

(19) **DANMARK**

(10) **DK/EP 2493843 T3**



(12) **Oversættelse af  
europæisk patentskrift**

Patent- og  
Varemærkestyrelsen

- 
- (51) Int.Cl.: **C 07 C 229/30 (2006.01)** **C 07 C 227/16 (2006.01)** **C 07 K 7/58 (2006.01)**
- (45) Oversættelsen bekendtgjort den: **2016-01-25**
- (80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2015-11-11**
- (86) Europæisk ansøgning nr.: **10759663.7**
- (86) Europæisk indleveringsdag: **2010-09-30**
- (87) Den europæiske ansøgnings publiceringsdag: **2012-09-05**
- (86) International ansøgning nr.: **EP2010064511**
- (87) Internationalt publikationsnr.: **WO2011051071**
- (30) Prioritet: **2009-10-28 US 255521 P**
- (84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR**
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- (74) Fuldmægtig i Danmark: **NORDIC PATENT SERVICE A/S, Bredgade 30, 1260 København K, Danmark**
- (54) Benævnelse: **2-AMINO-3-METHYL-HEX-5-ENSYRE OG ANVENDELSE HERAF I FREMSTILLINGEN AF PEPTIDER, SÅSOM BACITRACINER**
- (56) Fremdragne publikationer:  
**WO-A1-97/47313**  
**WO-A1-2011/051073**  
**I. WILSON, R. F. W. JACKSON: "Palladium(0) catalysed and copper(I) promoted reactions of the secondary zinc reagent derived from L-threonine", JOURNAL OF THE CHEMICAL SOCIETY, PERKIN TRANSACTIONS 1, 19 November 2002 (2002-11-19), pages 2845-2850, XP002615743, DOI: 10.1039/b208667k**



## DESCRIPTION

### Field of invention

[0001] The present invention relates to new amino acid compounds.

### Background of invention

[0002] The majority of proteins are made of 20 different  $\alpha$ -amino acids: Alanine, Arginine, Asparagine, Aspartic acid, Cysteine, Glutamine, Glutamate, Phenylalanine, Glycine, Histidine, Isoleucine, Lysine, Leucine, Methionine, Proline, Serine, Threonine, Tryptophan, Tyrosine, and Valine.

[0003] However, there are many biologically active peptides comprising other amino acids such as: Homocysteine, Ornithine, 4-Hydroxyproline, 5-Hydroxylysine, Selenocysteine, Formylmethionin, Phosphoserine, Acetylserine, Methylarginine, etc.

[0004] Amino acids in D-configuration are common in non-ribosomally synthesized bacterial peptides and less common in ribosomally synthesized proteins. For example in the non-ribosomally synthesized Bacitracins, the amino acid residues in position 4, 7, 9 and 11 are usually in D-configuration (Glu, Orn, Phe and Asp). Bacitracins are peptide antibiotics naturally produced by *Bacillus subtilis* and *Bacillus licheniformis*. Several Bacitracins have been identified of which Bacitracin A is of primary importance and is highly active (Biochemistry, vol. 39 no 14, 2000, page 4037-45 by Epperson and Ming). The primary structure of Bacitracin A is  $\text{NH}_2\text{-L-Ile}_1\text{-L-Thiazoline}_2\text{-L-Leu}_3\text{-D-Glu}_4\text{-L-Ile}_5\text{-L-Lys}_6\text{-D-Orn}_7\text{-L-Ile}_8\text{-D-Phe}_9\text{-L-His}_{10}\text{-D-Asp}_{11}\text{-L-Asn}_{12}\text{-COOH}$  which is cyclized between the  $\epsilon$ -amino group of L-Lys<sub>6</sub> and the R-carboxyl group of L-Asn<sub>12</sub>.

### Prior art

[0005] Several non-ribosomally synthesized peptides comprise unusual amino acids. For example cyclosporin A comprises 2(S)-amino-3(R)-hydroxy-4(R)-methyl-6(E)-octenoic acid which is crucial for binding to the intracellular receptor for cyclophilin, and thus for its immunosuppressive activity (Journal of Biological Chemistry, vol. 268 no 35, 1993 by Offenzeller *et al*).

[0006] Several uncommon amino acids resemble the structure of Isoleucine:

2-Amino-5-methyl-5-hexenoic acid, a new methionine analogue, was isolated from a fermentation broth of *Streptomyces* (Journal of Antibiotics vol. 32 no. 11, page 1118-1124, 1979 by Takeuchi *et al*).

