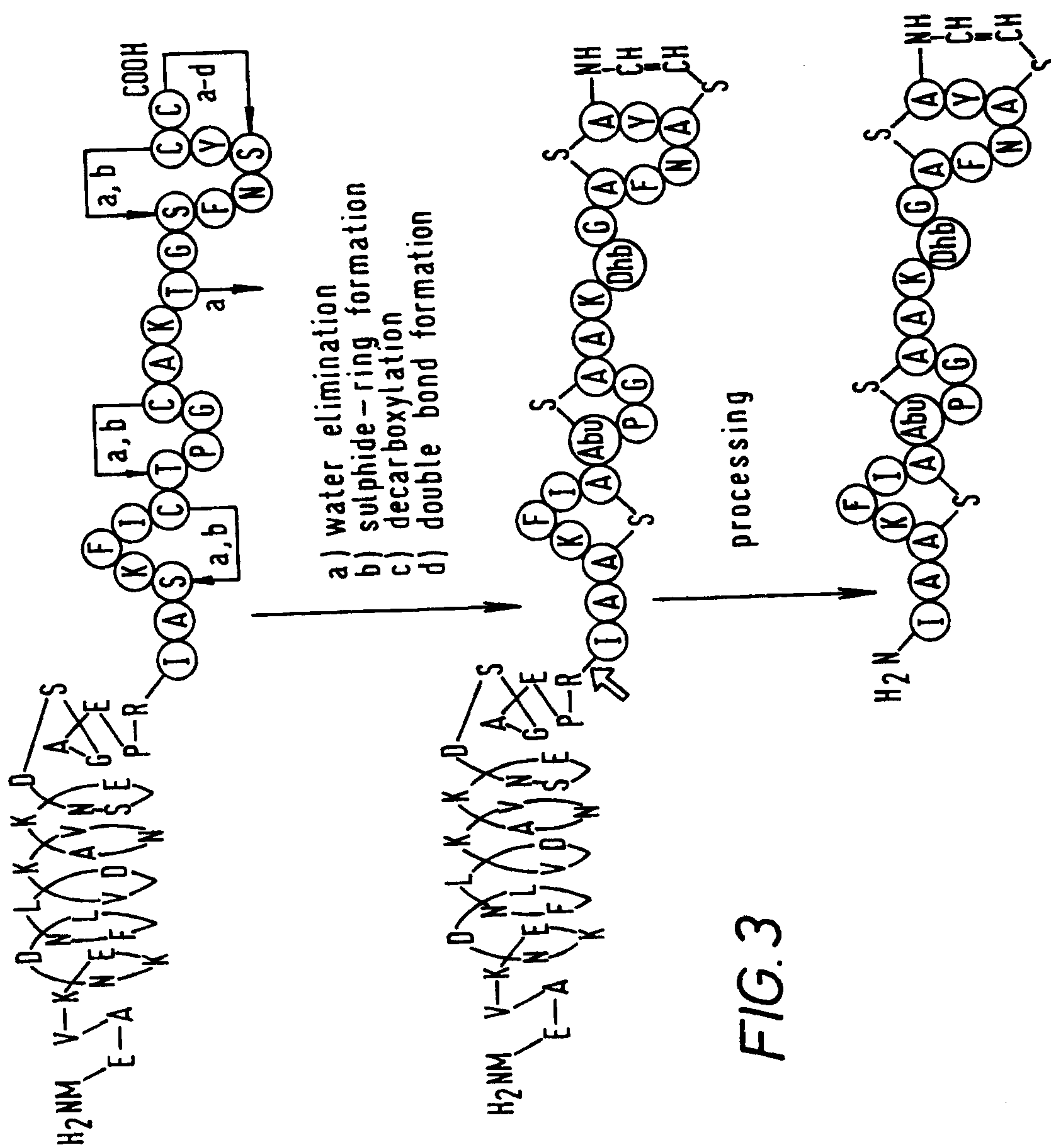
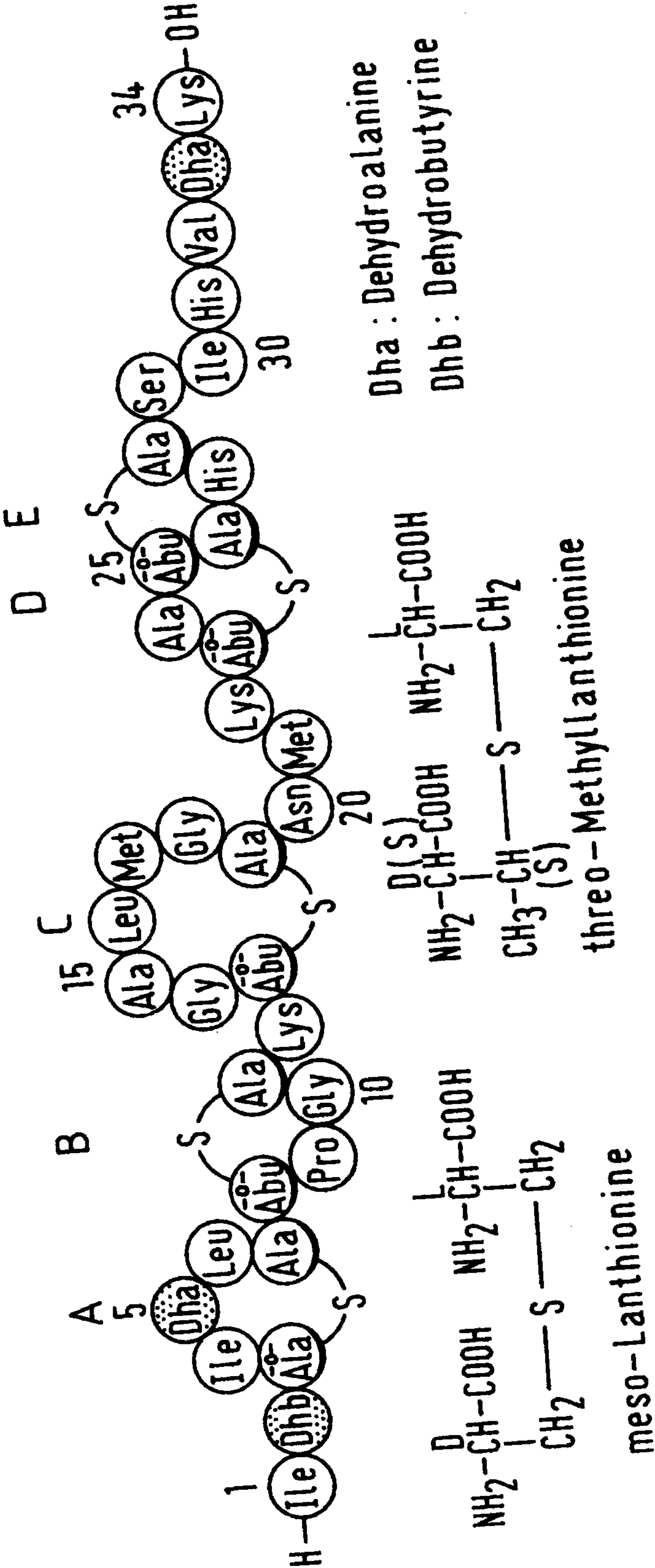


FIG. 3

FIG. 4



7/32

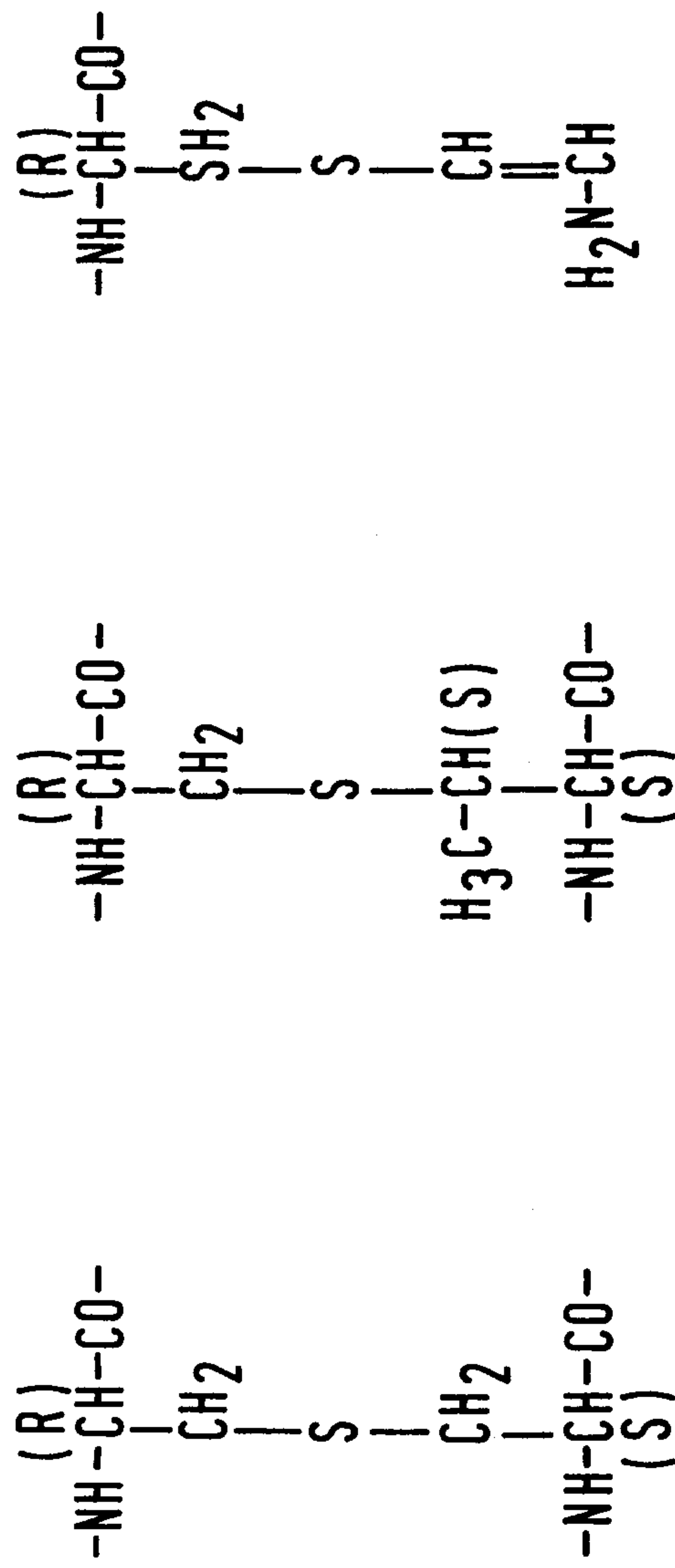
Unusual amino acids found in lanthionine peptide antibiotics
 ("lantibiotics") derived from protein proantibiotics

FIG.5 (1/2)



dehydroalanine, Dha

2,3-dehydro-2-aminobutyric acid, Dhb



meso-lanthionine, (2S,3S,6R)-3-methyl- S-(2-(7)-aminovinyl)-D-
meso-Lan, D-Ala S Ala lanthionine, 3-MeLan, cysteine, D-Cys(Avi)
D-Abu S Ala

