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(54) Title: INHIBITORS OF BLOOD COAGULATION FACTOR XIII

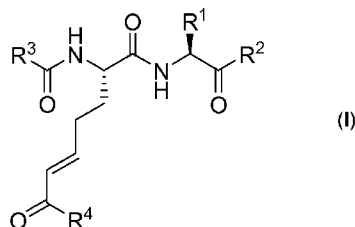
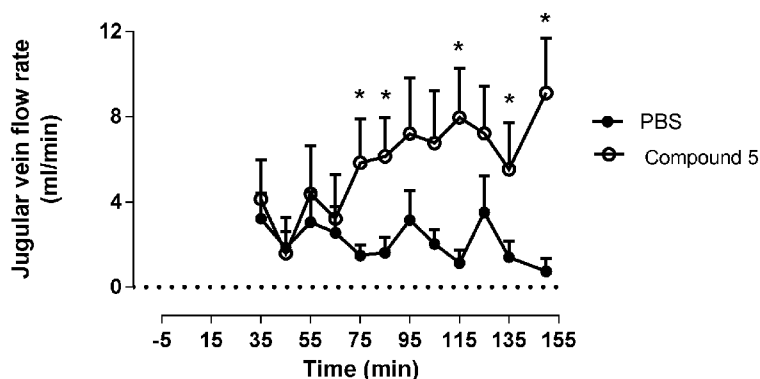


Figure 4

B.



(57) Abstract: The invention relates to a compound of general formula (I) as novel inhibitor of blood coagulation factor XIII, methods for synthesis thereof and to use thereof for the prophylaxis or treatment of diseases associated with blood coagulation factor XIII.

Inhibitors of blood coagulation factor XIII

Description

5

The invention relates to novel inhibitors of blood coagulation factor XIII, methods for their synthesis and to their use for the prophylaxis or treatment of diseases associated with blood coagulation factor XIII.

10 Background of the invention

Substantial effort has been dedicated to the development of drugs targeting coagulation factors or platelet activation in order to prevent and treat venous thromboembolism, acute coronary syndrome or for reducing the risk of stroke in patients with atrial fibrillation. Coagulation factor XIII (FXIII, F13) is a promising but yet
15 widely untapped and challenging target for drug development (LORAND L., JACOBSEN A., *Nature* 1962; **195**: 911–2; Stieler M, et al., *Angew Chemie Int Ed* 2013; **52**: 11930–4; Böhm M, et al., *J Med Chem* 2014; **57**: 10355–65.) Whereas all the other enzymes within the coagulation cascade are serine proteases, the FXIII-A subunit belongs to the transglutaminase family (EC 2.3.2.13: protein-glutamine γ -glutamyltransferase) consisting of eight human isoenzymes (FXIII-A and TG1–TG7).
20 The most characteristic catalytic function for transglutaminases is the formation of isopeptide bonds between the side chains of susceptible protein bound glutamine and lysine residues in a tightly controlled manner.

FXIII plays a key role in clot formation, maturation and composition (Muszbek L, et al.,
25 *Physiol Rev* 2011; **91**: 931–72; Byrnes JR, et al. *Blood* 2015, **126**, 1940–8).

FXIII recognizes fibrin as substrate and covalently cross-links fibrin γ -chains and, in an ordered sequence, fibrin α -chains providing mechanical stability to the fibrin fibers. In parallel, enzymatic incorporation of anti-fibrinolytic proteins such as α_2 -antiplasmin renders the clot biochemically stable. In blood, the non-covalent FXIII-A₂B₂
30 heterotetramer (pFXIII) is bound to fibrinogen. During activation thrombin cleaves the N-terminal activation peptide from the FXIII-A subunits. Subsequent binding of calcium ions promotes dissociation of the carrier B-subunits yielding active FXIIIa.

The clot-modulating function and the positioning downstream of thrombin make FXIII a
35 promising target for drug development (Lorand L, *Arterioscler Thromb. Vasc. Biol.*, 2000; **20**: 2–9.). Specific inhibitors targeting FXIII would not interfere with thrombin generation, fibrin formation or with platelet activation. Blocking thrombin – directly or via upstream FXa – by the currently available anticoagulants is characterized by an enhanced bleeding risk, thus excluding many patients from beneficial treatment (Griffin

JH, *Nature*, 1995; **378**: 337–8.). Considering this well-known medical need, novel therapeutic approaches with minimal or no bleeding risk are desperately needed (Weitz JI, Fredenburgh JC., *Front Med* 2017; **4**). Even if the development of FXIII inhibitors might provide one such option, noticeably few FXIII-blockers have been identified or synthesized so far.

Finney et al. reported that the 66 amino acid polypeptide “tridegin” from the salivary gland of the giant Amazon leech *Haementeria ghilianii* is a potent FXIII inhibitor (Finney S, et al., *Biochem J*, 1997; **324 (Pt 3)**: 797–805.). Further, in the late 1980s, a series of small molecules irreversibly inhibiting FXIIIa were explored in animal models of thrombosis in the presence of t-PA facilitating increased clot lysis *in vivo* (Leidy EM, et al., *Thromb Res*, 1990; **59**: 15–26; Shebuski RJ, et al., *Blood* 1990; **75**: 1455–9.). Due to the lack of selectivity and potency along with short plasma half-lives of only a few minutes, these inhibitors were solely considered as pharmacological tools but not as prospective drug candidates. The pharmacokinetic profile of an irreversibly acting inhibitor carrying a thiadiazole warhead was studied in rabbits in order to support and facilitate the design and selection of drug candidates (Novakovic J, et al., *J Pharm Biomed Anal* 2005; **38**: 293–7.). Further, medicinal chemists reported cyclopropanone derivatives from fungi and synthetic analogues as potent FXIIIa inhibitors (Kogen H, et al., *J. Am. Chem. Soc.* 2000, **122**, 1842-1843.). In both cases, from a drug discovery perspective, the low potency of the compounds disqualifies them for further development. In accordance with this assumption no (pre)clinical studies have been reported.

Potent, drug-like FXIII-inhibitors are a prerequisite that is still lacking for further exploring the therapeutic concept.

The objective of the present invention is to provide novel, most probably irreversible inhibitors of blood coagulation factor XIII and methods for the synthesis thereof as well as their use for the prophylaxis and treatment of diseases associated with blood coagulation factor XIII.

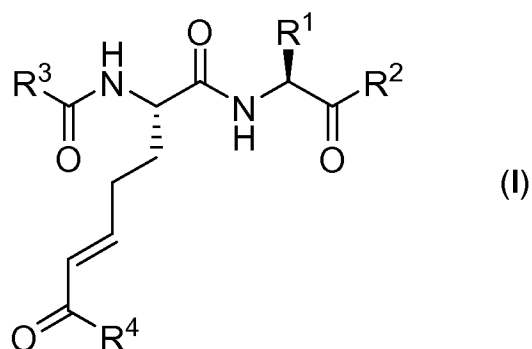
Said objective is solved by the technical teachings of the independent claims. Further advantageous embodiments, aspects and details of the invention are evident from the dependent claims, the description and the examples.

Surprisingly, it was found that certain peptidomimetic inhibitors carrying a Michael-acceptor warhead are potent and selective inhibitors of FXIIIa. The patent application discloses preferred structures characterized by the position 2 towards the C-terminus of the warhead. It was found that exactly at that position constrained peptide-mimetic amino acids are preferred to obtain potent and/or selective FXIIIa-blockers. The

peptide-mimetic backbone positions the soft electrophilic warhead in perfect orientation to the active site cysteine. The mechanism-based inhibitors efficiently inactivate FXIIIa even if the intrinsic reactivity of the Michael-acceptor warhead is low – a prerequisite to avoid side effects and toxicity.

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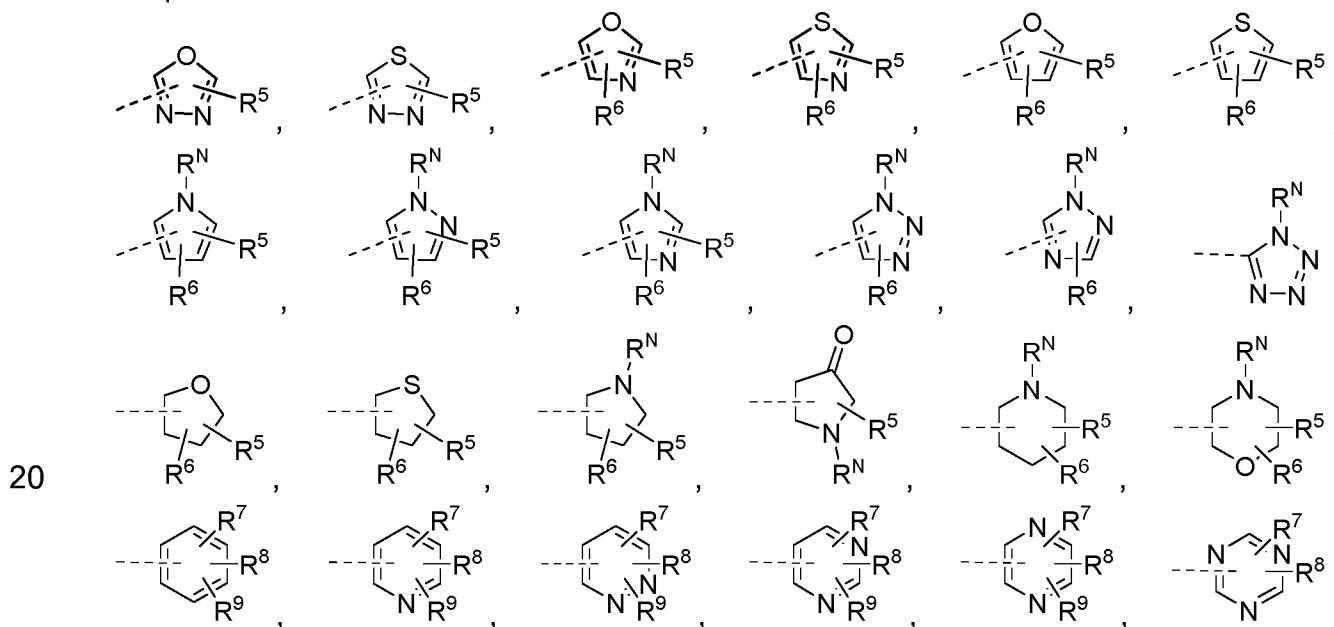
Thus, the present invention relates to a compound of the general formula (I):

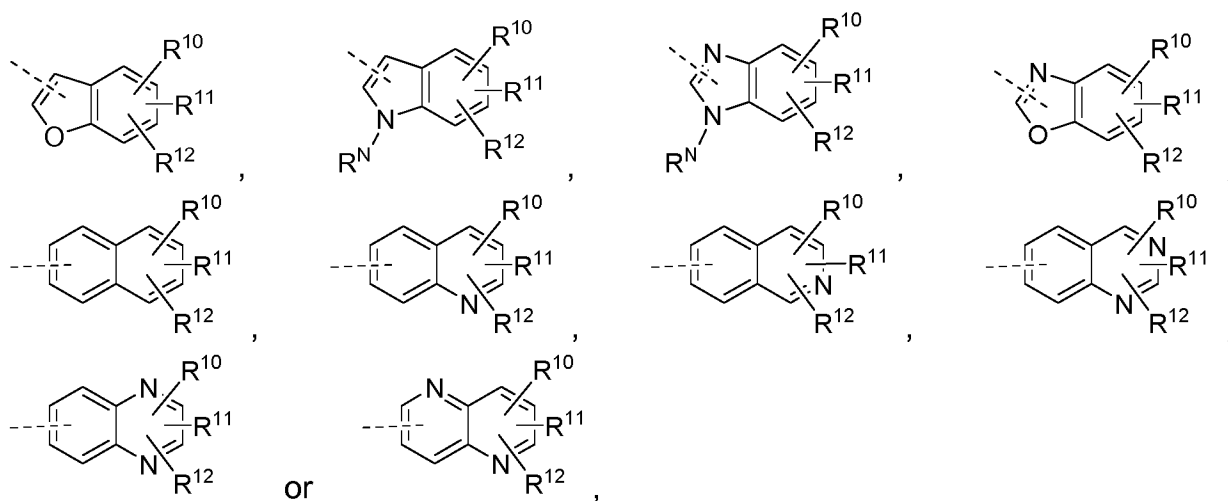


wherein

- 10 **R¹** represents –H, –CH₃, –C(CH₃)₃, –cyclo-C₃H₅, –cyclo-C₄H₇, –cyclo-C₅H₉, –cyclo-C₆H₁₁, –CH₂–CH(CH₃)₂, –CH₂CH₃, –CH₂CH₂CH₃, –CH₂CH₂CH₂CH₃, –CH₂CH₂CH₂CH₂CH₃, –CH₂CH₂CH₂CH₂CH₂CH₃, –CH(CH₃)₂, –CH₂–C(CH₃)₃, –CH₂CH₂SCH₃, –CH₂–cyclo-C₃H₅, –CH₂–cyclo-C₄H₇, –CH₂–cyclo-C₅H₉ or –CH₂–cyclo-C₆H₁₁;
- 15 **R²** represents –**A¹–A²–A³–E**, –**A¹–A²–A³–A⁴–E** or –**A¹–A²–A³–A⁴–A⁵–E**;