- 4 methylene-norleucine and 2-aminohept-6-enoic acid are compounds with the formula:  $\text{C}_7\text{H}_{13}\text{NO}_2$ .
- 4 methyl-norleucine is an isoleucine derivative which can be incorporated into a recombinant protein. (J Pharm Biomed Anal, vol 31. no. 5, 2003, page 979-987 by Muramatsu *et al*).
- 2-amino-3-methyl-4-pentenoic acid is an unsaturated isoleucine analogue which can be incorporated into proteins (Chembiochem vol. 7 no. 1, 2006, page 83-87 by Mock *et al*).
- The unsaturated norleucines of *Amanita solitaria*. Chemical and pharmacological studies (Lloydia vol. 36 no.2, 1973, page 69-73 by Chilton *et al*).
- Beta-methylnorleucine, an antimetabolite produced by *Serratia marcescens* (J Antibiot, vol. 34 no. 10, 1981 page 1278-82 by Sugiura *et al*)
- US6168912 describes various allyl derivatives of amino acids for use in a multidimensional combinatorial chemical library.
- Allylglycine and crotylglycine are described in Journal of Bacteriology, vol. 148 no. 1, 1981 by Kunz *et al*.

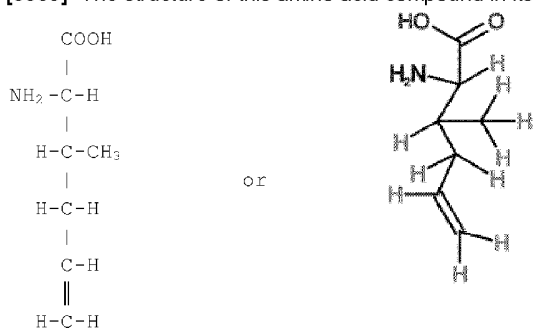
### Summary of the invention

[0007] The invention concerns the compound 2-amino-3-methyl-hex-5-enoic acid.

[0008] Although we use the name 2-amino-3-methyl-hex-5-enoic acid, it covers the same compound as 2-amino-3-methyl-5-

hexenoic acid.

[0009] The structure of this amino acid compound in its free form is represented by Formula I:



Formula I

[0010] Formula I is not to be interpreted as a Fischer projection, but rather as a compound without specification of stereochemistry.

[0011] The amino acid of Formula I comprises two chiral carbon atoms. The present invention covers the four stereoisomers of 2-amino-3-methyl-hex-5-enoic acid:

(2S,3S)-2-amino-3-methyl-hex-5-enoic acid,

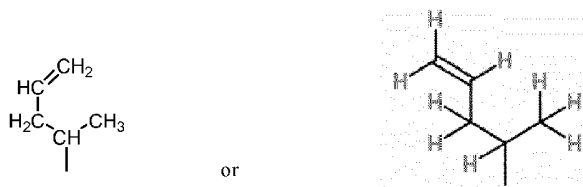
(2R,3S)-2-amino-3-methyl-hex-5-enoic acid,

(2S,3R)-2-amino-3-methyl-hex-5-enoic acid, and

(2R,3R)-2-amino-3-methyl-hex-5-enoic acid.

[0012] Further, the present invention covers salts of 2-amino-3-methyl-hex-5-enoic acid.

[0013] We propose and use the name 5-Methylene-Isoleucine for 2-amino-3-methyl-hex-5-enoic acid. Accordingly, the 5-Methylene-Isoleucine side chain has the structure  $-\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}=\text{CH}_2$  which could be represented



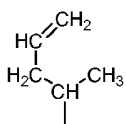
[0014] The invention also concerns use of 5-Methylene-Isoleucine for producing Bacitracins and a process for making 5-Methylene-Isoleucine.

[0015] 5-Methylene-Isoleucine can be used for production of Bacitracin J1, Bacitracin J2, Bacitracin J3, Bacitracin K1, Bacitracin K2, Bacitracin K3 and Bacitracin L.

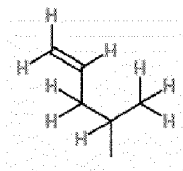
[0016] The aspects of the invention may be obtained by the features as set forth in the following description of the invention and/or the appended patent claims.