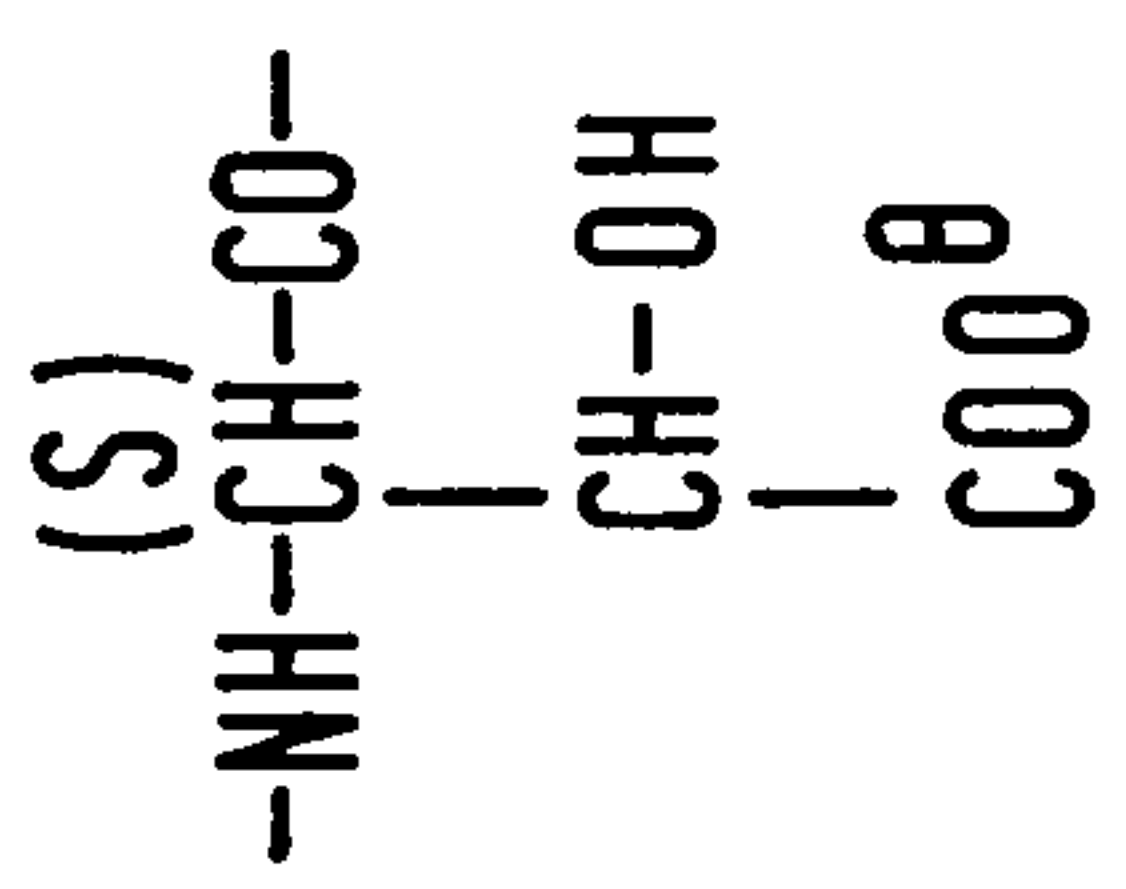
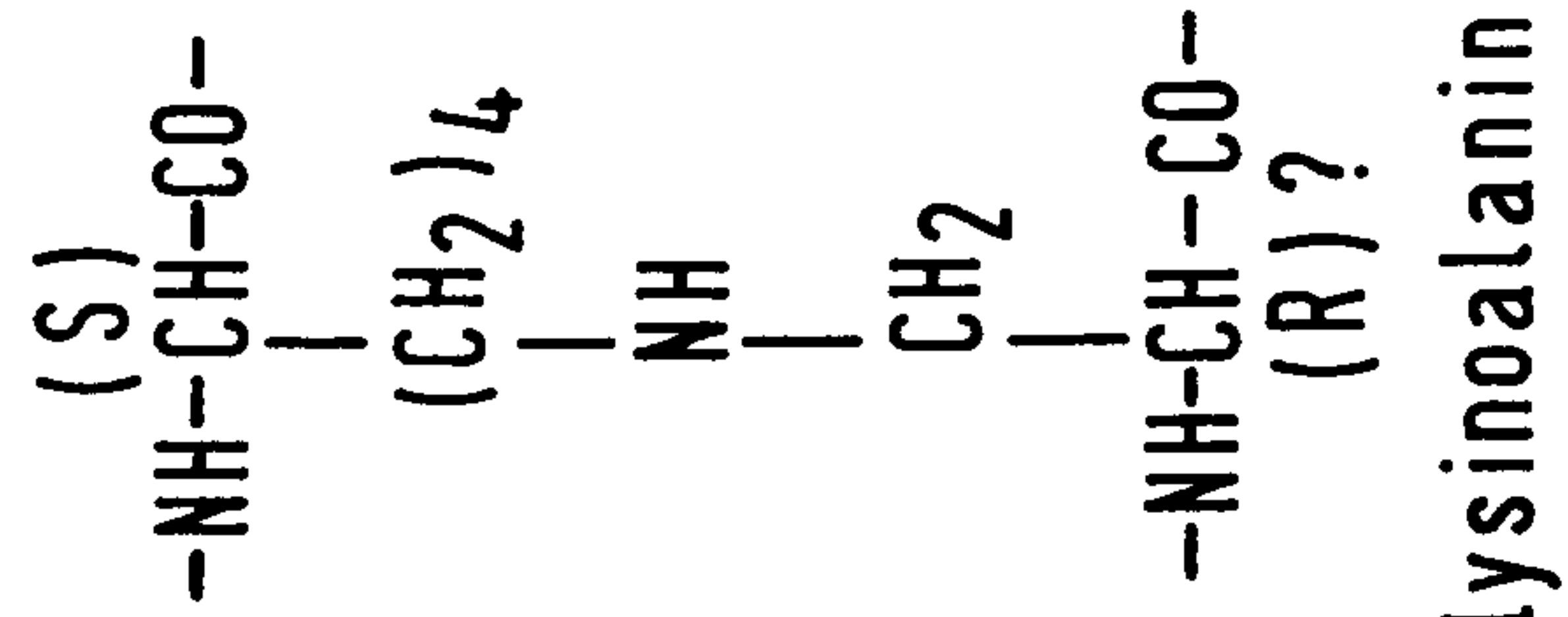


FIG.5_(2/2)

β-hydroxyaspartic acid,
Asp(β-OH)

9/32

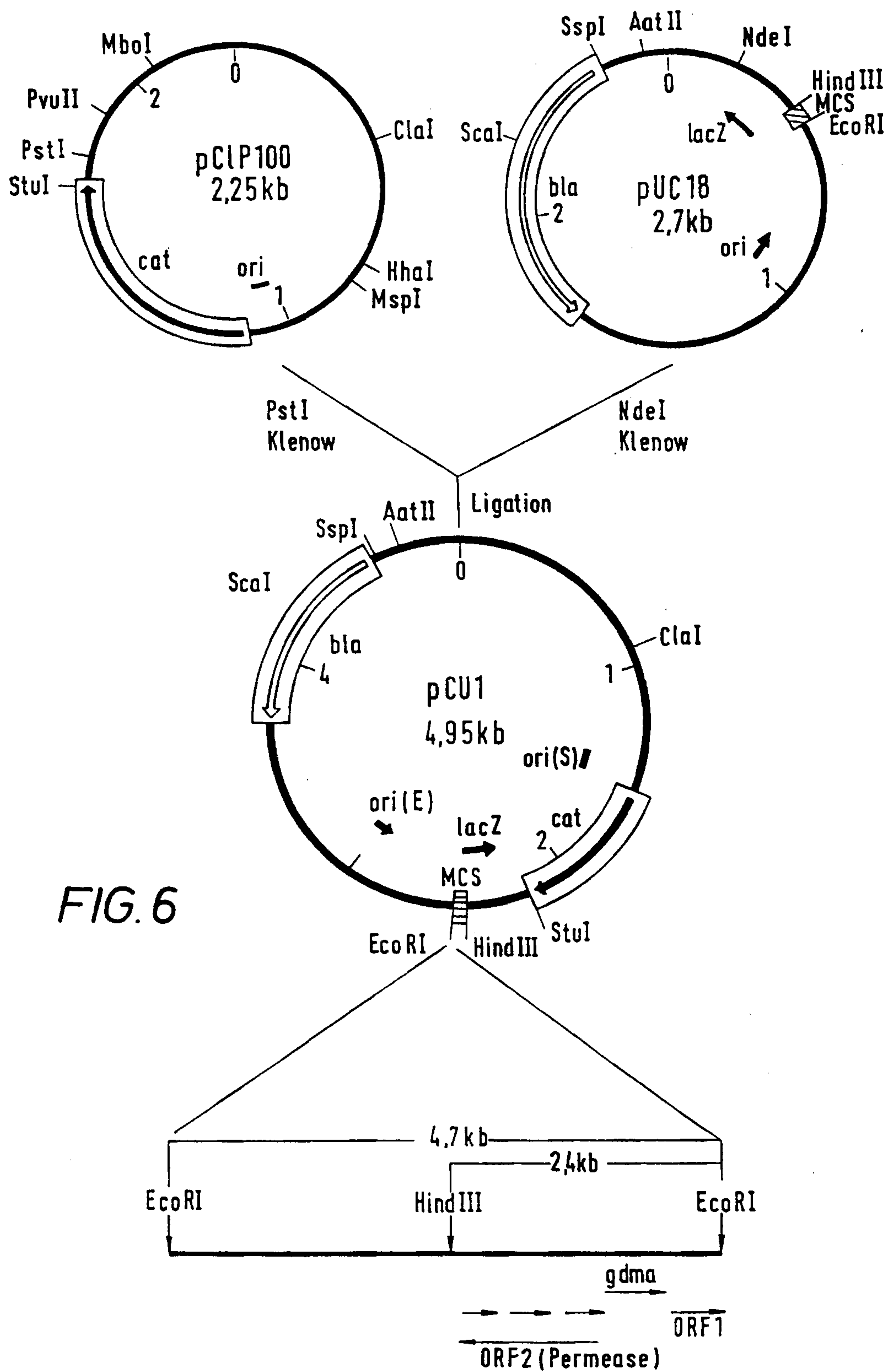
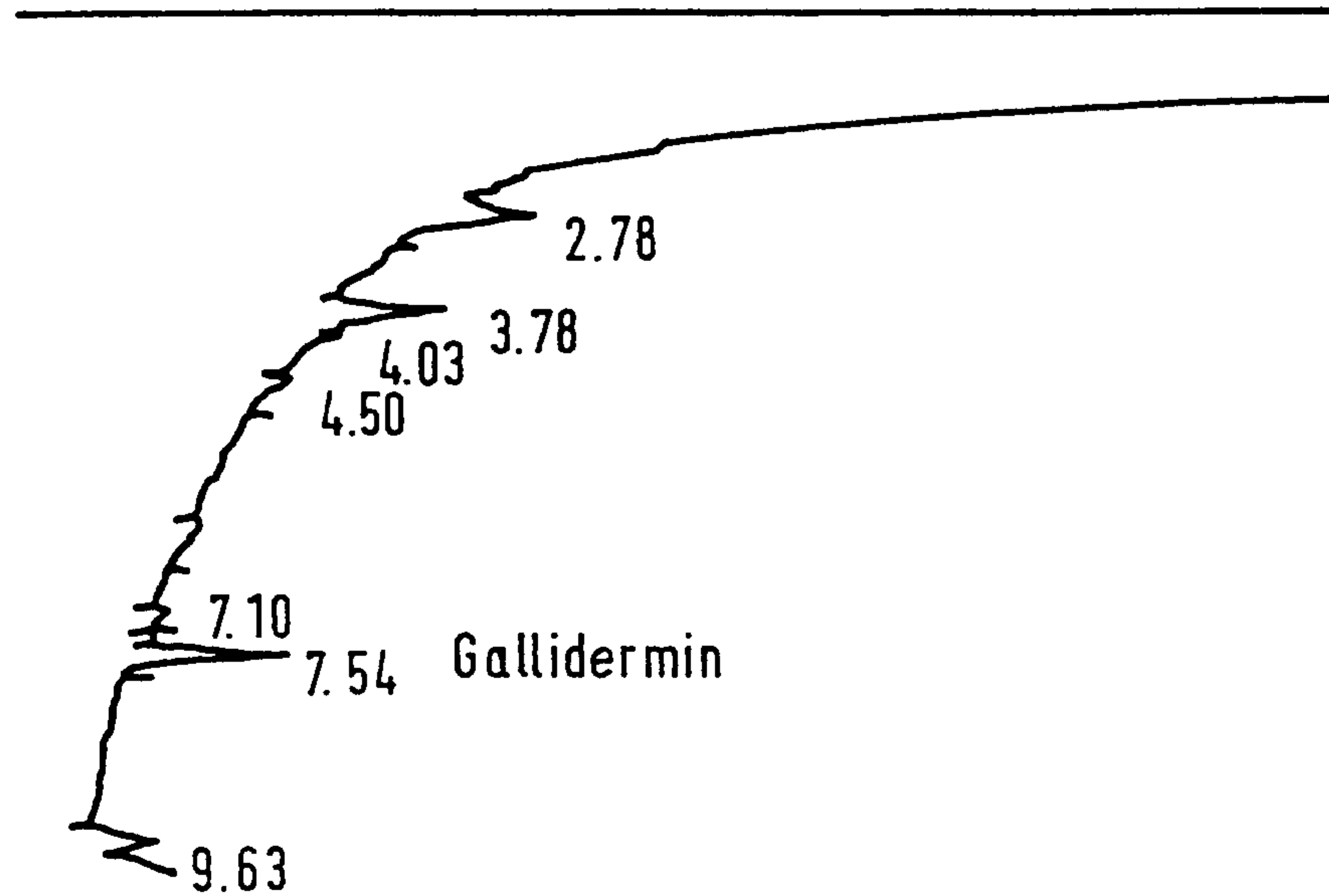