R³ represents

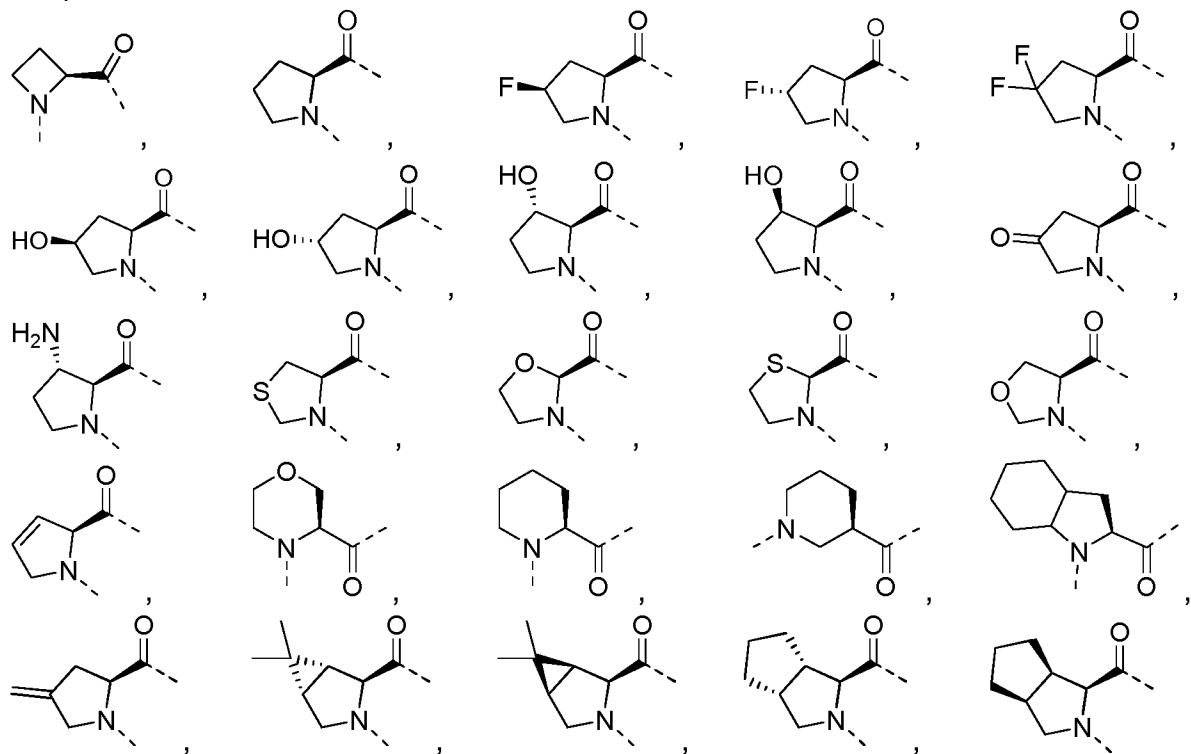


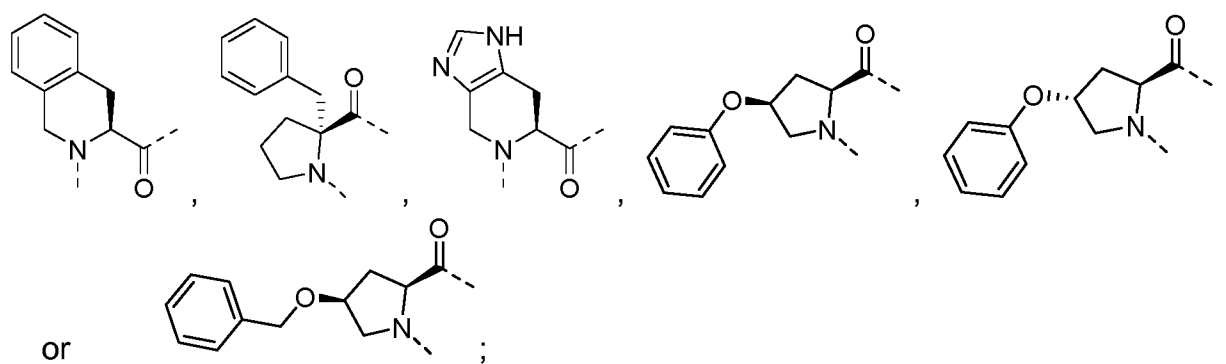


5 R^4 represents $-OR^*$, $-NH_2$, $-NHR^\#$ or $-NR^*R^\#$;

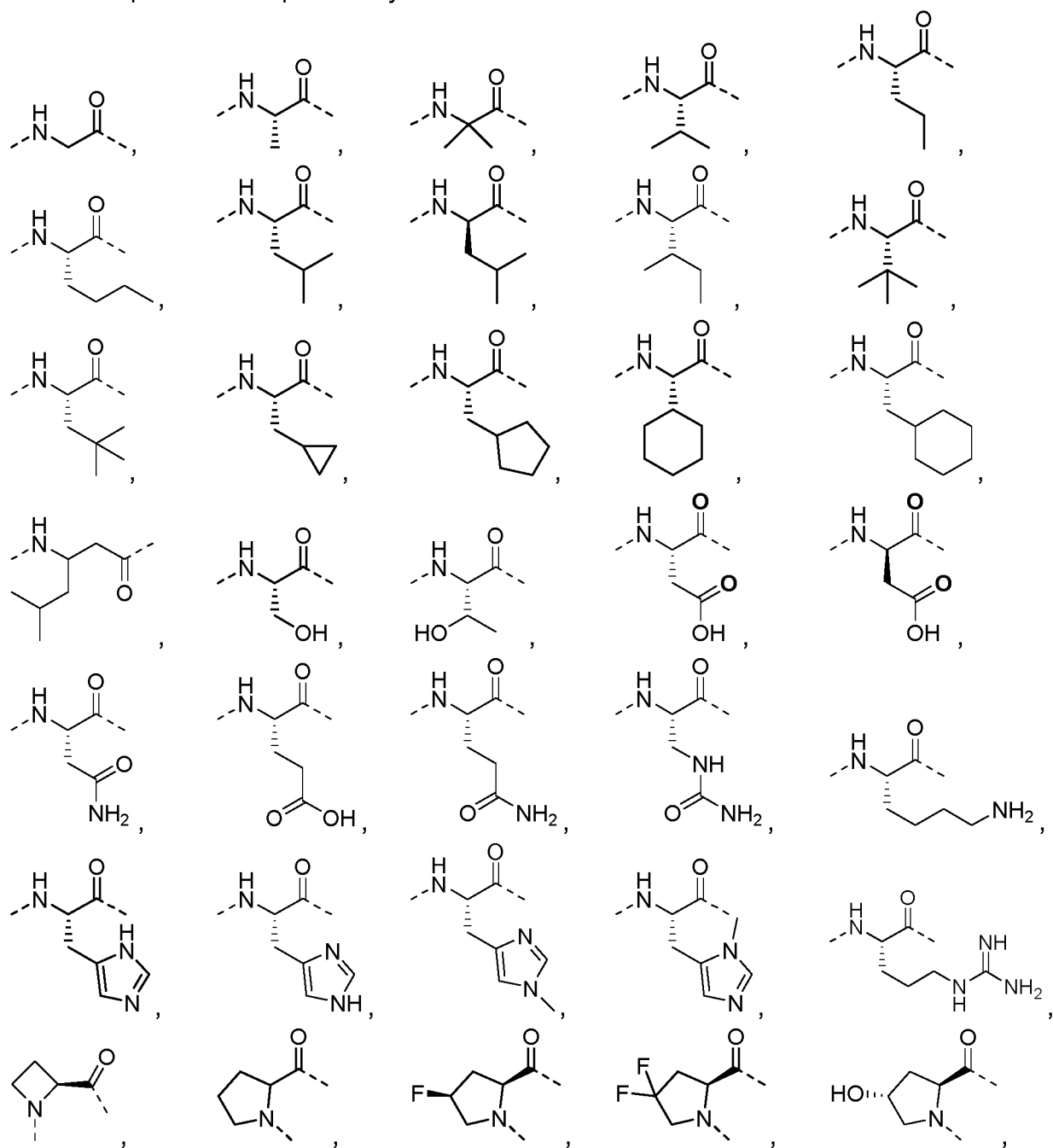
R^* and $R^\#$ represent independently of each other $-CH_3$, $-CH_2CH_3$, $-CH(CH_3)_2$, $-CH_2CH_2CH_3$, $-CH_2CH(CH_3)_2$, $-C(CH_3)_3$, $-cyclo-C_3H_5$, $-cyclo-C_4H_7$, $-cyclo-C_5H_9$, $-cyclo-C_6H_{11}$, $-CH_2-cyclo-C_3H_5$, $-CH_2-cyclo-C_4H_7$,
 10 $-CH_2-cyclo-C_5H_9$, $-CH_2-cyclo-C_6H_{11}$, $-CH_2-Ph$, $-CH_2OCH_3$, $-CH_2OCH_2CH_3$, $-CH_2CH_2OCH_3$, or $-CH_2CH_2SCH_3$;