#### Detailed description of the invention

[0017] Some highly active Bacitracins comprise an uncommon amino acid side chain which has the following structure:



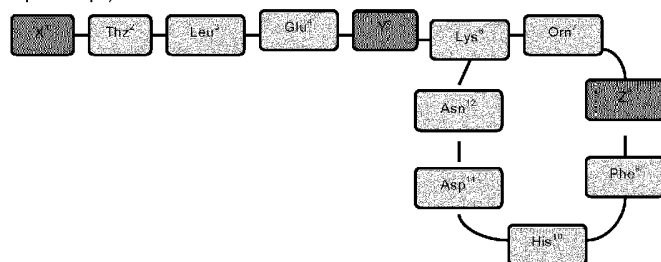
or



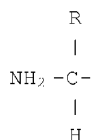
[0018] We have proposed and use the names Bacitracin J, K or L for Bacitracins comprising structure above. The structures of these Bacitracins are represented in Figure 1A-G.

### Definitions

[0019] "Bacitracins" are peptide compounds comprising the following structure (with amino acid residue numbering in superscript):



wherein X is



and, wherein R is the side chain of the amino acid residue of Isoleucine, Valine or 5-Methylene-Isoleucine;

and wherein

Y and Z are independently

the amino acid residue of

Isoleucine, Valine or 5-Methylene-Isoleucine;

and wherein

Thz is a Thiazoline ring



2' coupled to X and 4' coupled to the  $\alpha$ -carbon in Leu;

and wherein

Leu is a Leucine amino acid residue

Glu is a Glutamine amino acid residue

Lys is a Lysine amino acid residue forming peptide bonds with Y and Orn while its  $\epsilon$ -amine is coupled to the  $\alpha$ -carboxyl group of Asparagine by a peptide bond

Orn is an Ornithine amino acid residue

Phe is a Phenylalanine amino acid residue

His is a Histidine amino acid residue

Asp is an Aspartic acid amino acid residue

Asn is an Asparagine amino acid residue forming peptide bond with Asp while its  $\alpha$ -carboxyl group is coupled to the  $\epsilon$ -amine of Lysine by a peptide bond.

[0020] When used in this application; "Bacitracins" is meant to embrace any compound having the primary structure above regardless of the production method. Thus, the term "Bacitracins" includes the antibiotic compounds naturally produced by *Bacillus licheniformis* but also *in vitro* produced compounds (synthetic) and semisynthetic compounds having the primary structure above. "Bacitracins" is also meant to embrace any compound having the primary structure above regardless of the charge which varies with pH. "Bacitracins" is also meant to embrace any compound having the primary structure above regardless of the

stereochemistry. "Bacitracins" is also meant to embrace salts and hydrates of the compounds having the primary structure above.

**[0021]** "Bacitracins comprising at least one 5-Methylene-Isoleucine residue" is meant to embrace any Bacitracin comprising the structure that would be generated if a Isoleucine or Valine residue(s) was substituted with 5-Methylene-Isoleucine residue(s) in position 1 and/or 5 and/or 8.

**[0022]** When the N-terminal amino group and/or the Thiazoline ring of Bacitracins is oxidized, a substantial amount of the antibacterial activity is lost. For example the low activity compound Bacitracin F, comprises a keto-thiazole moiety instead of the amino-thiazoline moiety (J. Org. Chem, vol. 22, 1957, page 1345-1353 by Craig *et al*).

**[0023]** "Amino acid" is any compound comprising both an amine and a carboxyl group. Most proteins are built as a linear polymer of 20 different standard  $\alpha$ -amino acids in L-configuration: Alanine, Arginine, Asparagine, Aspartic acid, Cysteine, Glutamine, Glutamate, Phenylalanine, Glycine Histidine, Isoleucine, Lysine, Leucine, Methionine, Proline, Serine, Threonine, Tryptophan, Tyrosine and Valine.

**[0024]** An "Amino acid residue" is the unit in a peptide which comprises

-NH-CHR-COOH (C-terminal)

or

NH<sub>2</sub>-CHR-CO- (N-terminal)

or

-NH-CHR-CO- (internal)

where R is

H in Glycine,

CH<sub>3</sub> in Alanine,

OH in Serine,

CH<sub>2</sub>SH in Cysteine,

CH(CH<sub>3</sub>)CH<sub>2</sub>CH<sub>3</sub> in Isoleucine,

CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub> in Leucine

CH(CH<sub>3</sub>)<sub>2</sub> in Valine

etc.