FIG. 6

10/32

FIG. 7A**EMS 5 plus pCuGal (Gallidermin)**

ESTD

RT	AREA	TYPE	CAL #	AMOUNT
0.73	8.4107E+07	1SBH		0.000
0.88	434710	DTBB		0.000
1.01	3.7223E+07	SHH		0.000
1.29	4978700	SHH		0.000
1.38	5.3775E+07	1SHH		0.000
1.53	349830	TBB		0.000
2.78	343360	TPB		0.000
3.78	444590	TBY		0.000
4.03	218110	TYY		0.000
7.54	408470	TYB	1	11.519
9.63	132570	TBP		0.000

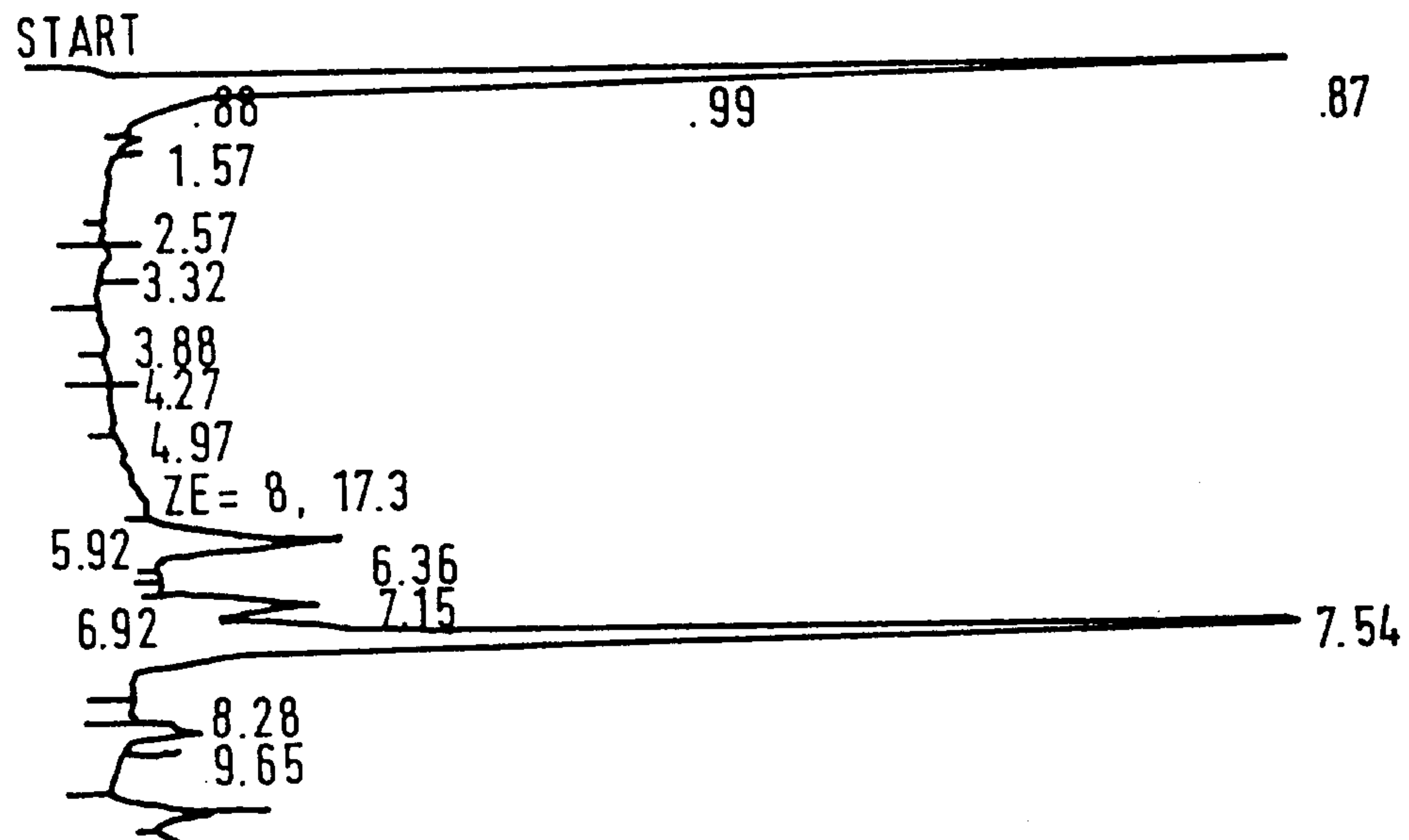
TOTAL AREA = 1.8242E+08

MIN FACTOR = 1.0000E+00

11/32

FIG. 7B

Gallidermin- Standard



ESTD

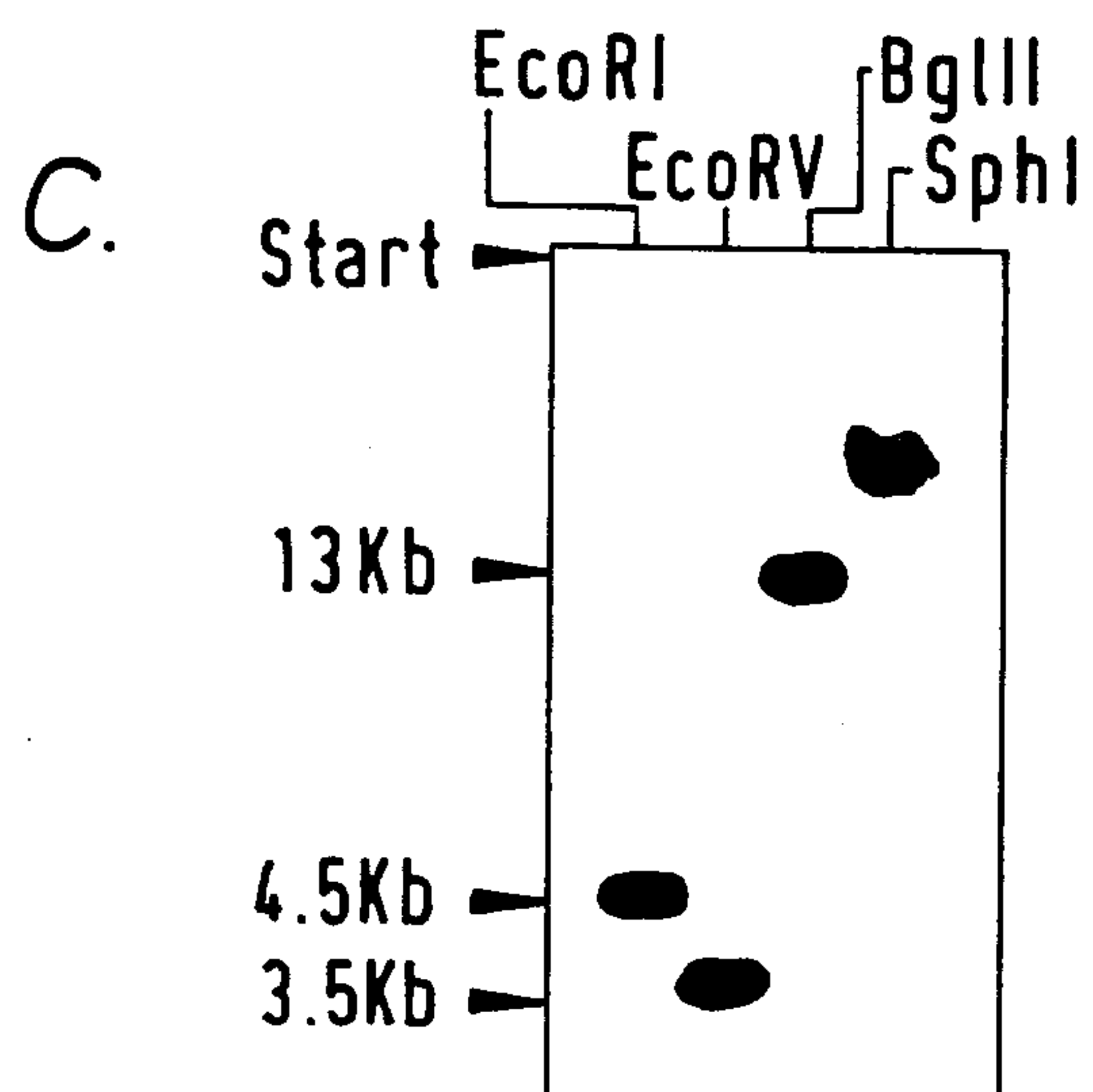
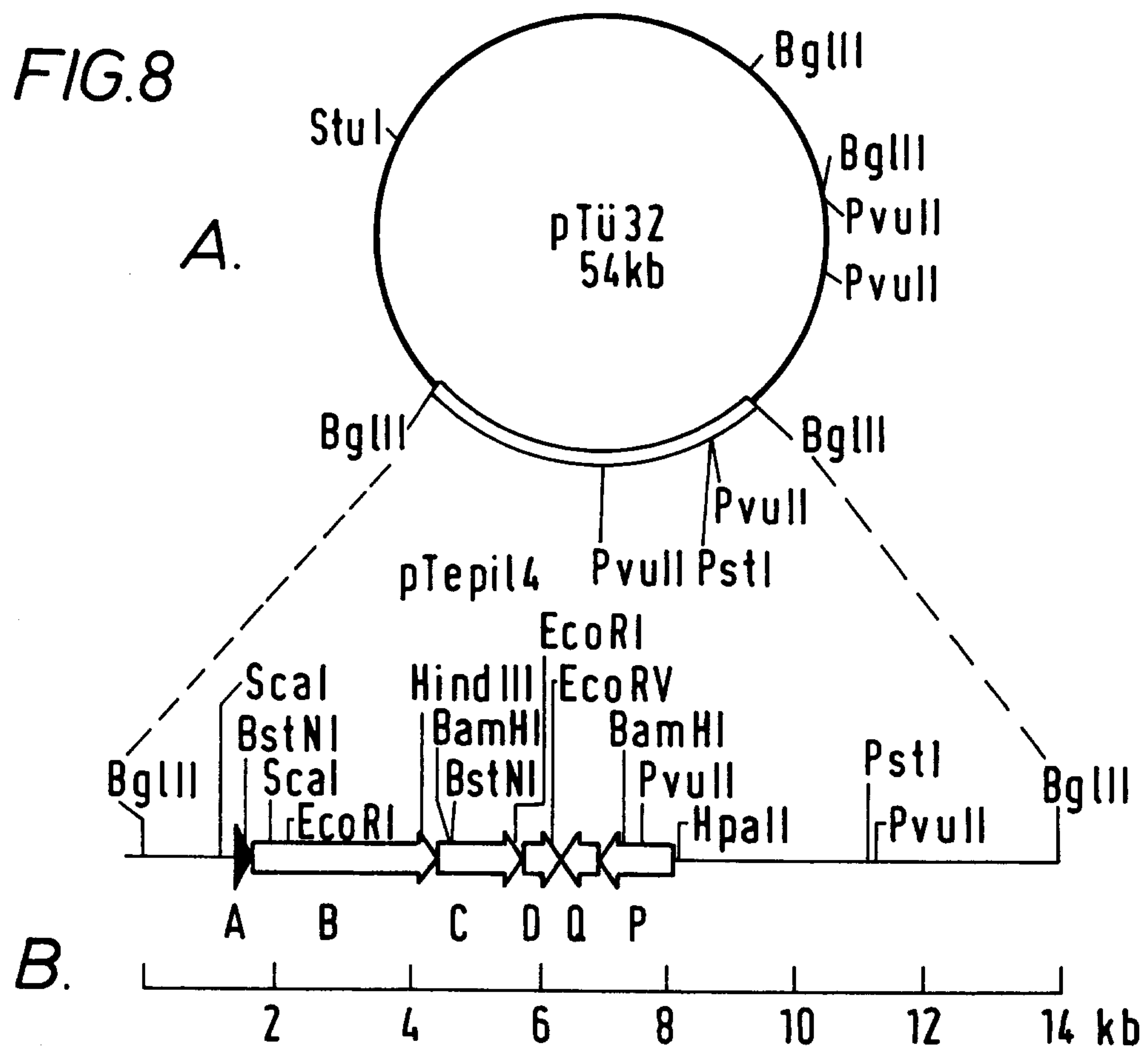
RT	AREA	TYPE	CAL #	AMOUNT
0.80	111200	YH		0.000
0.87	1.0928E+07	SHB		0.000
0.99	153190	DTBB		0.000
5.92	156570	PY		0.000
6.36	967060	YY		0.000
7.15	580800	PY		0.000
7.54	7492100	YB	1	211.280
8.65	212540	BB		0.000
9.61	413430	PY		0.000
9.68	256920	D YY		0.000
9.94	255140	I YH		0.000