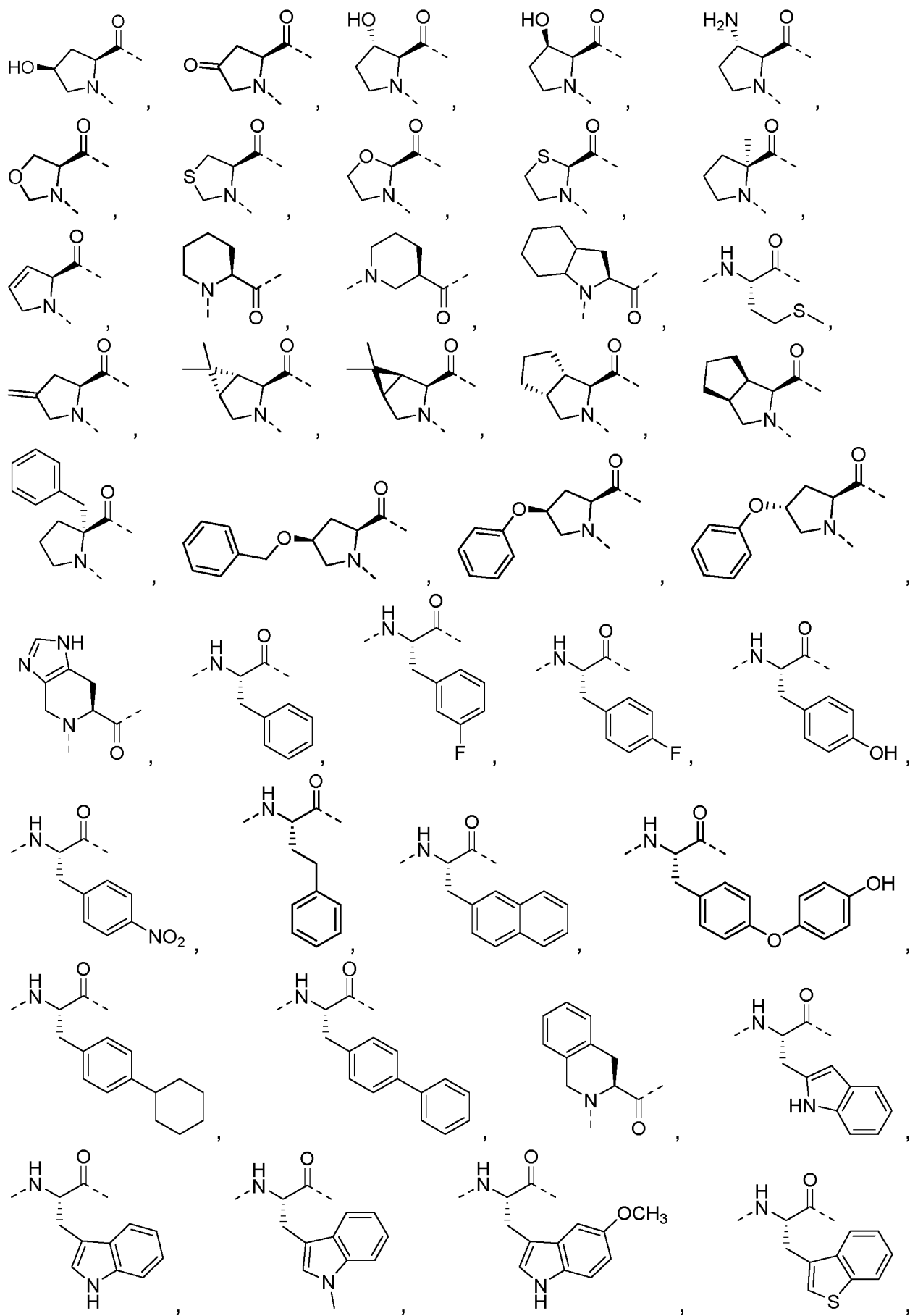
A^1 represents

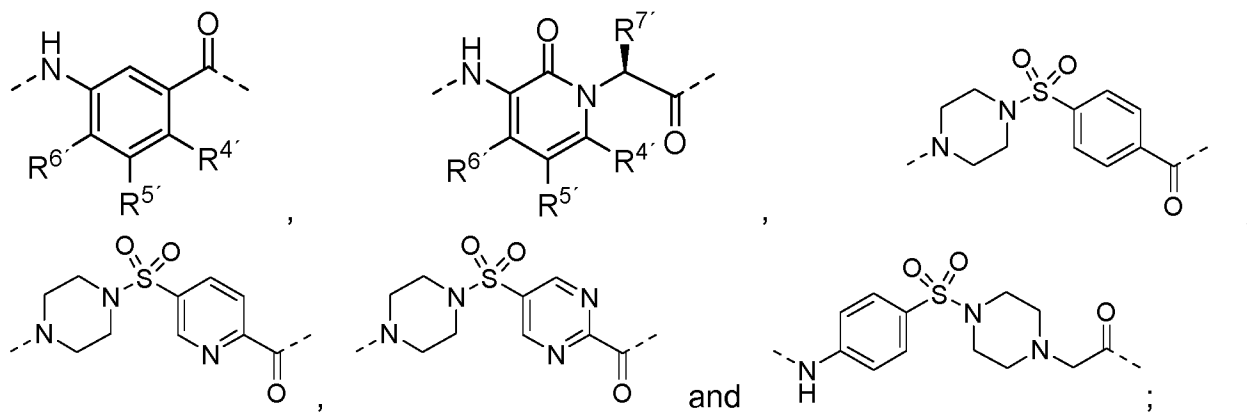




$A^2 - A^5$ represent independently of each other

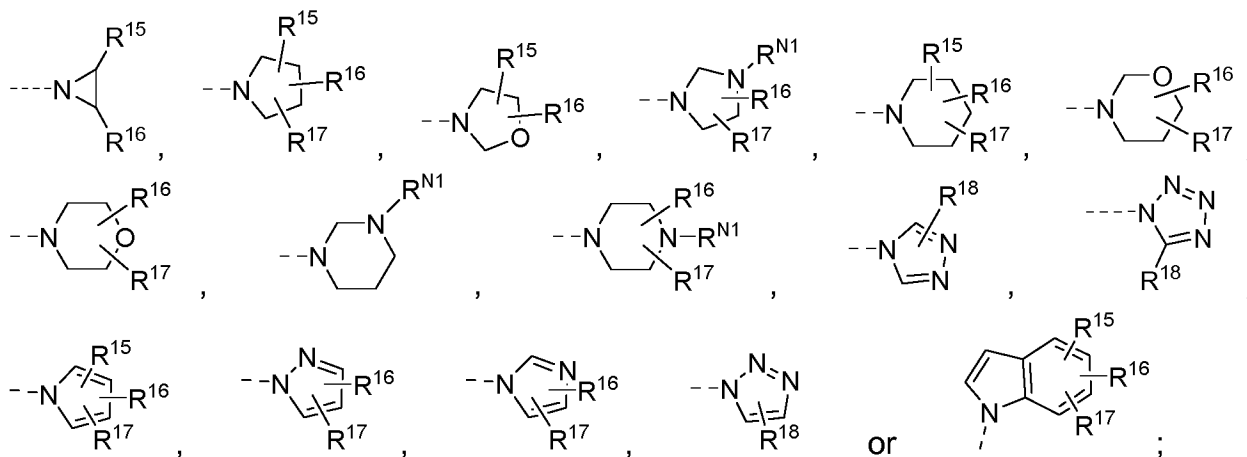




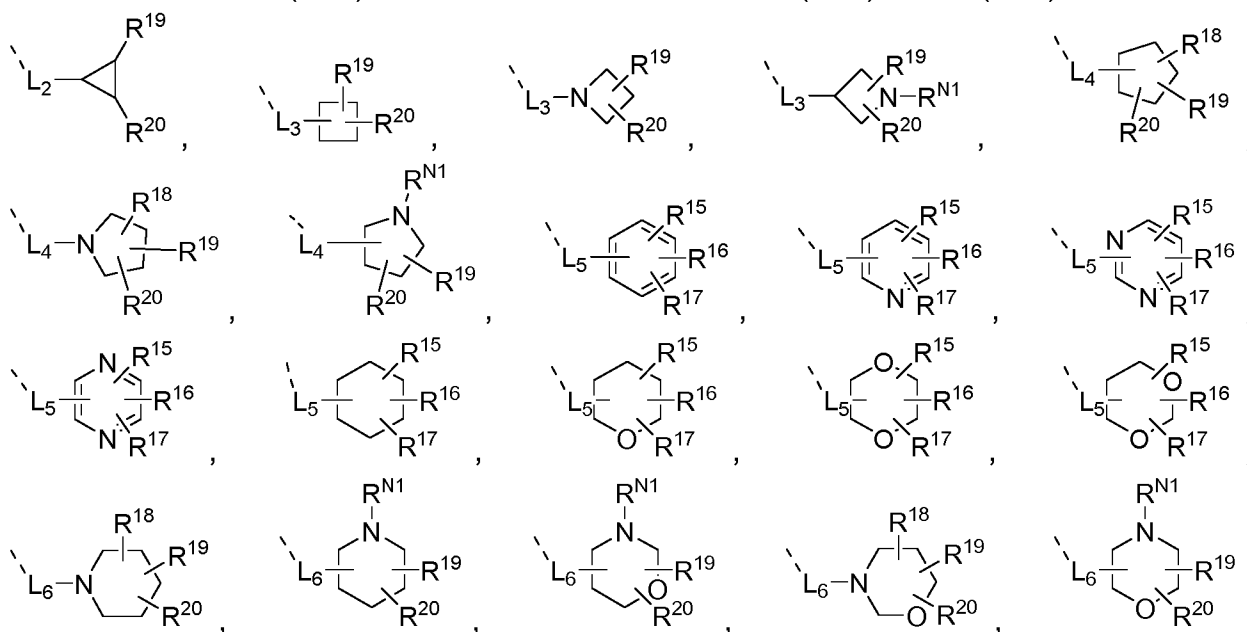


E represents: $-\text{OR}^{13}$, $-\text{NR}^{13}\text{R}^{14}$, $-\text{NHSO}_2\text{R}^{13}$, $-\text{O}-\text{L}_1-\text{R}^{13}$, $-\text{O}-\text{L}_1-\text{O}-\text{R}^{13}$,

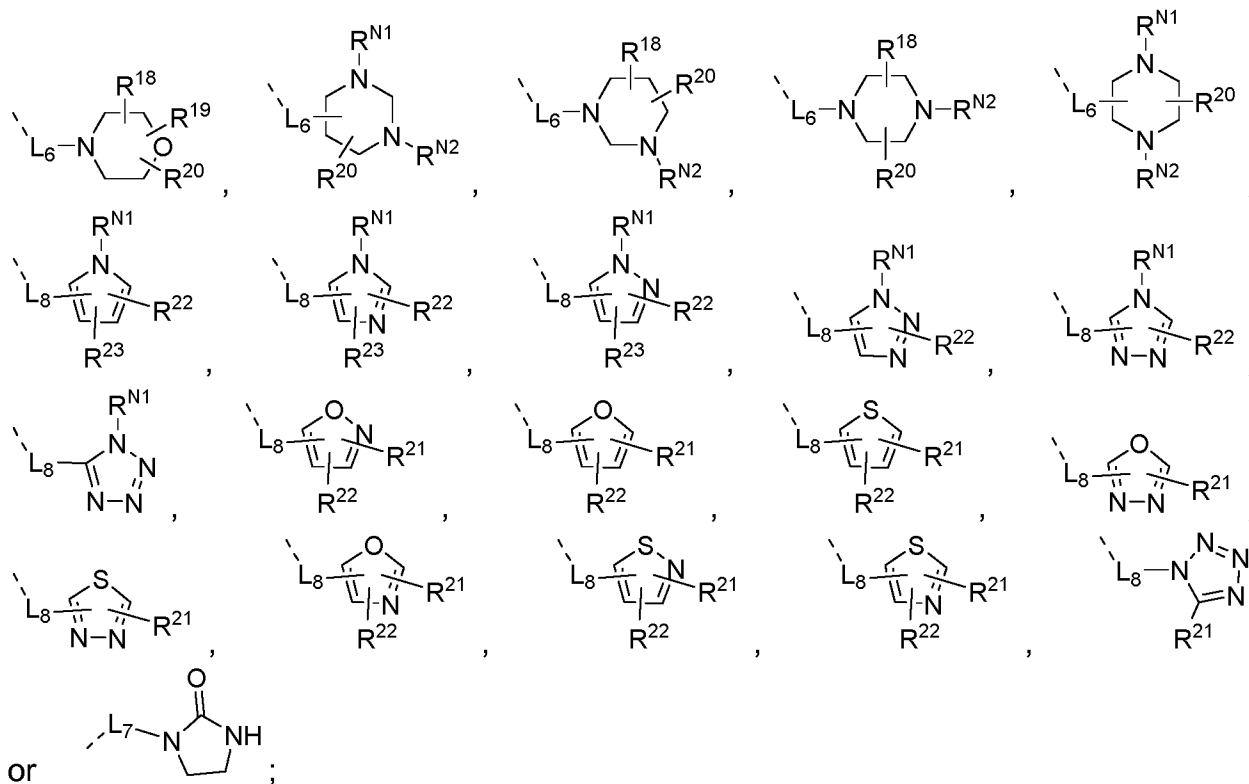
5 $-\text{NH}-\text{L}_1-\text{O}-\text{R}^{13}$, $-\text{NH}-\text{L}_1-\text{NR}^{13}\text{R}^{14}$, $-\text{NHSO}_2-\text{L}_1-\text{R}^{13}$, $-\text{N}(\text{R}^{15})\text{R}^{16}$, $-\text{N}(\text{R}^{15})\text{O}(\text{R}^{16})$,



10 R^{13} and R^{14} represent independently of each other: $-\text{H}$, $-\text{CH}_3$, $-\text{CH}_2\text{CH}_3$, $-\text{C}(\text{CH}_3)_3$, $-\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}(\text{CH}_3)_2$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}(\text{CH}_3)_2$, $-\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$,