**[0025]** An "Amino acid side chain" is the R-group of an "Amino acid residue". For example, the R-group is

CH(CH<sub>3</sub>)CH<sub>2</sub>CH<sub>3</sub> in Isoleucine,

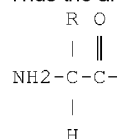
CH<sub>2</sub>CH(CH<sub>3</sub>)<sub>2</sub> in Leucine

CH(CH<sub>3</sub>)<sub>2</sub> in Valine

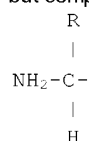
**[0026]** "Antibacterial activity" is any activity which inhibits the growth, metabolism or reproduction of bacteria, or increases the mortality of bacteria, or reduces the pathogenicity of bacteria.

**[0027]** The "positions" of the amino acid residues in Bacitracins are numbered from the N-terminal which can be Isoleucine, Valine or 5-Methylene-Isoleucine in position 1 (the left end in all figures showing Bacitracins in this application). Hence, Lys is in position number 6 and Asn is in position number 12.

**[0028]** In Bacitracins, the "position 1" is special, because this amino acid residue is partly incorporated into the Thiazoline ring. Thus the amino acid residue in position 1 in Bacitracins does not comprise the usual N-terminal unit:



but comprises instead:



coupled to Thiazoline

[0029] A "composition" is any mixture comprising more than two different compounds, for example a mixture of two active pharmaceutical ingredients, or a mixture of an active pharmaceutical ingredient and one or more pharmaceutical excipients.

[0030] A "pharmaceutical composition" is any composition suitable for use *in vivo*. Such compositions can thus be administered cutaneously, subcutaneously, intravenously, parenterally etc.

[0031] 5-Methylene-Isoleucine comprises two chiral carbon atoms which independently could be in R or S configuration.

[0032] The Bacitracins comprising at least one 5-Methylene-Isoleucine residue in position 1, 5 or 8 can be used for inhibiting unwanted bacterial growth both *in vitro* and *in vivo*. These compounds can thus have therapeutic effect if administered to an animal or a human with a bacterial infection.

[0033] The invention concerns the compound 5-Methylene-Isoleucine which could be used for production of the new Bacitracins; e.g. by *in vitro* synthesis of Bacitracin J1-3, K1-3 or L.

[0034] By substituting Isoleucine or Valine with 5-Methylene-Isoleucine in the methods described in J Org Chem, vol. 61 no. 12, 1996, page 3983-3986 by Lee *et al* or WO199747313, Bacitracins with antibacterial activity can be produced.

#### Brief description of the figures

##### [0035]

Figure 1A shows the structure of Bacitracin with a 5-Methylene-Isoleucine residue in position 5 (= Bacitracin J1)

Figure 1B shows the structure of Bacitracin with a 5-Methylene-Isoleucine residue in position 8 (= Bacitracin J2)

Figure 1C shows the structure of Bacitracin with a 5-Methylene-Isoleucine residue in position 1 (= Bacitracin J3)

Figure 1D shows the structure of Bacitracin with 5-Methylene-Isoleucine residues in position 5 and 8 (= Bacitracin K1)

Figure 1E shows the structure of Bacitracin with 5-Methylene-Isoleucine residues in position 1 and 5 (= Bacitracin K2)

Figure 1F shows the structure of Bacitracin with 5-Methylene-Isoleucine residues in position 1 and 8 (= Bacitracin K3)

Figure 1G shows the structure of Bacitracin with 5-Methylene-Isoleucine residues in position 1, 5 and 8 (= Bacitracin L)

Figure 2 shows a route for production of 5-Methylene-Isoleucine as disclosed in the examples

[0036] The invention is defined by the claims and not by the following illustrative examples:

#### Examples

##### Example 1:

[0037] (2*S*,3*R*)- 2-(1,3-Dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester and (2*S*,3*S*)- 2-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester Vinylmagnesium bromide in THF (1,0 M, 83,64 mL, 83,64 mmol) is added to a precooled (-10 °C) mixture of (2*S*, 3*S*) and (2*S*, 3*R*)-4-Iodo-*N*-phthaloylvaline methyl ester (26,96 g, 69,68 mmol), CuCl<sub>2</sub> (0,47 g, 3,5 mmol), dry LiCl (0,29 g, 7,0 mmol) in THF (100 mL). The reaction mixture is stirred over night at this temperature. The reaction mixture is added to saturated ammonium chloride solution (aq) (300 mL). The phases are separated and the aqueous phase is extracted with diethyl ether (3 x 100 mL). The combined organic phases are washed with saturated brine (100 mL), dried (MgSO<sub>4</sub>) and the solvents are removed at reduced pressure. 10 g of the product mixture is isolated The (2*S*,3*S*) and (2*S*,3*R*) products are separated by column chromatography.