TOTAL AREA = 2.1527E+07

MIN FACTOR = 1.0000E+00

12/32

FIG.8



13/32

FIG.9

BglIII 20 40
AGATCTTGTGTTATATAACTAAACAAATTTCTCCATTCGTATTTAGAAAATTGACT
D Q T I Y S F L N R W E Y K S F Q S

60 80 100 120
TTTATCAAGTTTATCCAAATATATATTTCCAGTATATTCTGTATTTAACCCAGCTAATATATTT
D L K K D L Y I N G T Y E T N L G A L I N

140 160 180
AATAATGTACTTTTTCCACACCCACTTTCACCTATAATATTGTAGATATAACCTTTATGAAGAT
L L T S K G C G S E G I I N Y I Y G K H L D

200 220 240
CCAAACTTATAGAATTTATTATTTGTTTATTGTCTTTTGTGAAGTTCAAATCATTTATTTCCAT
L S I S N I I Q K N D K T F N L D N I E M

260 280 300
TTTTTGAACAAAGTTATTGTAAGTTGTTTTAATAGTTAATACCTCTTCTGGTTCTTTATTTATT
K Q V F N N Y T T K I T L V E E P E K N I

320 340 360
TTTAAAATTCTATCTGAAGATCCAATTGCTCGTTGTACTTCCGTCCAATAAGATGTAATAGATA
K L I R D S S G I A R Q V E T W Y S T I S V

380 400 420 440
CTATTGGATTAATAATTTGAAATAAATATAAAACATAAGCAAACATATCTCCGCTTTTCATCAT
I P N I I Q E L Y L V Y A F M D G S K M M

460 480 500
ATTATTTTCCATTAAAGTAATAACCCAAAAATAAAATACCAAAAATGTTAATAAATAGAATTAAG
N N E H L Y Y G L F L I G F I N I F L I L

520 540 560
TTCATAATTGGTTCGAAAAAAGATAATACTTTGATCTTATGTAACCTATATCGAATATATTTT
N M I P E F F S L V K I K H L E I D F I N K

580 600 620
TTAATAGGGTATAGTTTTTTTATTTTTTCGATATTATATGTACTTAAAGTTTTTATTAATTTTAT
L L T Y N K I K E I N Y T S L T K I L K I

640 660 680
TGTAGATAATCTATTACTATAATAAGAAGATAATTTAGCAGTAGCTTCTTGAGATTTACTTGAT
T S L R N S Y Y S S L K A T A E Q S K S S

700 720 740 760
ACTCTTTTCATTATATTTTCCTATAGGTAGTATTACAATTATCAATATAGGTAATGTACACACTA
V R K M I N G I P L I V I I L I P L T C V L

14/32

FIG. 9

780 800 820
 AATATAATGTCAAGGTTTTGTTAATTATATATAAAAAATATTAGTGATACTATAACTGAAAATAA
 Y L T L T K N I I Y L F I L S V I V S F L
 oc N Y I F I N T I S Y S F I F

840 860 880
 ATTCTACAGAAAAAAGTCTAGTTATGTTTCATAGTATCGTTTACTAACCTACTAGTTAAGTTACT
 N am
 E V S F V R T I N M T D N V L R S T L N S

900 920 940
 TGCTGAGTTTTTTAAGTGAAAACTATAAGGTAAGTTTATCACTTTATTCCATGTAACACTTCTA
 A S N K L H F S Y P L K I V K N W T V S R

960 980 1000
 ATGTTTTGTATTATTTTTTGACCTATATATCCAAGAATATAAGTAGAAACACCAGAAAATATTA
 I N Q I I K Q G I Y G L I Y T S V G S F I L

1020 1040 1060 1080
 AAGTCAGACCAAAACATATAATAATGATTACAATTTTATCTGTTGATAAGCTAGATTTGTTTAA
 T L G F C I I I I V I K D T S L S S K N L

1100 1120 1140
 GGCATTTCTAATTATTAAAGGAATGTATAATGAAAACTAGTTCCAATCAAACCTAAATATTAGT
 A N R I I L P I Y L S F S T G I L S F I L

1160 1180 1200
 CCAATACTTAAAAGTAGAGTGTTAGGTTTGGTTATTTTCCATAAATCATATAGACCTTTGATAA
 G I S L L L T N P K T I K W L D Y L G K I I

S/D 1240 1260
 TATCATCACCTTTTAAACTTTATATCATTAATATAATGTTTAGGAAAAGTAGAAGAAAATTACA
 D D G K L S < epiY

IR 1280 1300 1320
 CTTTTGTAATTTTCTGAATATACATAGTATTTATTTTGGGGGAGTACTAAAATAATAATTGAAA

1340 IR 1360 S/D 1380 epiA > 1400
 AGGGTTTATAATCCTTTTTAATAAATTTTATAGGAGTGTTTAAAATGGAAGCAGTAAAAGAAAA
 M E A V K E K

1420 1440 1460
 AAATGATCTTTTTAATCTTGATGTTAAAGTTAATGCAAAAGAATCTAACGATTCAGGAGCTGAA
 N D L F N L D V K V N A K E S N D S G A E

1480 1500 1520
 CCAAGAATTGCTAGTAAATTTATATGTACTCCTGGATGTGCAAAAACAGGTAGTTTTAACAGTT
 P R I A S K F I C T P G C A K T G S F N S

1540 1560 1580
 ATTGTTGTTAATTCAGAAGAATTAGATTGGCAGGGCTTCAATAGAGGCTCTGTCTTAATTTTGA
 Y C C oc epiB >

15/32

FIG. 9

S/D1600 1620 1640
 GGTGAAATAGAATTGGATAATATATTTGTTCCATCGAATATATATATGGTAAGAACTCCTATAT
 G E I E L D N I F V P S N I Y M V R T P I

1660 1680 1700 1720
 TTTCAATTGAATTATATAATCAATTCTTAAAATCTGACAATATAGATTATGACTTAATTTTACA
 F S I E L Y N Q F L K S D N I D Y D L I L Q

1740 1760 1780
 AAACGATATTTTAAAGAATCTATAATGACAACGACATATAATCTTTATCAAAGTATTGGCAAA
 N D I F K E S I M T T T Y N L Y Q S I G K

1800 1820 1840
 ATAGACTGGGAAAAGGATAATAAAAAAACCAGAAATGTAAAAGAAAGTTTATTAAAATATCTCA
 I D W E K D N K K T R N V K E S L L K Y L

1860 1880 1900
 TAAGAATGAGTACTAGAAAGTACACCATATGGAATGCTAAGCGGTGTAGCTTTAGGGGAATTTAG
 I R M S T R S T P Y G M L S G V A L G E F S

1920 1940 1960
 TGAAAATAATAATATTTAAATTAAGGACTCTTCGTTTCATAAAAAAGATGTAAAATAGATGGG
 E N N N I K I K D S S F H K K D V K I D G

1980 2000 2020 2040
 CAATGGTTATATAAATTAGTCCATTATTTAGAAAGCGATTACACATATTATAAAGACAGTTTTG
 Q W L Y K L V H Y L E S D Y T Y Y K D S F

2060 2080 2100
 TCATATGGAATCAACAAAATTATATTTATAACAATCGTTTATATTTAGATAATAATTCATCAAT
 V I W N Q Q N Y I Y N N R L Y L D N N S S I

2120 2140 2160
 CACTGAAAATAAAAGAAATGATGTATTATCTGTCAAATACAATTCTATATTAGTGTTTATACAT
 T E N K R N D V L S V K Y N S I L V F I H

EcoRI 2180 2200 2220
 GAGAATTCTAAAAAAATATTACTTATGAAGAACTTGTACAATTGATATCTAGTAAGTACAGTA
 E N S K K N I T Y E E L V Q L I S S K Y S

2240 2260 2280
 TAGAAAATAAAGAAGAAGTAAAAGTATTTGTTCAAGAACTCATAAATAAAGAAATTATATTTTC
 I E N K E E V K V F V Q E L I N K E I I F S

2300 2320 2340 2360
 TGATTTGAGACCTACATTAGAGAATAAAAAATCCTTTAGATTACATTATTAATAGTTTAAATCCA
 D L R P T L E N K N P L D Y I I N S L N P

2380 2400 2420
 AAAAATAGTTTAGTTGGAACACTTATTAATATTTCTAATGAAATTACAAAATATTCTAAAATGC
 K N S L V G T L I N I S N E I T K Y S K M

16/32

FIG. 9

2440 2460 2480
 CTTTAGGAAAAGGAGAATATAAATATTTAGATATTGTTAATTTAATGTCACAATTATTTGTTTC
 P L G K G E Y K Y L D I V N L M S Q L F V S