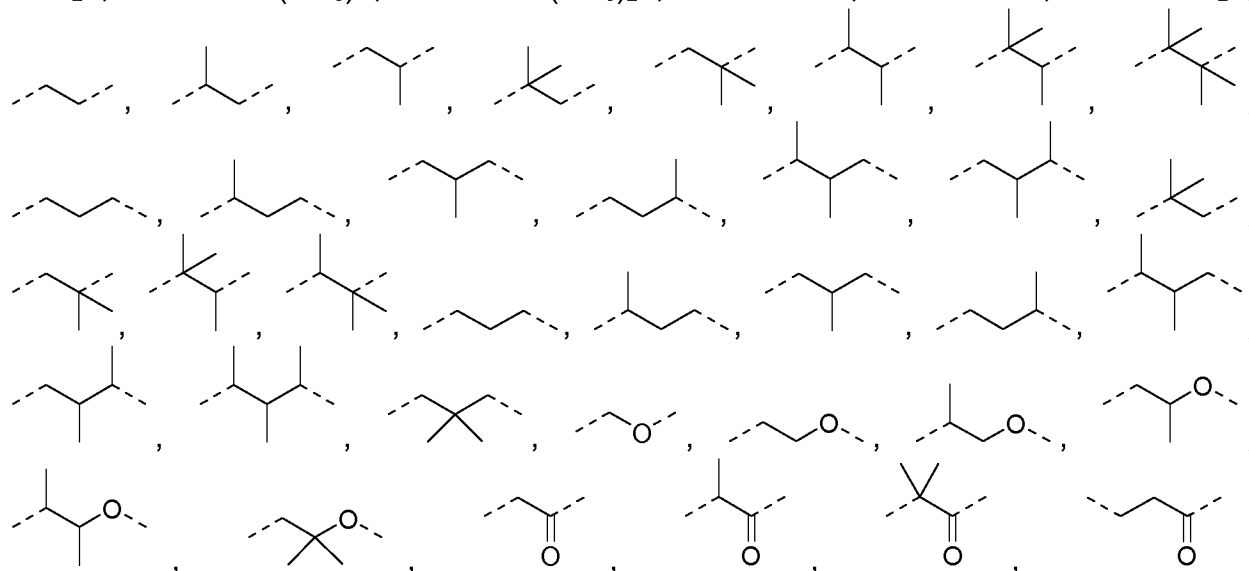


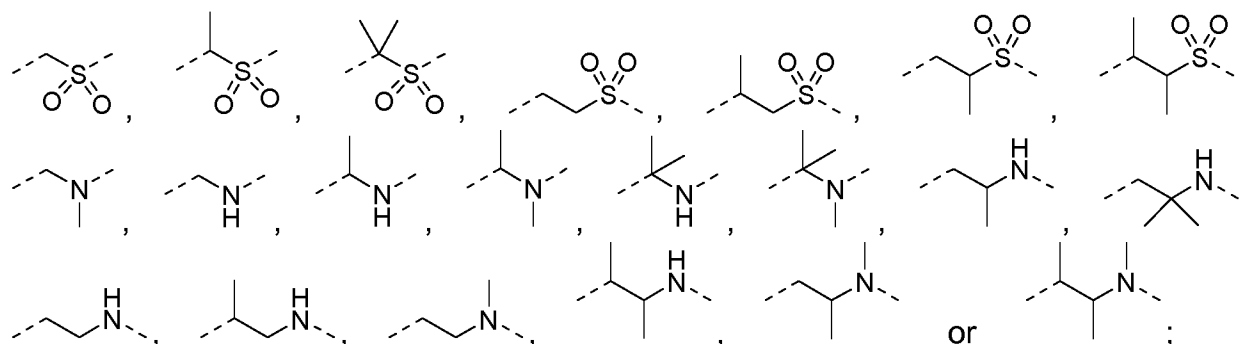
15 $-\text{L}_6-\text{N}(\text{R}^{18})\text{R}^{19}$, $-\text{L}_6-\text{N}(\text{R}^{18})\text{O}(\text{R}^{19})$, $-\text{L}_6-\text{N}(\text{R}^{18})\text{O}(\text{R}^{20})$, $-\text{L}_6-\text{N}(\text{R}^{18})\text{O}(\text{R}^{20})$,



R^N , R^{N1} and R^{N2} represents independently of each other $-H$, $-CH_3$, $-C_2H_5$, $-C_3H_7$, $-CH(CH_3)_2$, $-C_4H_9$, $-CH_2-CH(CH_3)_2$, $-CH(CH_3)-C_2H_5$, $-C(CH_3)_3$, $-cyclo-C_3H_5$, $-CH_2-cyclo-C_3H_5$, $-CH_2F$, $-CHF_2$, $-CF_3$, $-CH_2Cl$, $-CH_2Br$, $-CH_2I$, $-CH_2-CH_2F$, $-CH_2-CHF_2$, $-CH_2-CF_3$, $-CH_2-CH_2Cl$, $-CH_2-CH_2Br$, $-CH_2-CH_2I$, $-CH_2-CH=CH_2$, $-CH_2-C\equiv CH$, $-CHO$, $-COCH_3$, $-COC_2H_5$, $-COC_3H_7$, $-COCH(CH_3)_2$, $-COC(CH_3)_3$, $-COOCH_3$, $-COOC_2H_5$, $-COOC_3H_7$, $-COOCH(CH_3)_2$, or $-COOC(CH_3)_3$;

$L^1 - L^8$ represents independently of each other a covalent bond, $-CH_2-$, $-CH(CH_3)-$, $-CH(CH_3)_2-$, $-CO-$, $-SO-$, $-SO_2-$,

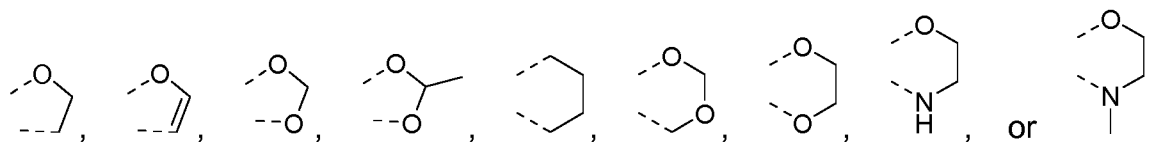




- 5 $R^5 - R^{12}$, $R^{4'} - R^{7'}$, and $R^{15} - R^{23}$ represents independently of each other
 $-H$, $-F$, $-Cl$, $-Br$, $-I$, $-OH$, $-CN$, $-NO_2$, $-CH_3$, $-C_2H_5$, $-C_3H_7$,
 $-CH(CH_3)_2$, $-C_4H_9$, $-CH_2-CH(CH_3)_2$, $-CH(CH_3)-C_2H_5$, $-C(CH_3)_3$,
 $-cyclo-C_3H_5$, $-CH_2-cyclo-C_3H_5$, $-CH_2F$, $-CHF_2$, $-CF_3$, $-CH_2Cl$, $-CH_2Br$,
 $-CH_2I$, $-CH_2-CH_2F$, $-CH_2-CHF_2$, $-CH_2-CF_3$, $-CH_2-CH_2Cl$, $-CH_2-CH_2Br$,
10 $-CH_2-CH_2I$, $-OCH_3$, $-OC_2H_5$, $-OC_3H_7$, $-OCH(CH_3)_2$, $-OC(CH_3)_3$,
 $-OC_4H_9$, $-OCHF_2$, $-OCF_3$, $-OCH_2CF_3$, $-OC_2F_5$, $-OCH_2OCH_3$,
 $-O-cyclo-C_3H_5$, $-OCH_2-cyclo-C_3H_5$, $-O-C_2H_4-cyclo-C_3H_5$, $-CHO$, $-COCH_3$,
 $-COCF_3$, $-COC_2H_5$, $-COC_3H_7$, $-COCH(CH_3)_2$, $-COC(CH_3)_3$,
 $-COOH$, $-COOCH_3$, $-COOC_2H_5$, $-COOC_3H_7$, $-COOCH(CH_3)_2$, $-COOC(CH_3)_3$,
15 $-OOC-CH_3$, $-OOC-CF_3$, $-OOC-C_2H_5$, $-OOC-C_3H_7$, $-OOC-CH(CH_3)_2$,
 $-OOC-C(CH_3)_3$, $-NH_2$, $-NHCH_3$, $-NHC_2H_5$, $-NHC_3H_7$, $-NHCH(CH_3)_2$,
 $-NHC(CH_3)_3$, $-N(CH_3)_2$, $-N(C_2H_5)_2$, $-N(C_3H_7)_2$, $-N[CH(CH_3)_2]_2$, $-N[C(CH_3)_3]_2$,
 $-NHCOCH_3$, $-NHCOCF_3$, $-NHCOC_2H_5$, $-NHCOC_3H_7$, $-NHCOCH(CH_3)_2$,
 $-NHCOC(CH_3)_3$, $-CONH_2$, $-CONHCH_3$, $-CONHC_2H_5$, $-CONHC_3H_7$,
20 $-CONHCH(CH_3)_2$, $-CONH-cyclo-C_3H_5$, $-CONHC(CH_3)_3$, $-CON(CH_3)_2$,
 $-CON(C_2H_5)_2$, $-CON(C_3H_7)_2$, $-CON[CH(CH_3)_2]_2$, $-CON[C(CH_3)_3]_2$, $-SO_2NH_2$,
 $-SO_2NHCH_3$, $-SO_2NHC_2H_5$, $-SO_2NHC_3H_7$, $-SO_2NHCH(CH_3)_2$,
 $-SO_2NH-cyclo-C_3H_5$, $-SO_2NHC(CH_3)_3$, $-SO_2N(CH_3)_2$, $-SO_2N(C_2H_5)_2$,
 $-SO_2N(C_3H_7)_2$, $-SO_2N[CH(CH_3)_2]_2$, $-SO_2N[C(CH_3)_3]_2$, $-NHSO_2CH_3$,
25 $-NHSO_2CF_3$, $-NHSO_2C_2H_5$, $-NHSO_2C_3H_7$, $-NHSO_2CH(CH_3)_2$,
 $-NHSO_2C(CH_3)_3$, $-CH=CH_2$, $-CH_2-CH=CH_2$, $-C(CH_3)=CH_2$, $-CH=CH-CH_3$,
 $-C\equiv CH$, $-C\equiv C-CH_3$, $-CH_2-C\equiv CH$, $-Ph$, $-O-Ph$, or $-O-CH_2-Ph$,

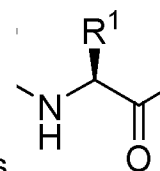
30

or R^7 and R^8 or R^8 and R^9 form together one of the following ring moieties;



or E/Z-isomer, regiomers, diastereomers, enantiomers, a mixture of E/Z-isomers, a mixture of regiomers, a mixture of diastereomers, a mixture of enantiomers, prodrug, solvate, hydrate, or pharmaceutically acceptable salts thereof.

Surprisingly it was found that good factor XIII or FXIIIa inhibitors, both terms are used synonymously herein, have to be irreversible inhibitors with certain peptidic or peptidomimetic backbones. Reversible inhibitors have been proven to be less efficient in comparison to the irreversible inhibitors disclosed herein which in addition are very specific for FXIIIa and consequently show a minimum of side effects in case certain structural requirements are fulfilled. Further, irreversible acting inhibitors avoid the potential rebound of FXIII activity. One specific requirement is that the peptidic or peptidomimetic backbone has to have a certain length of at least 5 amino acids including amino acid derivatives and peptidomimetics as disclosed herein (cf. Ref. 6 and Ref. 7). Consequently, is $R^2 = -A^1-A^2-A^3-E$ a pentapeptide results and with $R^2 = -A^1-A^2-A^3-A^4-E$ a hexapeptide and with $R^2 = -A^1-A^2-A^3-A^4-A^5-E$ a heptapeptide is obtained. Preferred are hexapeptides with $R^2 = -A^1-A^2-A^3-A^4-E$ as well as heptapeptides with $-A^1-A^2-A^3-A^4-A^5-E$. The amino acid bearing the warhead is the first amino acid, second is the amino acid with substituent R^1 , third amino acid is A^1 and so on. Longer peptides with more than 7 amino acids including amino acid derivatives and peptidomimetics are still good to moderate FXIIIa inhibitors in case only the inhibitory activity is considered, but of less therapeutical value because the inventors found that these longer peptides are degraded in blood within minutes and consequently do not have a sufficient half-life or stability in blood in order to become a therapeutically useful FXIIIa inhibitor (cf. Ref. 17 and Ref. 18). Consequently, the FXIIIa inhibitors disclosed herein are pentapeptides, hexapeptides and heptapeptides containing A^1 as being a conformational constraint amino acid, i.e. (S)-proline (L-proline) or a cyclic proline derivative as disclosed herein having the same configuration, i.e. L-proline derivative and A^2 as amino acid with an alkyl or cycloalkyl side chain. In addition to this required minimum length of the peptidic or peptidomimetic backbone the two amino acids attached c-terminal to the amino acid with the Michael system are very important. In general formula (I) the amino acid



attached c-terminal to the Michael system bearing amino acid is drawn as
wherein the substituent R^1 is limited to a small group of alkyl and cycloalkyl residues