##### Example 2:

**(2S,3R)-2-Amino-3-methyl-hex-5-enoic acid**

**[0038]** (2S,3R)- 2-(1,3-Dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester (2,01 g, 7,00 mmol) is dissolved in a 2:1 mixture of 6 N hydrochloric acid and glacial acetic acid (62,5 mL), and the solution is heated at reflux for 4 h. The solution is cooled to room temperature and concentrated under reduced pressure. The product is taken up in water and the solution is filtered. The filtrate is concentrated under reduced pressure and the residue is dissolved in water, then the solution is applied to a column of amberlite IR 120 cation exchange resin (NH<sub>4</sub><sup>+</sup> form.). The column is washed with water (2,5 L), then eluted with aqueous ammonia solution (2,5 L). The eluate is boiled until no ammonia can be detected, then concentrated under reduced pressure affording the title compound (0,5 g, 3,50 mmol).

**Example 3:****(2S,3S)-2-Amino-3-methyl-hex-5-enoic acid**

**[0039]** (2S,3S)- 2-(1,3-Dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester (2,01 g, 7,00 mmol) is dissolved in a 2:1 mixture of 6 N hydrochloric acid and glacial acetic acid (62,5 mL), and the solution is heated at reflux for 4 h. The solution is cooled to room temperature and concentrated under reduced pressure. The product is taken up in water and the solution is filtered. The filtrate is concentrated under reduced pressure and the residue is dissolved in water, then the solution is applied to a column of amberlite IR 120 cation exchange resin (NH<sub>4</sub><sup>+</sup> form.). The column is washed with water (2,5 L), then eluted with aqueous ammonia solution (2,5 L). The eluate is boiled until no ammonia can be detected, then concentrated under reduced pressure affording the title compound (0,5 g, 3,50 mmol).

**Example 4:****(2R,3R)- 2-(1,3-Dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester and (2R,3S)- 2-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester**

**[0040]** Vinylmagnesium bromide in THF (1,0 M, 83,64 mL, 83,64 mmol) is added to a precooled (-10 °C) mixture of (2S,3S) and (2S, 3R)-4-Iodo-N-phthaloylvaline methyl ester (26,96 g, 69,68 mmol), CuCl<sub>2</sub> (0,47 g, 3,5 mmol), dry LiCl (0,29 g, 7,0 mmol) in THF (100 mL). The reaction mixture is stirred over night at this temperature. The reaction mixture is added to saturated ammonium chloride solution (aq) (300 mL). The phases are separated and the aqueous phase is extracted with diethyl ether (3 x 100 mL). The combined organic phases are washed with saturated brine (100 mL), dried (MgSO<sub>4</sub>) and the solvents are removed at reduced pressure. 10 g of the product mixture is isolated. The (2R,3S) and (2R,3R) products are separated by column chromatography.

**Example 5:****(2R,3R)-2-Amino-3-methyl-hex-5-enoic acid**

**[0041]** (2R,3R)- 2-(1,3-Dioxo-1,3-dihydro-isoindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester (2,01 g, 7,00 mmol) is dissolved in a 2:1 mixture of 6 N hydrochloric acid and glacial acetic acid (62,5 mL), and the solution is heated at reflux for 4 h. The solution is cooled to room temperature and concentrated under reduced pressure. The product is taken up in water and the solution is filtered. The filtrate is concentrated under reduced pressure and the residue is dissolved in water, then the solution is applied to a column of amberlite IR 120 cation exchange resin (NH<sub>4</sub><sup>+</sup> form.). The column is washed with water (2,5 L), then eluted with aqueous ammonia solution (2,5 L). The eluate is boiled until no ammonia can be detected, then concentrated under reduced

pressure affording the title compound (0,5 g, 3,50 mmol).

**Example 6:**

**(2R,3S)-2-Amino-3-methyl-hex-5-enoic acid**

**[0042]** (2R,3S)- 2-(1,3-Dioxo-1,3-dihydro-isindol-2-yl)-3-methyl-hex-5-enoic acid methyl ester (2,01 g, 7,00 mmol) is dissolved in a 2:1 mixture of 6 N hydrochloric acid and glacial acetic acid (62,5 mL), and the solution is heated at reflux for 4 h. The solution is cooled to room temperature and concentrated under reduced pressure. The product is taken up in water and the solution is filtered. The filtrate is concentrated under reduced pressure and the residue is dissolved in water, then the solution is applied to a column of amberlite IR 120 cation exchange resin (NH<sub>4</sub><sup>+</sup> form.). The column is washed with water (2,5 L), then eluted with aqueous ammonia solution (2,5 L). The eluate is boiled until no ammonia can be detected, then concentrated under reduced pressure affording the title compound (0,5 g, 3,50 mmol).