2500 2520 2540
 TAAAACTATTTGCAAATAGATACCTATATAGATTATTCAAGAAATGAATTAAAACAAAGTTTA
 K N Y L Q I D T Y I D Y S R N E L K Q S L

2560 2580 2600
 GCTGATAATATTAGTGAAGCAGCATATATTCTCTGGTTATTATCTCCTAATCATTTTGGTACAA
 A D N I S E A A Y I L W L L S P N H F G T

2620 2640 2660 2680
 AAAC TATTAGGAATTATCACGAATTTTTTATGGATAAATATGGATTGGAACAAC TAGTAAATTT
 K T I R N Y H E F F M D K Y G F E Q L V N L

2700 2720 2740
 AAAGCAATTGCTCTCAGATATAAATGGATTGCTATCCCCAAAAAGACAGTTATAGTTTTCT
 K Q L L S D I N G F G Y P K K D S Y S F S

2760 2780 2800
 AATAACATTGCATTTTTTAAAAGAAAAGTATTTGCTTGCAATTCAAATAACAGCCATATTGAAA
 N N I A F L K E K Y L L A I Q N N S H I E

2820 2840 2860
 TAACAGAAAACGACGTTAAAAATTTAGAAAAGAATAATACAGTTTCTAAAATCAATGCGCCTGT
 I T E N D V K N L E K N N T V S K I N A P V

2880 2900 2920
 TTCAACTGAAATATATAGTGAGATATATTTTGGAAATTCAATAAAAGGTTATGAGGATTTTGCC
 S T E I Y S E I Y F G N S I K G Y E D F A

2940 2960 2980 3000
 GTGATAAGTCCAATATTAGGATCTTTTAATGCCGGTGCAACTTTTGGAAAGGTTTACGGGAAATT
 V I S P I L G S F N A G A T F G R F T G N

3020 3040 3060
 TCAATATAAAGAAAAAAATCAATTACAAAAAGAAATAGTGCATCATTACAATAATTACATGAA
 F N I K K K N Q L Q K E I V H H Y N N Y M N

3080 3100 3120
 TGAAAATGGTTTAGAAATAAGCCAATTAAATGAAGGTCCTCTTA ACTCAAGAAATGTAAATATT
 E N D L E I S Q L N E A P L N S R N V N I

3140 3160 3180
 TTGAATAATAATAGAATATATAATACTTGTTTAAATTTAAATTTACCTAAAAGTGATATAGATA
 L N N N R I Y N T C L N L N L P K S D I D

3200 3220 3240
 TAAATGACATATTTATTGGAGCTACATTTAACAACCTTTATCTATATTCTGAAAAACATGATTC
 I N D I F I G A T F N K L Y L Y S E K H D S

17/32

FIG. 9

3260 3280 3300 3320
 AAGAATTGTATTCGTATCTAATTCAATGTTTAATTATGAGTTTGGATCTGAATTATACAAATTT
 R I V F V S N S M F N Y E F G S E L Y K F

 3340 3360 3380
 TTAAGAGAAATTTCAATTTGAAAAACAAAATTTATACAACCTATAACTGAAGAAGGCATTGACT
 L R E I S F E K T K F I Q P I T E E G I D

 3400 3420 3440
 CATTACCTTTTTGTCCAAGAATTATTTATAAAAAATATTATTTTAAAACCAGCTACTTGGAAT
 S L P F C P R I I Y K N I I L K P A T W K I

 3460 3480 3500
 AAATTCAGAAATGTTTTCTGAAACTGAAAATTGGTTAAATAGGTTCGCAACTATTAGAGAAAAA
 N S E M F S E T E N W L N R F A T I R E K

 3520 3540 3560
 TGGCATATTCCAAAAGATGTAATTATTGCTTTTGGAGATAATCGATTGCTATTAAATTTATTAA
 W H I P K D V I I A F G D N R L L L N L L

3580 3600 3620 3640
 ATGACAAGCATCTCATTATACTAAAAAAGAACTAAAAAACATGGTAGGATTCTGAATATTAGA
 N D K H L I I L K K E L K K H G R I R I L E

HindIII 3660 3680 3700
 AAGCTTTATCAATGAATCTAATAATGAGAGAATGTTAGAAATTGTTACGCCATTATATAAAAAA
 S F I N E S N N E R M L E I V T P L Y K K

 3720 3740 3760
 ACTAGTTTAAAAGAACAATCTTTCATTATACCTAAAAATAGAAATAAGCACTTCAATAATCTTA
 T S L K E Q S F I I P K N R N K H F N N L

 3780 3800 3820
 AAGATTGGTTTTCAATTCATTTAAGTATTCCTAAAACATACCAAGATAATTTTATTCAAGATTA
 K D W F S I H L S I P K T Y Q D N F I Q D Y

 3840 3860 3880
 TCTATTACCATTATATAACGGAATTAAAAGTTAATAATTTTATTAATAAATTTTTTTACATAAAA
 L L P F I T E L K V N N F I N K F F Y I K

3900 3920 3940 3960
 TTAAAGAAGATGAAGATTTTATAAAATTAAGATTATTAAGAGAAGATGAAGATTATTCTCAA
 F K E D E D F I K L R L L R E D E D Y S Q

 3980 4000 4020
 TTTATTCTTTCATAAAAAATTGGAAAGATTATTGCTTATTAAATAGTGAATTATATGACTATTC
 I Y S F I K N W K D Y C L L N S E L Y D Y S

 4040 4060 4080
 TATAGTTGATTATGTTTCCTGAAGTATATAGATATGGTGGTCCACACGTAATTGAAGATATTGAG
 I V D Y V P E V Y R Y G G P H V I E D I E

18/32

FIG. 9

4100 4120 4140
AATTTTTTTATGTATGATAGTCTATTATCAATAAATATAATACAATCAGAGTTCAAAATTCCAA
N F F M Y D S L L S I N I I Q S E F K I P

4160 4180 4200
AAGAATTTATCGTTGCTATATCAATAGATTTTTTTATTAGATTATTTAGAAATTAATAAAAGTGA
K E F I V A I S I D F L L D Y L E I N K S E

4220 4240 4260 4280
GAAAGAAGAAATTTTAATTAATAATGCGGAAGATTTATATCGTAGTAATGACATAAGAGAATAT
K E E I L I N N A E D L Y R S N D I R E Y

4300 4320 4340
AAAAATTTATTAGCTAAACTTACCAATCCTAAAAATGACTATGAAATTTTAAAAAAGAATTTTC
K N L L A K L T N P K N D Y E I L K K E F

4360 4380 4400
CGAATCTTCATGAATTTCTATTTAATAAAATTAGTATTTTAGAAAATCTTAAAAAGACACTACA
P N L H E F L F N K I S I L E N L K K T L Q

HindIII S/D_ epic > 4460
AAAAAGCTTATATACTTCACGTTCTAGGATAATTGGCAGTTTATACACATGCGTTGTAATAGA
K S L Y T S R S R I L G S F I H M R C N R
L A V L Y T C V V I E

4480 4500 4520
ATATTCGGTATTAATCCTGAAAAAGAAAAATTTGTTTTATCTATTTTAAATGAAATTACAAAA
I F G I N P E K E K F V L S I F N E I T K
Y S V L I L K K K N L F Y L F L M K L Q K

4540 4560 4580 4600
CTAAAAAATATTGGGATGGTTGTGATTAATATTAATAACATTAAAAAATTTTAGAAAATAAAA
T K K Y W D G C D oc oc oc
L K N I G M V V I N I N N I K K I L E N K

4620 4640 4660
TCACCTTTTTGTCTGACATTGAAAAAGCTACATATATTATAGAAAATCAAAGTGAGTATTGGGA
I T F L S D I E K A T Y I I E N Q S E Y W D

4680 4700 4720
TCCTTATACTCTATCTCATGGTTATCCAGGTATAATACTTTTTTTAAGCGCATCAGAAAAAGTA
P Y T L S H G Y P G I I L F L S A S E K V

4740 4760 4780
TTTCATAAAGATTTAGAAAAAGTAATACATCAATATATTAGAAAAGTAGGCCCTTATTAGAAA
F H K D L E K V I H Q Y I R K L G P Y L E

4800 4820 4840
GTGGTATTGATGGATTTTCACTTTTTAGTGGTCTTTCCGGAATTGGATTTGCGCTAGACATTGC
S G I D G F S L F S G L S G I G F A L D I A

19/32

FIG. 9

4860 4880 4900 4920
 GTCTGATAAACAGTACTCTTATCAAAGTATCTTAGAACAAATTGATAATTTACTTGTTCAATAT
 S D K Q Y S Y Q S I L E Q I D N L L V Q Y

 4940 4960 4980
 GTTTTTGATTTTTTAAATAACGATGCATTGGAAGTAACCCCTACTAACTATGATATAATACAAG
 V F D F L N N D A L E V T P T N Y D I I Q

 5000 5020 5040
 GATTTTCTGGTATAGGAAGGTACTTGTTAAATAGAATATCGTATAATTATAATGCAAAAAAAGC
 G F S G V G R Y L L N R I S Y N Y N A K K A

 5060 5080 5100
 ATTAAAGCATATACTTAATTACTTCAAAACAATTCATTACTCTAAAGACAATTGGTTAGTTTCA
 L K H I L N Y F K T I H Y S K D N W L V S

 5120 5140 5160
 AATGAACATCAATTTTTAGATATAGATAAGCAAAATTTTCCGTCAGGAAATATAAATTTAGGAT
 N E H Q F L D I D K Q N F P S G N I N L G

5180 5200 5220 5240
 TAGCGCATGGTATTTTAGGTCCTCTATCATTAACAGCTTTGAGTAAATGAATGGGATTGAAAT
 L A H G I L G P L S L T A L S K M N G I E I

 5260 5280 EcoRI
 CGAAGGCCATGAAGAGTTTTTACAAGACTTCACTTCATTTTTGCTCAAACCTGAATTCAAAAAT
 E G H E E F L Q D F T S F L L K P E F K N

 5320 5340 5360
 AATAATGAATGGTTCGATCGCTATGATATATTAGAAAATTATATACCTAATTATTCCGTCAGAA
 N N E W F D R Y D I L E N Y I P N Y S V R

 5380 5400 5420
 ACGGTTGGTGTTACGGTGATACAGGGATTATGAATACATTACTTTTGTCTGGTAAAGCCTTAAA
 N G W C Y G D T G I M N T L L L S G K A L N

 5440 5460 5480
 TAATGAAGGCTTAATTAAAATGTCTAAAAATATTTTAATTAACATAATAGATAAGAATAATGAT
 N E G L I K M S K N I L I N I I D K N N D

5500 5520 5540 5560
 GATTTAATCAGTCCAACCTTCTGTACGGACTAGCATCGCACTTAACCATTATTCATCAAGCGA
 D L I S P T F C H G L A S H L T I I H Q A

 5580 5600 5620
 ATAAATTCTTTAATCTATCTCAAGTAAGCACATATATCGATACCATTGTCAGAAAAATTATTAG
 N K F F N L S Q V S T Y I D T I V R K I I S

 5640 5660 5680
 TCATTATTCTGAAGAAAGTAGTTTTATGTTCCAAGACATAGAGTACTCATACGGACAAAAAATT
 H Y S E E S S F M F Q D I E Y S Y G Q K I

20/32

FIG. 9

5700 EcoRI 5720 5740
 TATAAAAACAAAGTGGGAATTCTAGAGGGTGAATTAGGTGTTCTTTTAGCTTTACTAGATTATA
 Y K N K V G I L E G E L G V L L A L L D Y