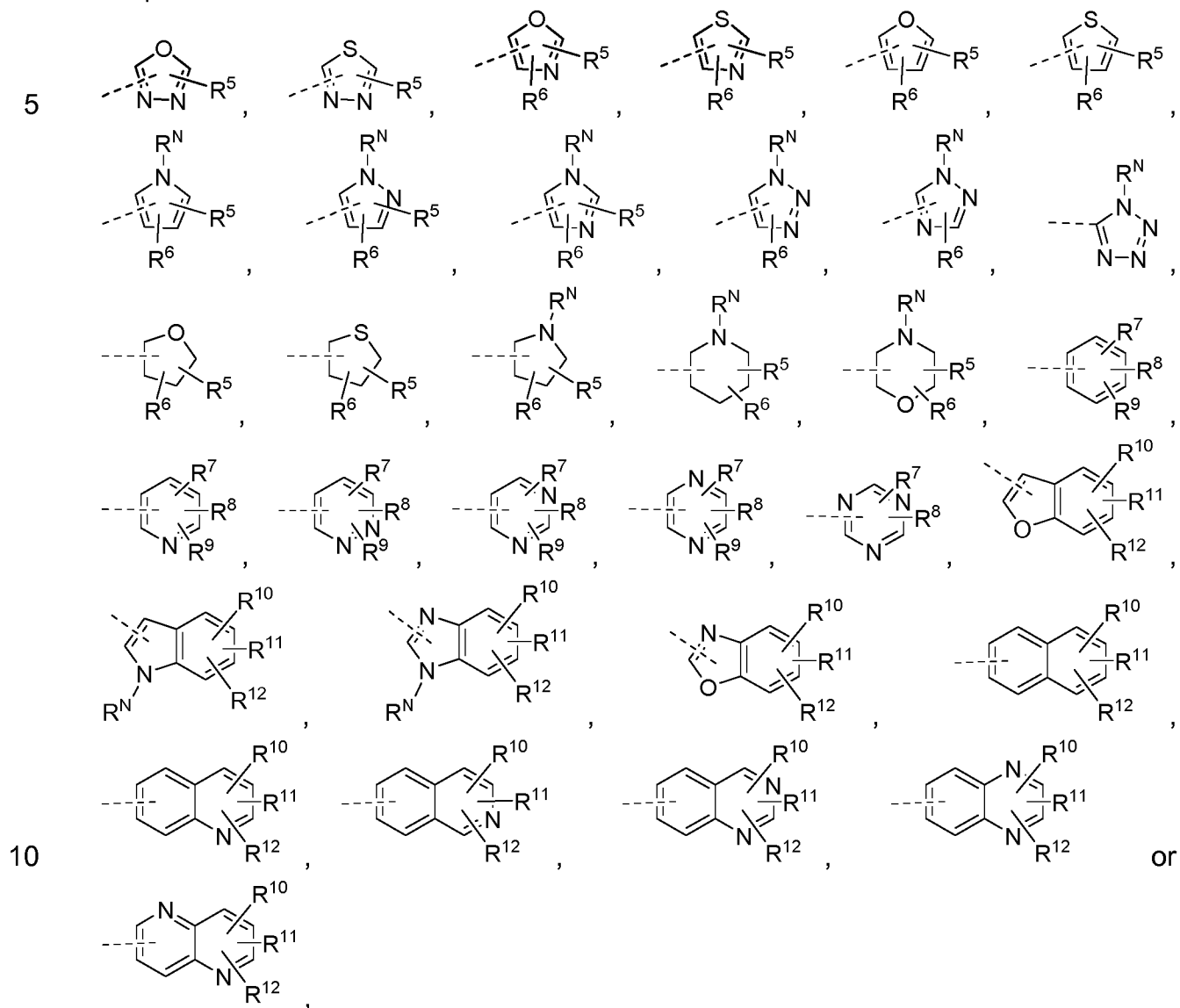
and methionine. Ionic or polar groups (such as side chains of Glu or Gln) or aromatic groups or quite bulky groups with more than 7, preferably with more than 6 carbon atoms are found to decrease the inhibitor activity drastically (cf. Ref. 11, Ref. 20 and Ref. 21). Also the stereochemistry of the substituent R^1 is important as shown in
5 general formula (I). Especially important is the amino acid connected to the amino acid with R^1 which is the second amino acid C-terminal to the amino acid with the Michael acceptor system (warhead). This amino acid or amino acid derivative is referred to herein as A^1 . A^1 must be a cyclic amino acid, namely a proline or proline derivative as disclosed herein. The stereochemistry of A^1 is also very important and
10 must be (S) or L in case of proline and in case of a proline derivative the same spatial orientation as (S)-proline is required which is most preferably the L configuration (cf. Ref. 4). Although the stereogenic center of the piperidine ring of A^1 in reference example 4 has (S) configuration, it has in comparison to the proline moiety the other spatial orientation and it was found to be inactive as factor XIII inhibitor. Moreover
15 stereogenic center in the proline moiety A^1 must not have a further substituent, i.e. one hydrogen atom must be present at the stereogenic center of the proline moiety (cf. Ref. 5). In the reference example 5 a methyl group is present at the stereogenic center and that makes the compound completely inactive as factor XIII inhibitor. Moreover it has to be stressed that a pyridinone moiety is not a proline derivative and a pyridinone moiety as A^1 leads also to compounds inactive as factor XIII inhibitors (cf. Ref. 1 – Ref.
20 3). Concerning A^1 the configuration, which is the L-configuration is very important and the fact that the chiral center must be a tertiary carbon atom (i.e. no fourth substituent). Moreover, to the N-terminus a cyclic group should be attached through a carbonyl function forming an amide bond. No further amino acid except an (oxo)-proline should
25 be attached to the N-terminus. The N-terminal cyclic group is preferably six-membered cyclic group, more preferably an aromatic group, more preferably an aromatic six-membered carbocyclic or N-heterocyclic group such as phenyl and pyridyl. Therefore there is a tight structural relationship (SAR: Structure – Activity – Relationship) between the inhibitory activity in regard to FXIIIa and the structural
30 features of the inhibitors disclosed herein. Such a SAR was not evident from the state of the art and is somehow surprising.

Preferably, the present invention relates to a compound of the general formula (I), wherein

35 R^1 represents $-C(CH_3)_3$, $-\text{cyclo-C}_3\text{H}_5$, $-\text{cyclo-C}_4\text{H}_7$, $-\text{cyclo-C}_5\text{H}_9$, $-\text{cyclo-C}_6\text{H}_{11}$, $-\text{CH}_2\text{-CH(CH}_3)_2$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{-C(CH}_3)_3$, $-\text{CH}_2\text{CH}_2\text{SCH}_3$, $-\text{CH}_2\text{-cyclo-C}_3\text{H}_5$, $-\text{CH}_2\text{-cyclo-C}_4\text{H}_7$, $-\text{CH}_2\text{-cyclo-C}_5\text{H}_9$ or $-\text{CH}_2\text{-cyclo-C}_6\text{H}_{11}$;

R^2 represents $-A^1-A^2-A^3-E$, $-A^1-A^2-A^3-A^4-E$ or $-A^1-A^2-A^3-A^4-A^5-E$;

R^3 represents

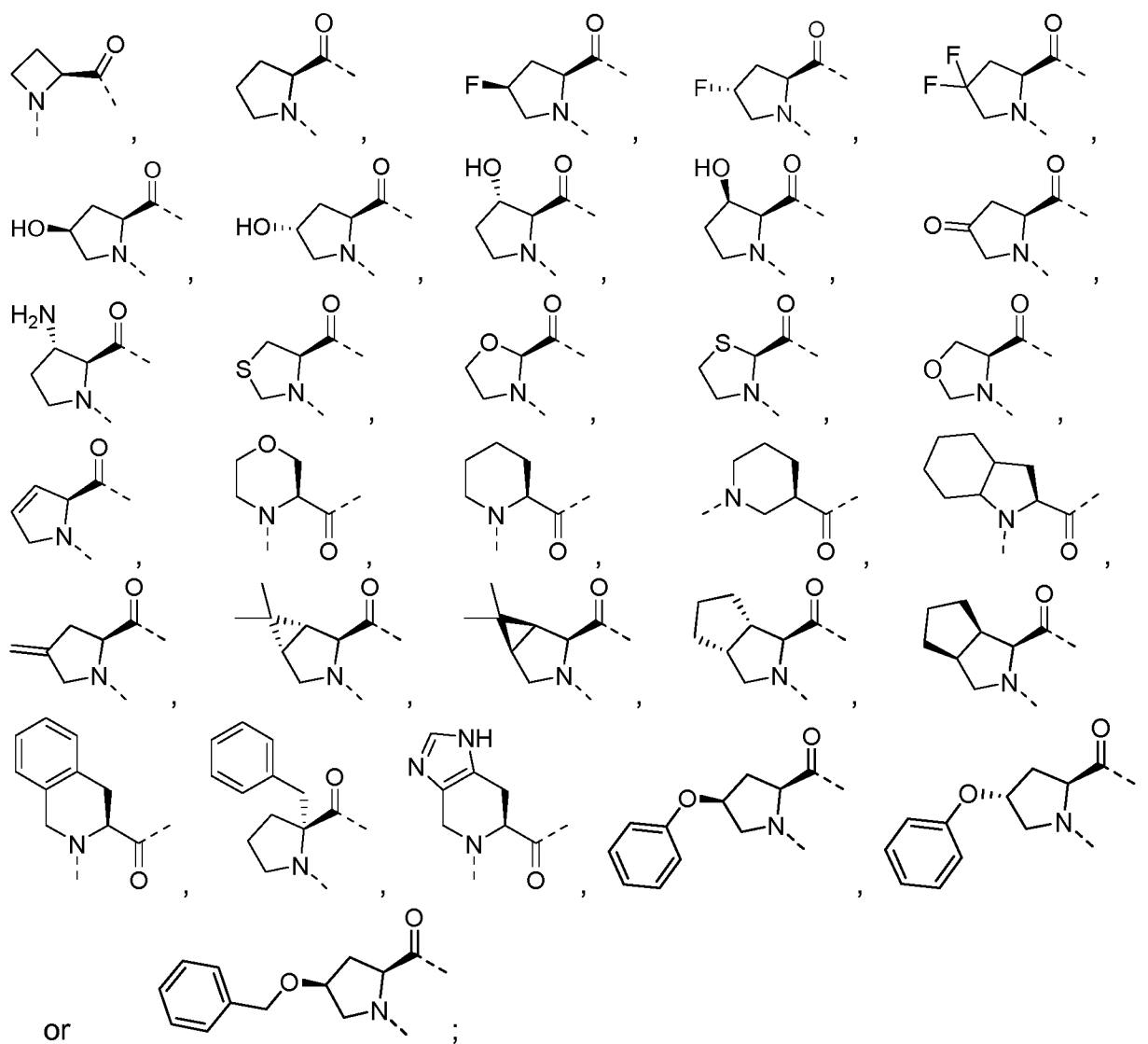


R^4 represents $-OR^*$, $-NH_2$, $-NHR^\#$ or $-NR^*R^\#$;

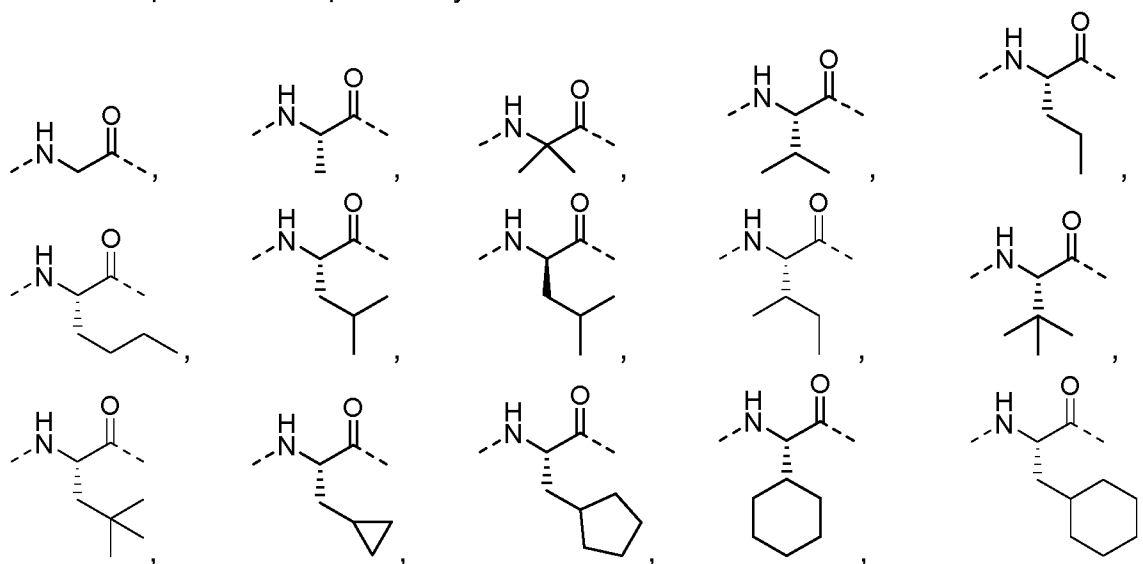
15 R^* and $R^\#$ represent independently of each other $-CH_3$, $-CH_2CH_3$, $-CH(CH_3)_2$, $-CH_2CH_2CH_3$, $-CH_2CH(CH_3)_2$, $-C(CH_3)_3$, $-cyclo-C_3H_5$, $-cyclo-C_4H_7$, $-cyclo-C_5H_9$, $-cyclo-C_6H_{11}$, $-CH_2-cyclo-C_3H_5$, $-CH_2-cyclo-C_4H_7$, $-CH_2-cyclo-C_5H_9$, $-CH_2-cyclo-C_6H_{11}$, $-CH_2-Ph$, $-CH_2OCH_3$, $-CH_2OCH_2CH_3$, $-CH_2CH_2OCH_3$;