## REFERENCES CITED IN THE DESCRIPTION

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**Patent documents cited in the description**

- [US61689125 \[0006\]](#)
- [WO199747313A \[0034\]](#)

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## PATENTKRAV

1. Forbindelsen 2-amino-3-methyl-hex-5-ensyre eller salte deraf.
- 5 2. Forbindelse ifølge krav 1 med konfigurationen (2*S*, 3*S*).
3. Forbindelse ifølge krav 1 med konfigurationen (2*R*, 3*S*).
4. Forbindelse ifølge krav 1 med konfigurationen (2*S*, 3*R*).
- 10 5. Forbindelse ifølge krav 1 med konfigurationen (2*R*, 3*R*).
6. Anvendelse af 2-amino-3-methyl-hex-5-ensyre til fremstilling af et peptid.
- 15 7. Anvendelse ifølge krav 6, hvor peptidet er et bacitracin.
8. Sammensætning omfattende 2-amino-3-methyl-hex-5-ensyre.
9. Fremgangsmåde til fremstilling af 2-amino-3-methyl-hex-5-ensyre, hvilken fremgangsmåde  
20 omfatter en krydskobling af et vinyl-Grignard-reagens med et alkylhalogenid.
10. Fremgangsmåde ifølge krav 9, hvor reaktionen katalyseres med Li<sub>2</sub>CuCl<sub>4</sub>.
11. Fremgangsmåde ifølge krav 10, hvor alkylhalogenidet er 4-iod-*N*-phthaloylvalinmethylester.  
25



Figure 1C

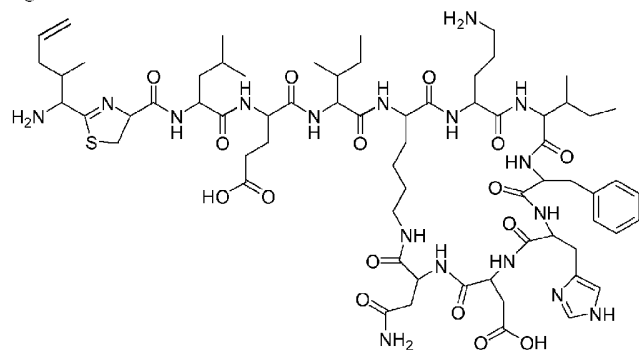


Figure 1D

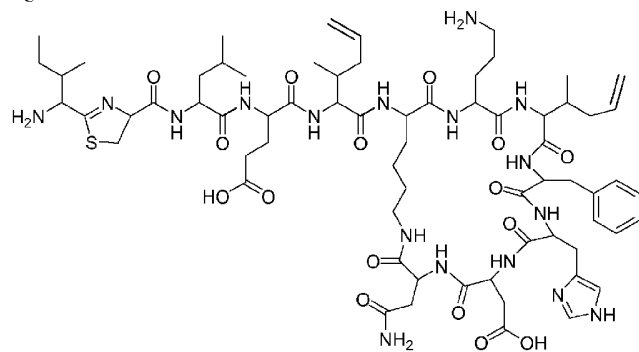


Figure 1E

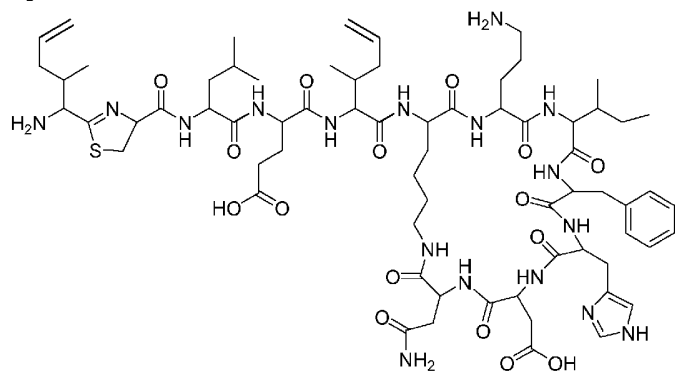


Figure 1F