5760 5780 5800 S/D
 TTGATACACAAAACCAATCAAGGAAAAATTGGAAAAATATGTTTTTAATAACATAATAGGAGGA
 I D T Q N Q S R K N W K N M F L I T oc

5820 epiD > 5840 5860 5880
 ATAAGATATGTATGGAAAATTATTGATATGCGCTACAGCATCGATAAATGTAATTAATATTAAT
 M Y G K K L L C A T A S I N V I N I N

5900 5920 5940
 CACTACATAGTTGAGTTAAAGCAACATTTTGATGAAGTTAATATATTATTTAGTCCTAGTAGTA
 H Y I V E L K Q H F D E V N I L F S P S S

5960 5980 6000
 AAAATTTTATAAATACTGATGTTCTCAAGTTATTTTGTGATAACTTGTACGATGAAATTAAAGA
 K N F I N T D V L K L F C D N L Y D E I K D

6020 6040 6060
 TCCTCTTTTAAATCATATCAATATTGTAGAAAATCATGAATATATTTTAGTATTACCTGCATCA
 P L L N H I N I V E N H E Y I L V L P A S

6080 6100 6120
 GCAAATACTATTAATAAAATAGCTAATGGTATATGTGATAATCTTTTAACTACTGTATGTTTAA
 A N T I N K I A N G I C D N L L T T V C L

EcoRV 6160 6180 6200
 CCGGATATCAAAAATTATTTATATTTCCAAATATGAACATAAGAATGTGGGGAAATCCATTTTT
 T G Y Q K L F I F P N M N I R M W G N P F L

6220 6240 6260
 ACAAAAAAATATTGATTTACTTAAAAATAATGATGTGAAAGTGTATTCCCCTGATATGAATAAA
 Q K N I D L L K N N D V K V Y S P D M N K

6280 6300 6320
 TCATTCGAAATATCTAGTGGCCGTTACAAAAACAATATCACAATGCCTAATATTGAAAATGTAC
 S F E I S S G R Y K N N I T M P N I E N V

6340 6360 Terminator 6380
 TAAATTTTGTATTAAATAACGAAAAAAGACCTTTGGATTAACAAAGGTCTTTTCTAATTAAAAT
 L N F V L N N E K R P L D oc
 oc C L D K R I L I

6400 6400 6440
 TTTATATCCGAGTTTACGTTTCATTAATAATTTCTATCTCTTTACAATTTTTTAACTATCCCTT
 K Y G L K R E N I I E I E K C N K L S D R

6460 6480 6500 6520
 AATCGATGGATATATACATTTATTGTATTAGAATCAACAAAGTCTTCTGTATCCCACACTCCCT
 L R H I Y V N I T N S D V F D E T D W V G K

21/32

FIG. 9

6540 6560 6580
 TTTTAAATTCCTCTTTTGATACATATCTTCCAAGATTAATATATAAGCACCGTAGAATTTTAA
 K L E E K S V Y R G L N I Y L C R L I K L

6600 6620 6640
 TTCTATATTAGAAAGATTAACCTAAGTAATTATTAAACACAAATTGATGGTTTTCAAAGTCTATA
 E I N S L N V L Y N N F V F Q H N E F D I

6660 6680 6700
 AAATCATCATTAACATATTTAATATACTTTTTTATTTCATTTAAAATTCTACATAATATTAAAC
 F D D N V Y K I Y K K I E N L I R C L I L S

6720 6740 6760
 TTTTGCTTTTCATTATTTTTTATAATATAAAATCTATGCCTAAACTATAAAAATAACACTTCCT
 K S E N N K I I Y L D I G L S Y F Y C K R

6780 6800 6820 6840
 ACTATAGCTAGTATTACCTGTTATTATAACTATTGGAATTTTTCCTATAAATTCTTTTAAAAAC
 S Y S T N G T I I V I P I K G I F E K L F

6860 6880 6900
 GTATAATACTCATCAAACCTTTTCATACACAATTATAAAATTTGGGTCTATATTTGAAGAATTAA
 T Y Y E D F K E Y V I I F N P D I N S S N I

6920 6940 6960
 TTGTAATTCTTCTATCTAATTCTAAAATACTTTCAATAAGAATAGAATCTACCTCACCGACAAT
 T I R R D L E L I S E I L I S D V E G V I

6980 S/D 7000 7020
 ATTAATAGAAATCATTTTATTCCCTTCATTCTTTAAGTAATTTGTATACGTCTAGTTTTCATT
 N I S I M < *epiQ* *op* E K L L K Y V D L K G N

7040 7060 7080
 ACCATAATGTTTTTTATCCATATATTTTTCTTTTTCTATCCCTTTTTTCTTAAATAACTCTATA
 G Y H K K D M Y K E K E I G K K K F L E I

7100 7120 7140 7160
 GCTGTTTCGGGTGTTGTTCTTTTAATTGATACTTATCAATTTCTAGTGCTAAAGCTCCAGAAACCT
 A T E P Q D K L Q Y K D I E L A L A G S V K

7180 7200 7220
 TGGGTGCAGCAAGTGATGTCCCTGATTGATATATGTATCTTCCATTAGAAGAAGTACTTAAAAC
 P A A L S T G S Q Y I Y R G N S S T S L V

7240 7260 7280
 ACTTTGTTTTTGCAATATATCCTTTTTCTAACCAAGCATCTTTTCCATACTTATCTAAAAGTTTA
 S Q K Q M Y G K E L W A D K G Y K D L L K

7300 7320 7340
 TAAGAACCTCCTATCGTCATTAAATCTATAAAATTATTTCCATAATTAGAAAACCTCAGAAATAT
 Y S G G I T M L D I F N N G Y N S F E S I Y

22/32

FIG. 9

7360 BamHI 7380 7400
 AATCATTATCATCGATGGATCCTACAGTCATAACATTATTTAGATTGCTGGGCTATCATATAC
 D N D D I S G V T M V N N L N A P S D Y V

7420 7440 7460 7480
 CTTTTTTGATGTTTTAGAAATTTAGATTTCTTTTTTTATTTATTTCTTTTACTTTTTTTACATTG
 K K S T K S N L N R K K N I E K-V K K V N

7500 7520 7540
 ATACCGTCATTACCCACAGCTGCAACAACAATACTACCTTTTTTTTGGAGCATAGTTTATAGCTT
 I G D N G V A A V V I S G K K Q A Y N I A K

7560 7580 7600
 TCTGTAGTGCATCGTAATCAACTTTTTCATCATCTCTTAATTTTTTTTTATTTTGATTATCTTT
 Q L A D Y D V K E D D R L K K K N Q N D K

7620 7640 7660
 AATTAAATAATTCCTAAACTAACGTTGATTACATCATTTGTCATCATTTGCTGCATCAATAATT
 I L Y N G L S V N I V D N D D N A A D I I

7680 7700 7720
 CCTTTAGATACCCAAAGCATTTCACTTTTCTTTGAGCCAAATACTCGGTATACATTCATCTCTA
 G K S V W L M E S K K S G F V R Y V N M E V

7740 7760 7780 7800
 CTCCAGGGTTTACACCTTTTAAATTACCGTTTGCTCCTATTTGTCCTGCTACTAATGTACCATG
 G P N V G K L N G N A G I Q G A V L T G H

7820 7840 7860
 ATTCAATTTATCTTCTTCAAAATTTTTATTTCTGATTCATCGTTTTGCTACCTCTAAAACCA
 N L K D E E F N K N G S E D N E S G R F G

7880 7900 7920
 TTTTATAGGCACTTCATTAACCTATCTTATTTATACTCTTTAAATCTGTATGACTACTATTACAC
 N K P V E N V I K N I S K L D T H S S N V G

7940 7960 7980
 CAGAATCTACTAAAGCAACTTTTGCTTTTTTTCTATCTGGACTTAGCTTATAACTTTTACCTTC
 S D V L A V K A K K R D P S L K Y S K G E

8000 8020 8040
 ATTTGTTATTTTTTCGCATATCCCATTTGTCTGTCAAATAAATCATGGCTGCCATTTTTTTTATTA
 N T I K R M D W Q R D F L D H S G N K K N

8060 8080 8100 8120
 TTAAATTTTTTCTGTCTTTACAGATTTTCAACTACACAAGTGGAACAGGTAGGATTTACAA
 N L N K G T K V S K E V V C T S C T P N V F

8140 8160 8180
 ACTTGACGTTTTTATTACTCTTTATTAGTGAATTTAATTTTGATTGCTAGTTTAAATTTGTGC
 K V N K N S K I L S N L K S K S T K I Q A

23/32

FIG. 9

8200 HindII 8220 8240
TGTATGTAGTTCAGGAATTTTATAAGTTAACTCGATATTTTTTTGTTTAATGGATTCTTTAAAA
T H L E P I K Y T L E I N K Q K I S E K F

8260 8280 8300
GTTTTGCAATTATCATATTCAACACTATAATAACTTAATTCTTCATTTAGTGAACCTCCAAAAG
T K A N D Y E V S Y Y S L E E N L S S G F A

8320 8340 8360
CATACTCATTTTGCAAAAAAACTAATGACAATATTAAAAAAACAATGAAAAATTTAAATTTGTT
Y E N Q L F V L S L I L F V I F F K F K N