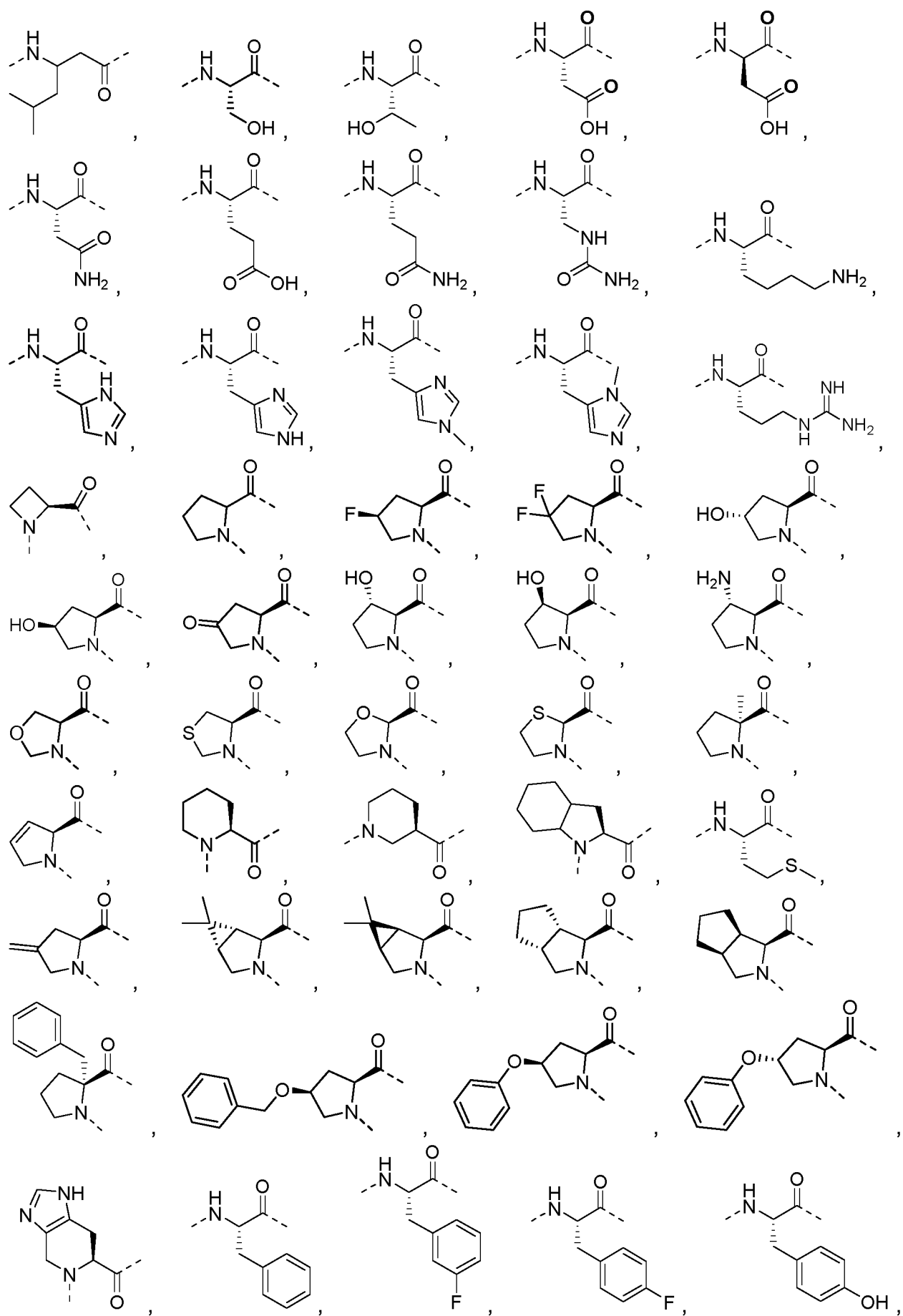
20

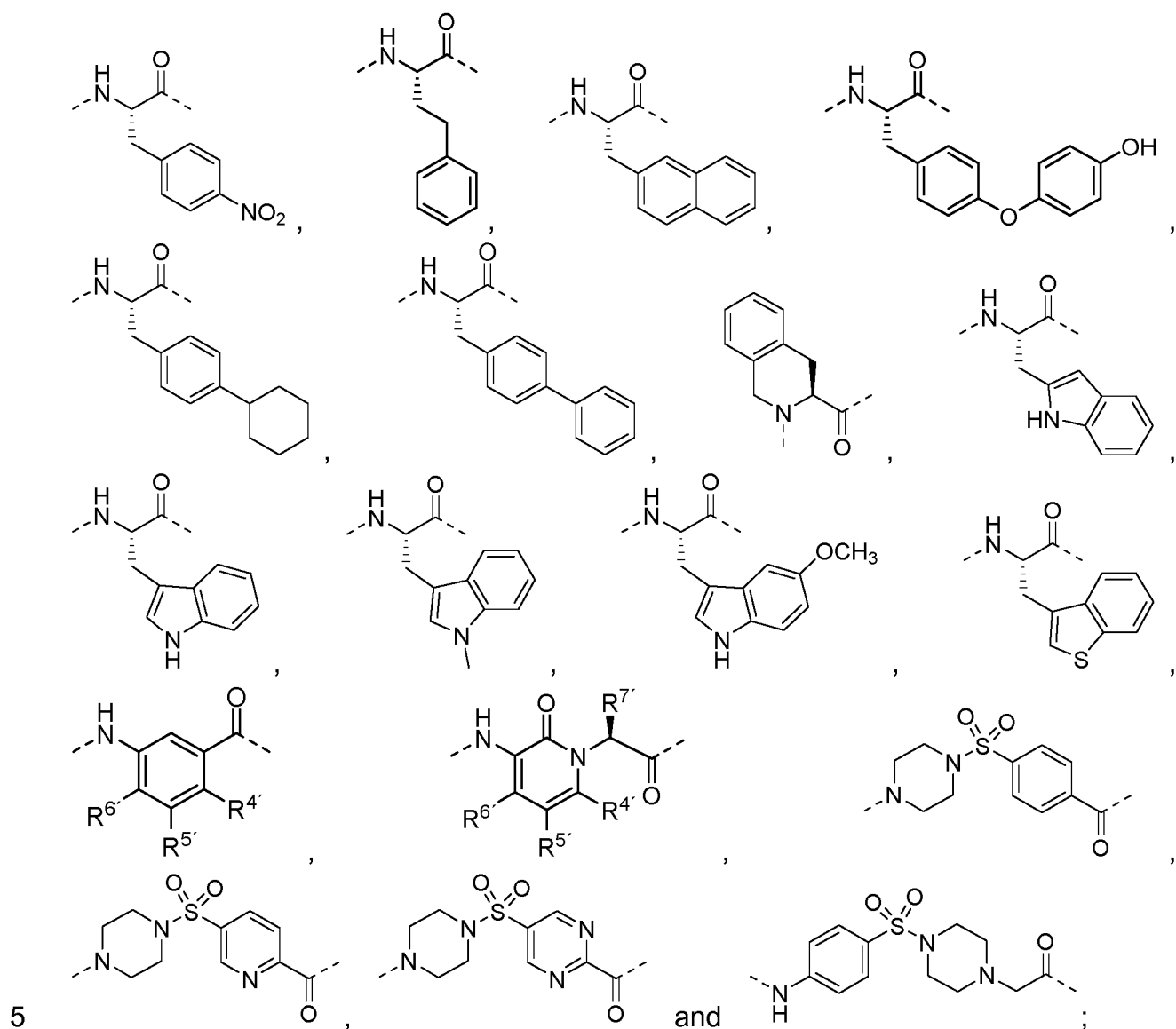
A^1 represents



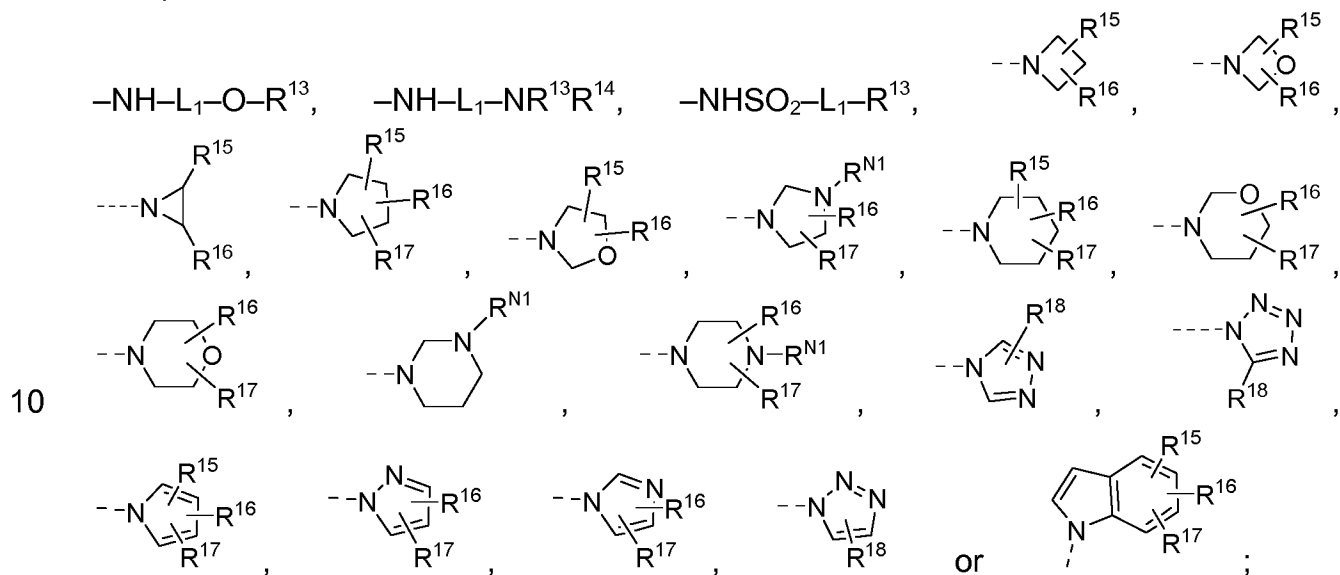
$A^2 - A^5$ represent independently of each other



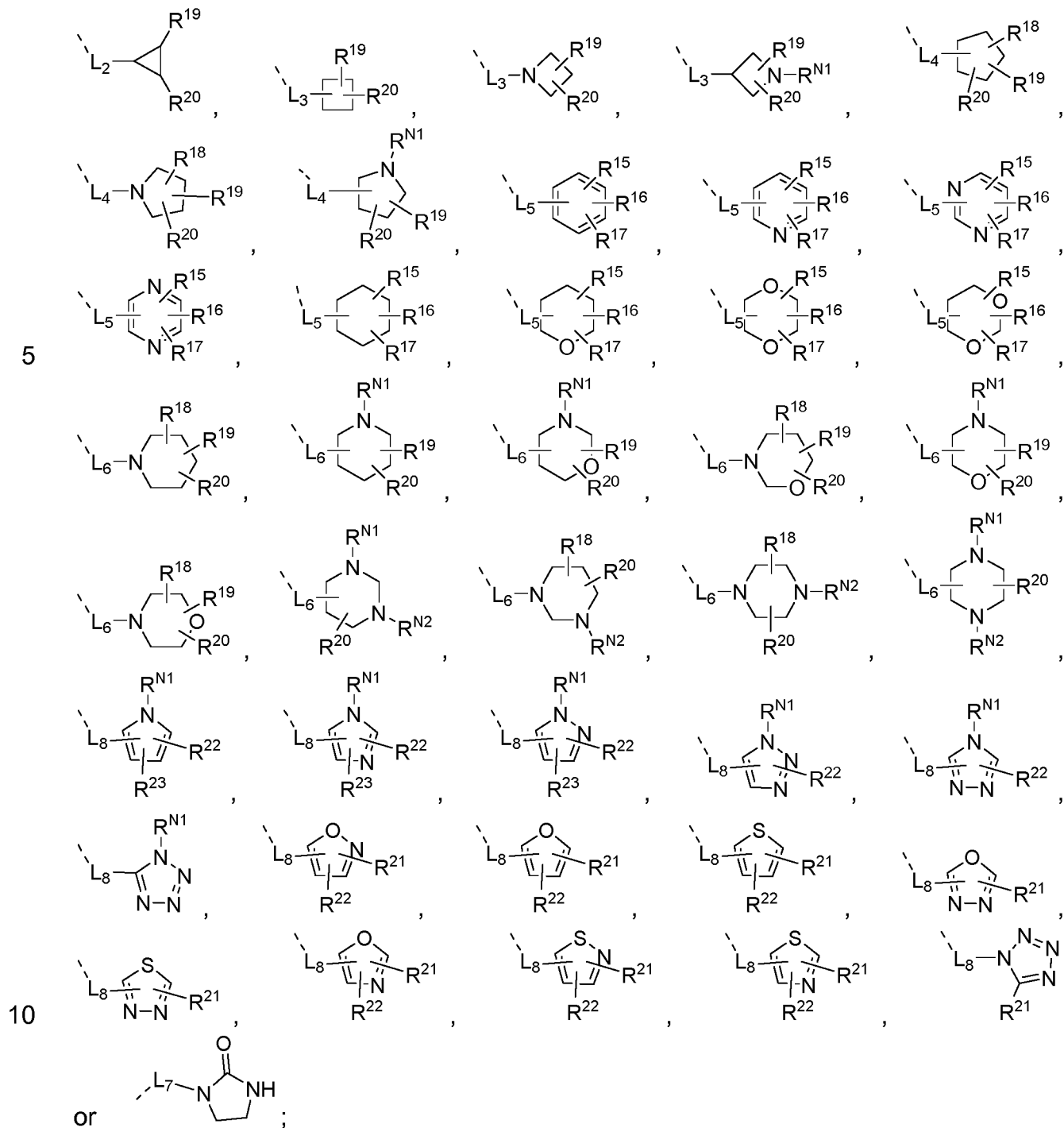




E represents: $-\text{OR}^{13}$, $-\text{NR}^{13}\text{R}^{14}$, $-\text{NHSO}_2\text{R}^{13}$, $-\text{O}-\text{L}_1-\text{R}^{13}$, $-\text{O}-\text{L}_1-\text{O}-\text{R}^{13}$,

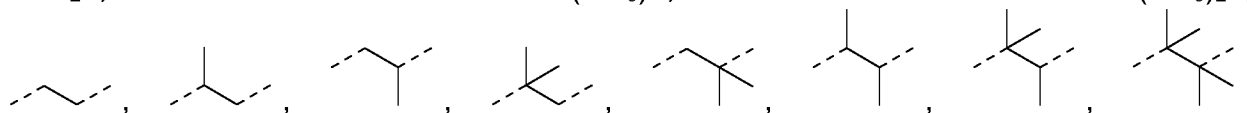


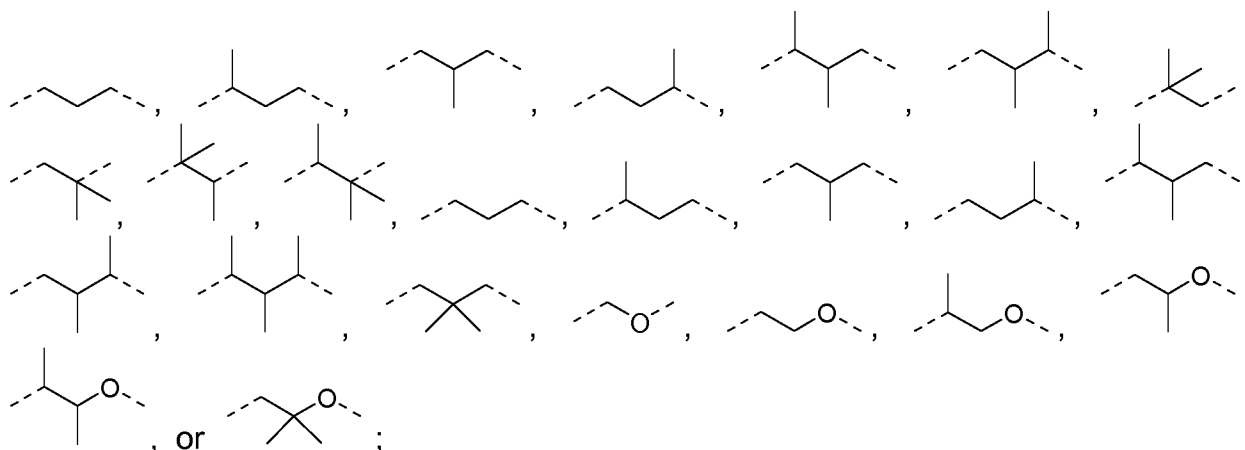
R^{13} and R^{14} represent independently of each other: $-H$, $-CH_3$, $-CH_2CH_3$, $-C(CH_3)_3$, $-CH_2CH_2CH_3$, $-CH(CH_3)_2$, $-CH_2CH_2CH_2CH_3$, $-CH_2CH(CH_3)_2$, $-CH(CH_3)CH_2CH_3$,



R^N , R^{N1} and R^{N2} represent $-H$;

15 $L^1 - L^8$ represents independently of each other a covalent bond, $-CH_2-$, $-CH(CH_3)-$, $-CH(CH_3)_2-$,





5

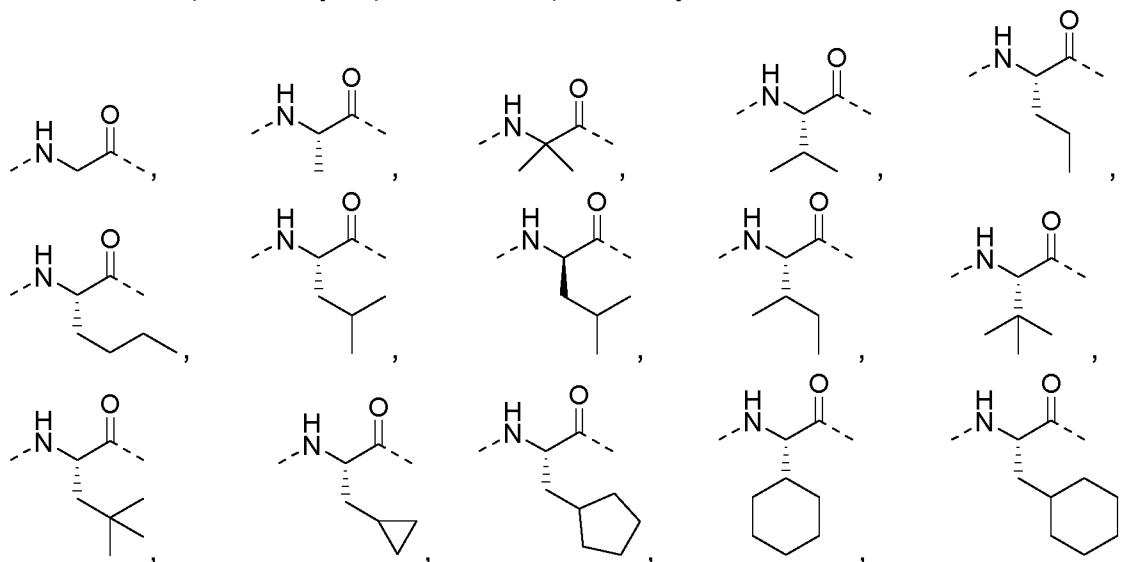
$R^{4'}$, $R^{5'}$, $R^{6'}$ and $R^{7'}$ represent $-H$;

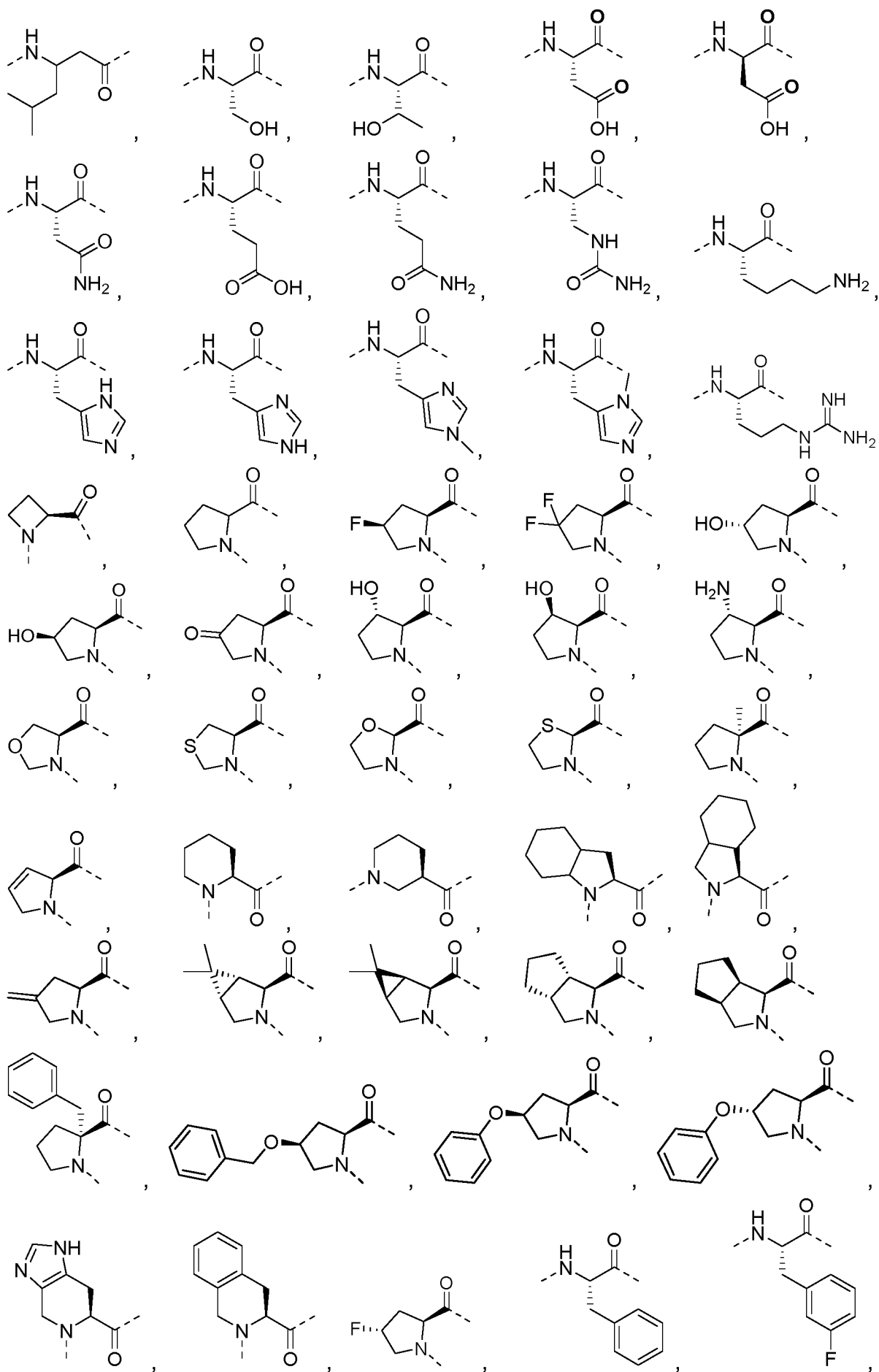
$R^5 - R^{12}$, and $R^{15} - R^{23}$ represents independently of each other $-H$, $-F$, $-Cl$, $-Br$, $-OH$, $-NO_2$, $-CH_3$, $-C_2H_5$, $-C_3H_7$, $-CH(CH_3)_2$, $-C_4H_9$, $-CH_2-CH(CH_3)_2$, $-C(CH_3)_3$, $-cyclo-C_3H_5$, $-CH_2-cyclo-C_3H_5$, $-OCH_3$, $-OC_2H_5$, $-OC_3H_7$, $-OCH(CH_3)_2$, $-OC(CH_3)_3$, $-O-cyclo-C_3H_5$, $-OCH_2-cyclo-C_3H_5$, $-O-C_2H_4-cyclo-C_3H_5$, $-COOH$, $-COOCH_3$, $-COOC_2H_5$, $-COOC_3H_7$, $-COOCH(CH_3)_2$, $-COOC(CH_3)_3$, $-NH_2$, $-NHCH_3$, $-NHC_2H_5$, $-NHC_3H_7$, $-NHCH(CH_3)_2$, $-NHC(CH_3)_3$, $-N(CH_3)_2$, $-N(C_2H_5)_2$, or $-N(C_3H_7)_2-CONH_2$;