8380 S/D 8400 8420 8440
CATATAGCACCTCTAACATATTATTTATATTAAACATTAATTTAACACTTATGTTTTTACTTTT
M < **epiP**

8460 8480 8500
TTATTTATATTATCTTTAATAATGTTCTGTTGCAAGATGAAAAATACGAGGTATCAAAGTACCG

8520 8540 8560
ATACAGCGAGTATTACACTCAATTAATTAAAAATAAAATATGTTGTGATTAAAATTTATTTTAT

8580 8600 KpaII
AAAAGTATGGGCAATTTATTATTATTCAAGTTAAAACAAAGAGTCCGGGACATAAAGTTTCAGC

8640 8660 8680
CTCTTCGTCCTAATTACCAAAAAAATACTCCAAAATCCTTTTTTTAGATTGGTTTTTTTCTAATT

8700
TTTT

24/32

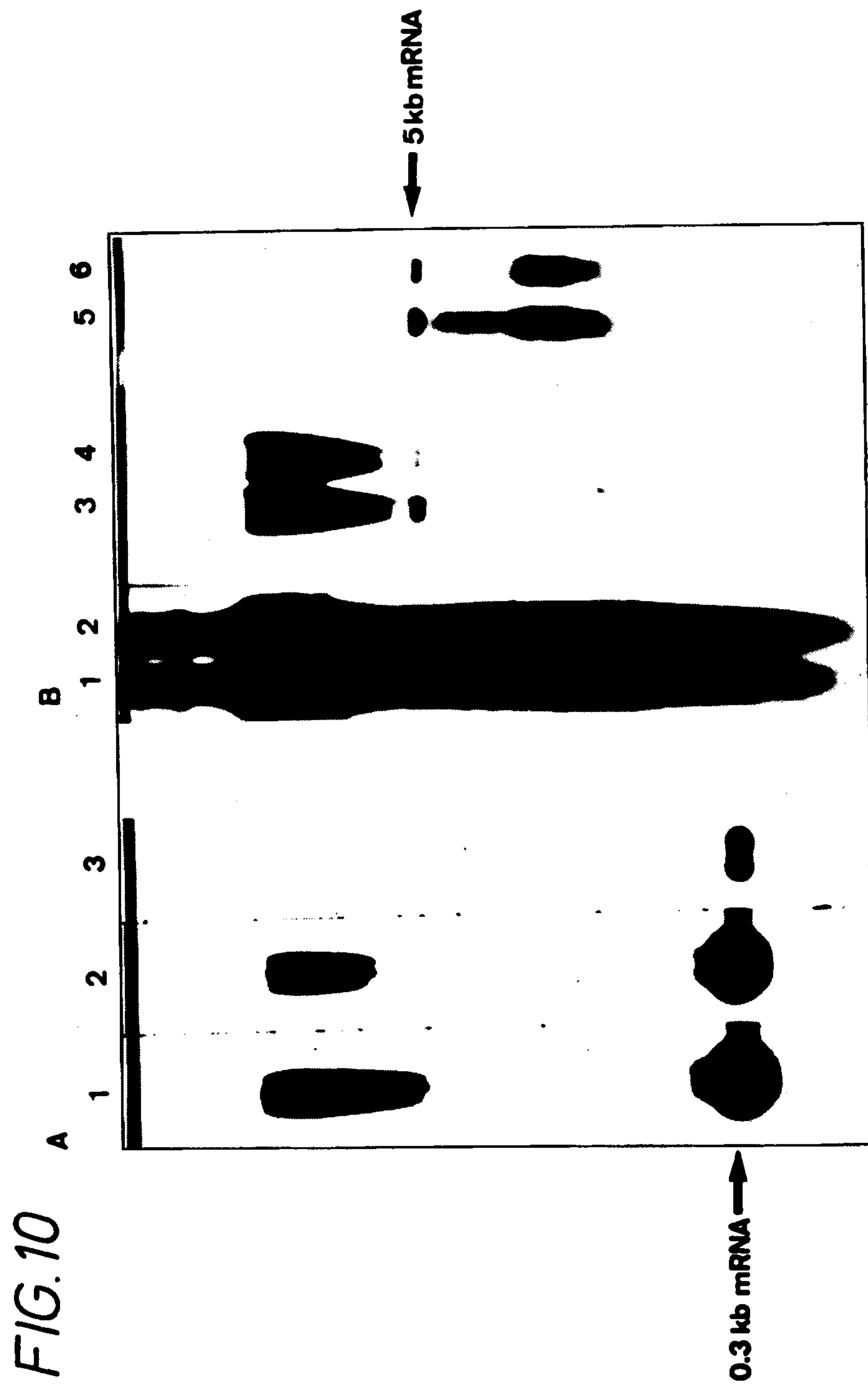


FIG. 11

Active site I:			
		*	
EPIP	130	EGKSYKLSPDRKKAKVALVDSGVNSSHTDLKSINKIVNEVP	170
			
SUBSI	119	APALHSQGYTGSNVKVAVIDSGIDSSHDPDLNVRGGASEVPS	159
			
ISPI	31	APEMWAKGVKGKNIKVAVLDTGCDTSHPD LKNQIIGGKNFS	71
			
SUMYTV	19	QAPQAWDIAEGSGAKIAIVDTGVQSNHPDLAGKVVGWDFV	59
		*	
			

FIG. 11

Active site II:

*

EPIP 170 PKNFGRSENDKNGKFEEDKLNHGTLVAGQIGANGNLKGVNPGVEMNVY 220
: . . :
SUBSI 146 PDLNVRGGASFVPSETNPYQDGS SHGTHVAGTIAALNNSIGVLGVSPSASL 196
: :
ISPI 163 QIIGCKNFSDDDGCKEDAI SDYNHGTHVAGTIAANDSNGGIAGVAPEASL 113
: :
SUMYTV 67 NGNGHGHGTHCAGIAAAVTNNST 87

Active site III:

*

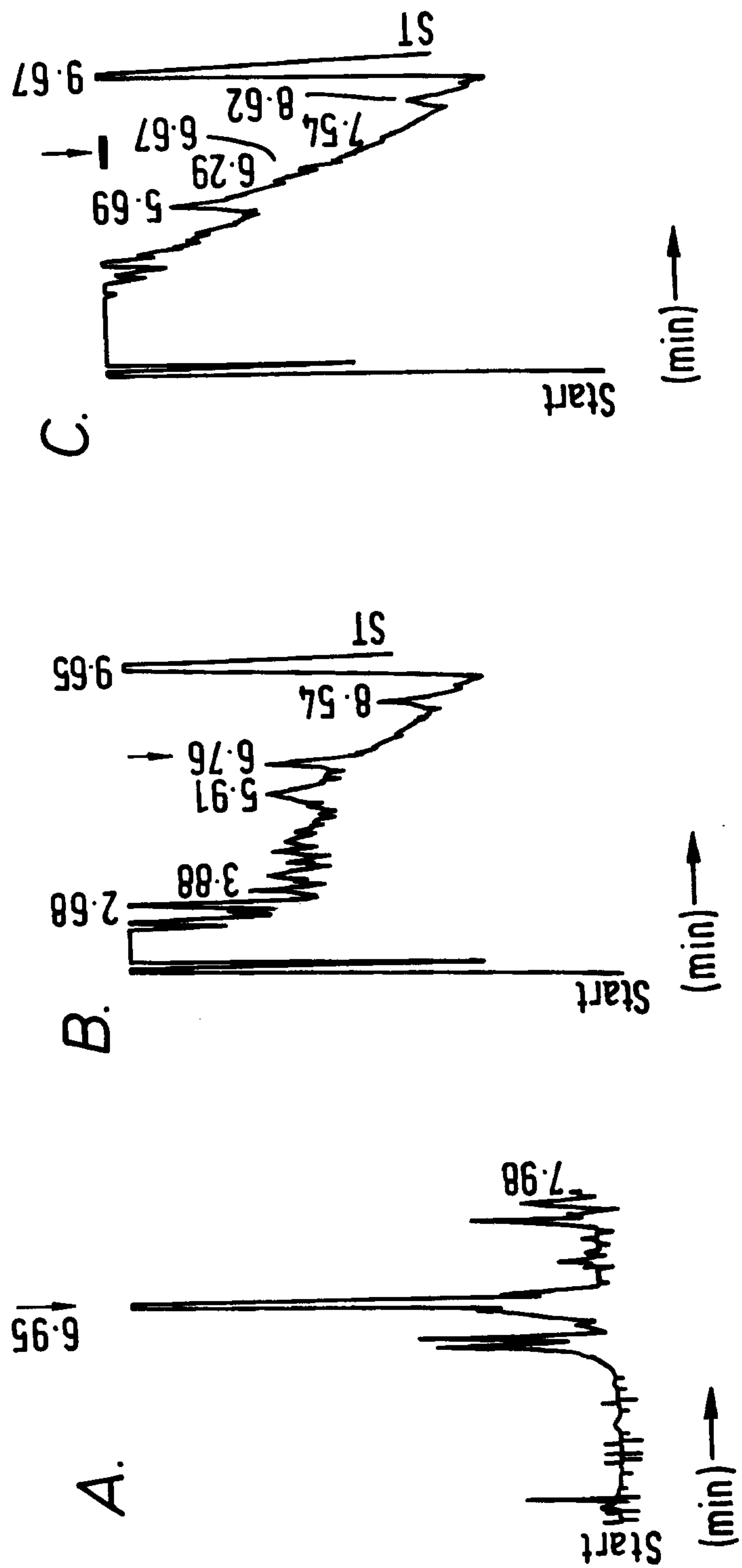
EPIP 380 YMQKQSVLSTSSNGRYIYQSGTSLAAPKVSCALALEIDKYQ 420
: . :
SUBSI 305 MAPGVSIQSTLPGGTYGAYNGTSMATPHVAGAAALILSKHP 345
: :
ISPI 224 VAPGENILSTLPNKKYKLTGTSMAPHVSGALAL-IKSYE 263
: :
SUMYTV 203 AAPGSWIYSTYPTSTYASLSGTSMATPHVAGVAGLLASQGR 243

*

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EPIQ MISINIVGEVDSILIESILELDRRITINSSNIDPNFIIVYEKFEYTFLEKFIGIKIPIV      10    20    30    40    50    60
PHOB VLEQNGFQPVEAEDYDSAVNQNLNEPWPDLILLDWMLPGSGIQFIKHLKRESMTRDIPVV      30    40    50    60    70    80
EPIQ IITGNTSYSRKCYFYSGLGIDLIIKNNESKSLILCRILNEIKKYIKYVNDDFID-----F      70    80    90   100   110
PHOB MLTARGEEDRVRGLETGADDYITKPFSPKELV-ARIKAVMRRI SPMAVEEVIEMQGLSL      90   100   110   120   130
EPIQ E--NHQVFNNYLVLNSNIELKILRCLYINLGRYVSKEELKKGVWDTEDFVDSNTINVVI      120   130   140   150   160   170
PHOB DPTSHRVMAGEEPLEMGPTEEFKLHFFMTHPERVYSREQLLNHVWGTVNYVEDRTVDVHI      150   160   170   180   190
EPIQ HRLRDSLKNCKEIEIINE-RKLG YKILIRKDLC      180   190   200
PHOB RRLRKALEPGGHDRMVQTVRGTGYRFSTRF      210   220
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28/32

FIG. 13



29/32

FIG. 14

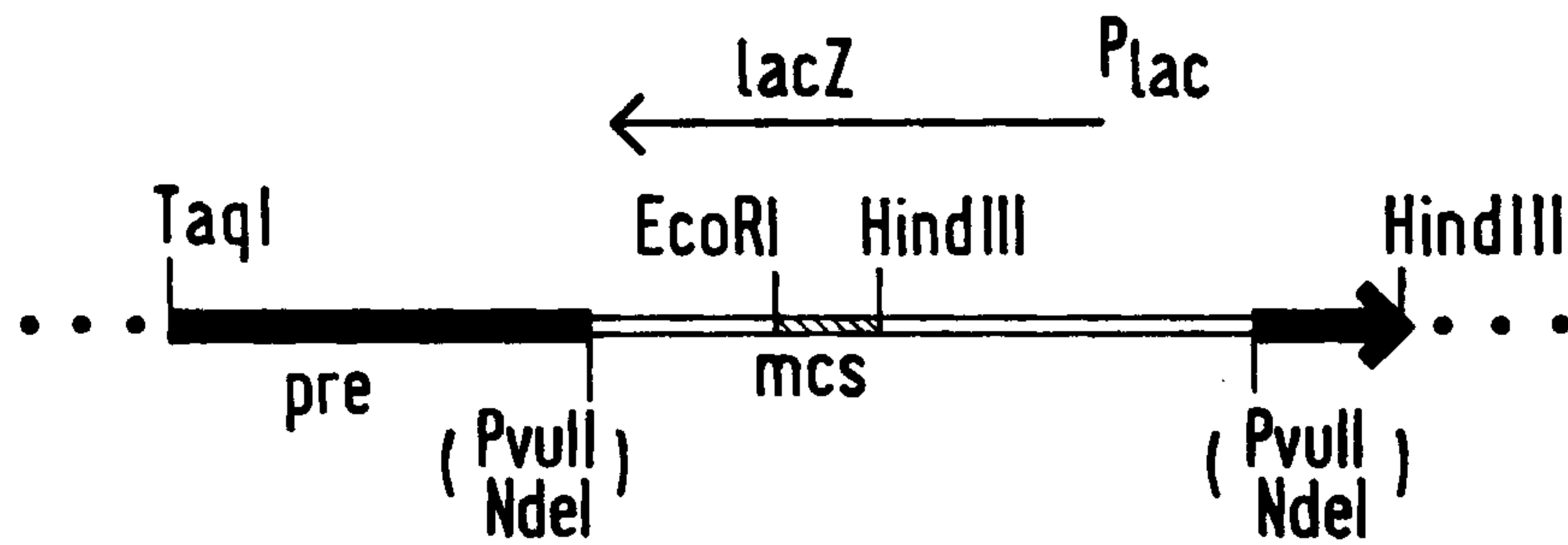
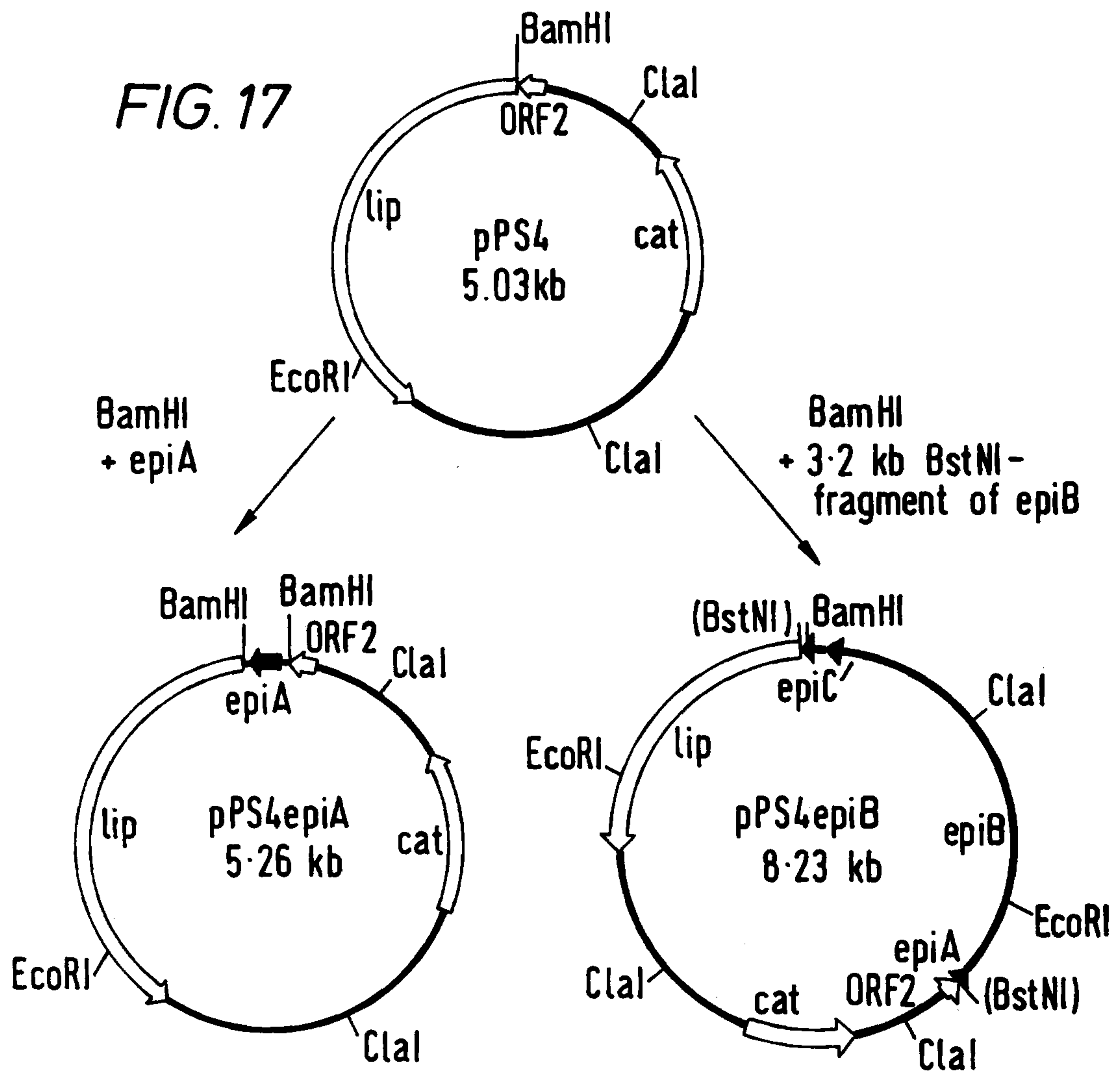
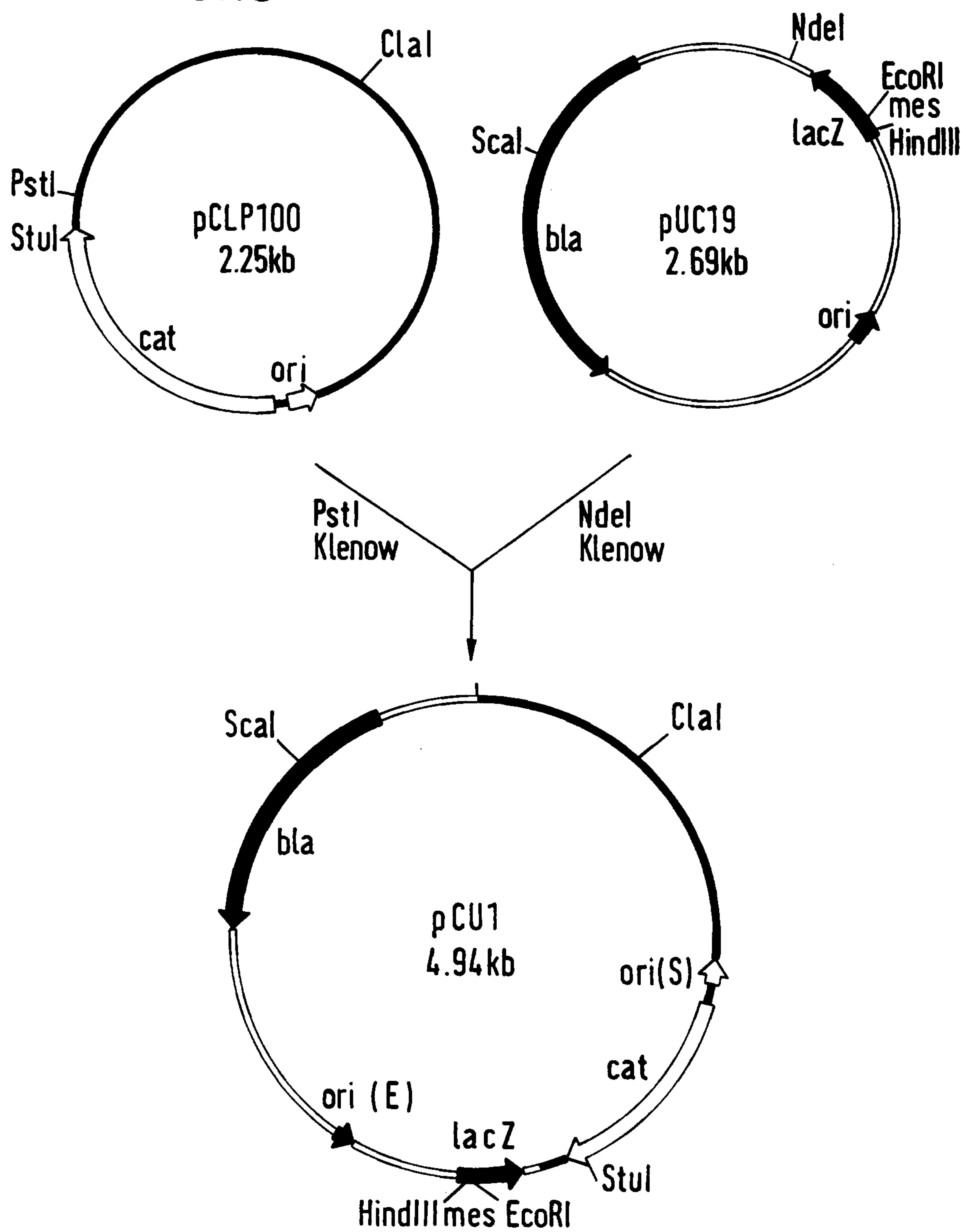


FIG. 17



30/32

FIG. 15



31/32

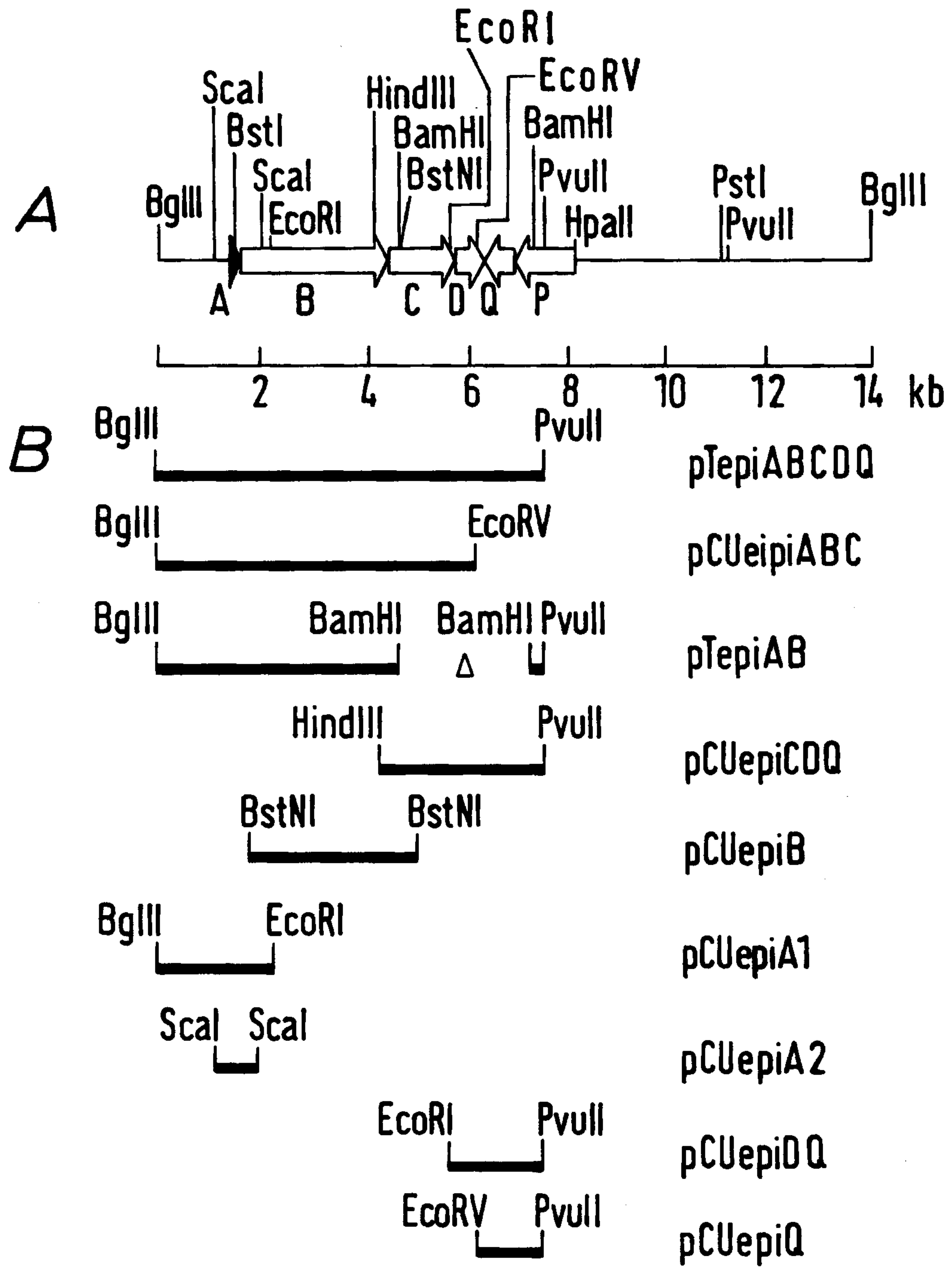
FIG. 16

FIG. 18