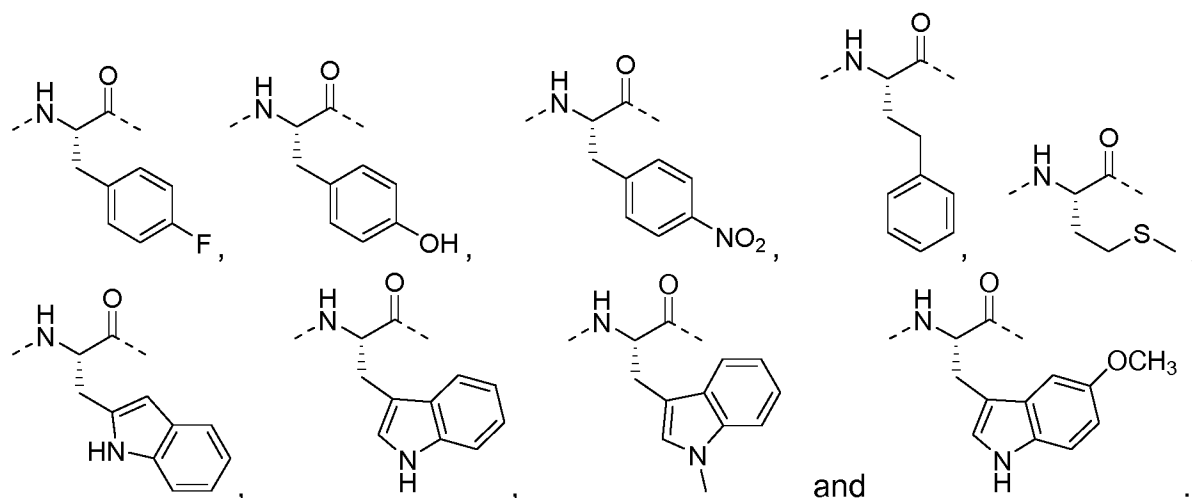
15

as well as E/Z-isomer, diastereomer, enantiomer, a mixture of E/Z-isomers, a mixture of diastereomers, a mixture of enantiomers, prodrugs, solvates, hydrates, or pharmaceutically acceptable salts thereof.

For all general formula disclosed herein unless otherwise defined, the amino acid residues $A^2 - A^5$ preferably represent independently of each other



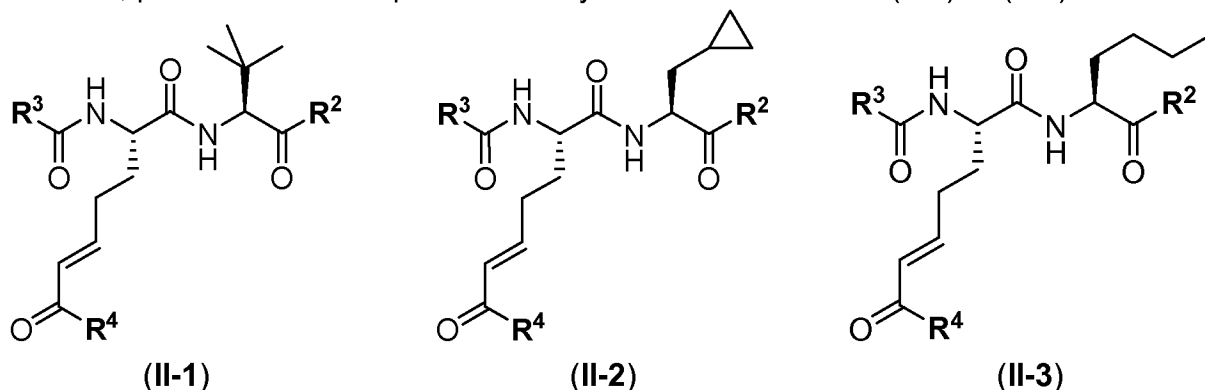




The oligopeptide residues $-A^1-A^2-A^3-E$, $-A^1-A^2-A^3-A^4-E$ and $-A^1-A^2-A^3-A^4-A^5-E$ represent a tri-, tetra- and pentapeptide, wherein the amino acids A^1 , A^2 , A^3 , A^4 , and A^5 are connected through an amide bond to each other and the N-terminus of the amino acid A^1 is attached to the C-terminus of the amino acid bearing the R^1 side chain which is next to the amino acid bearing the Michael system. Therefore, the direction the amino acids are attached to each other is well defined.

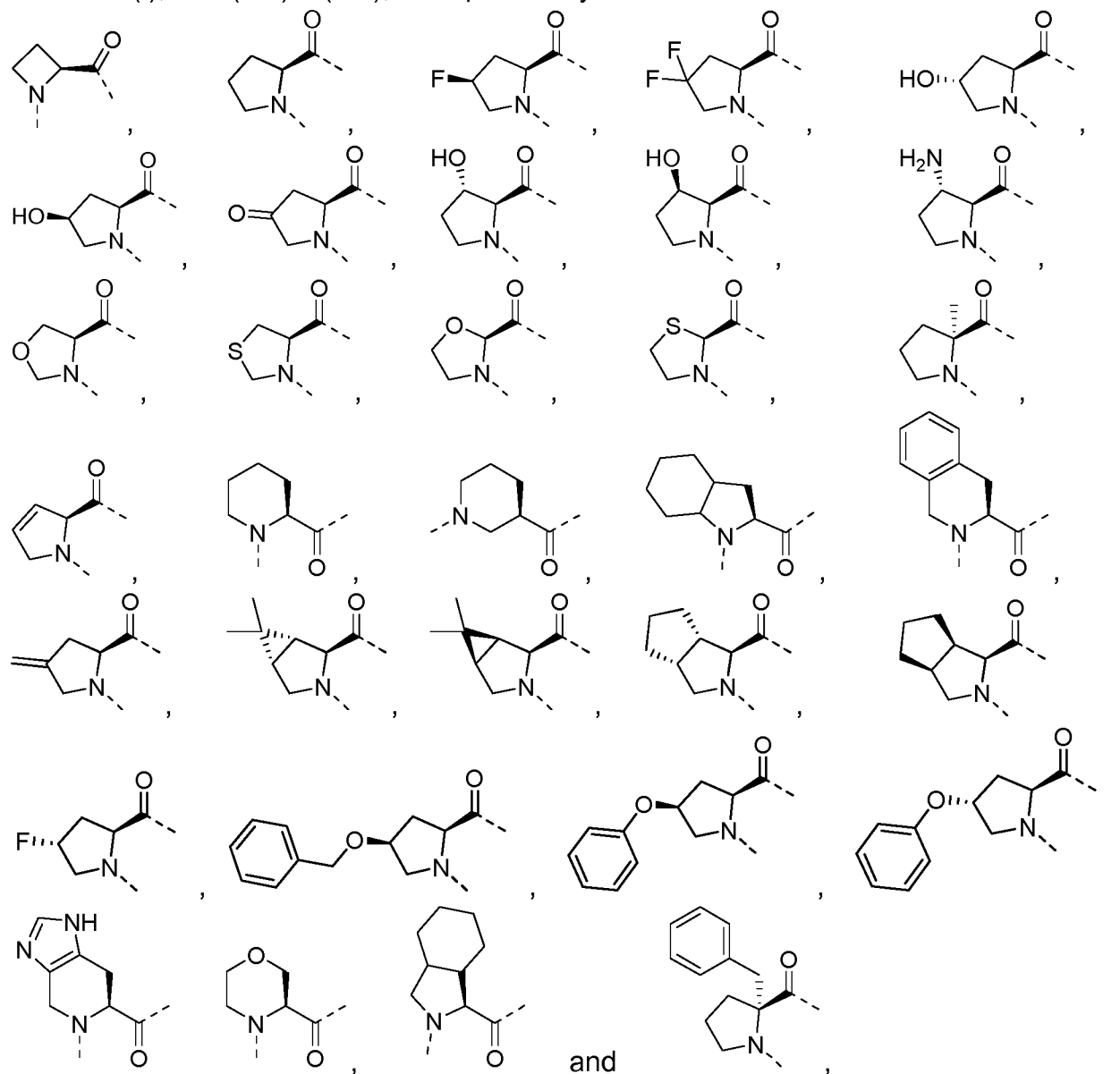
Preferably, in any general formula disclosed herein, R^1 represents $-C(CH_3)_3$, $-\text{cyclo-C}_3H_5$, $-\text{cyclo-C}_4H_7$, $-\text{cyclo-C}_5H_9$, $-\text{cyclo-C}_6H_{11}$, $-\text{CH}_2CH_2CH_3$, $-\text{CH}_2CH_2CH_2CH_3$, $-\text{CH}_2CH_2CH_2CH_2CH_3$, $-\text{CH}_2CH_2CH_2CH_2CH_2CH_3$, $-\text{CH}_2-C(CH_3)_3$, $-\text{CH}_2-\text{cyclo-C}_3H_5$, $-\text{CH}_2-\text{cyclo-C}_4H_7$, $-\text{CH}_2-\text{cyclo-C}_5H_9$, $-\text{CH}_2-\text{cyclo-C}_6H_{11}$, or $-\text{CH}_2CH_2SCH_3$; more preferably, R^1 represents in any general formula disclosed herein $-C(CH_3)_3$, $-\text{cyclo-C}_3H_5$, $-\text{CH}_2CH_2CH_2CH_3$, $-\text{CH}_2-C(CH_3)_3$, $-\text{CH}_2CH_2SCH_3$, or $-\text{CH}_2-\text{cyclo-C}_3H_5$; and most preferably R^1 represents $-C(CH_3)_3$, $-\text{CH}_2CH_2CH_2CH_3$, $-\text{CH}_2CH_2SCH_3$, or $-\text{CH}_2-\text{cyclo-C}_3H_5$.

Therefore, preferred are compounds of any one of the formulae (II-1) to (II-3):



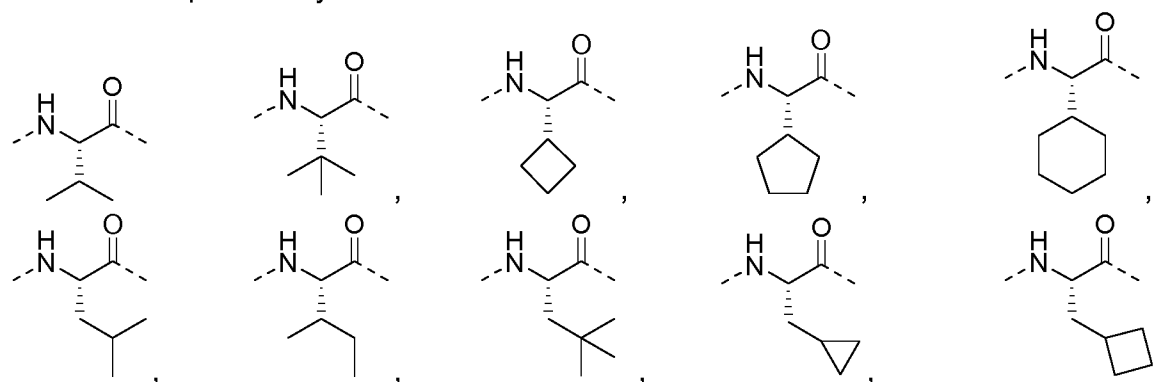
wherein R^2 , R^3 , and R^4 have the same meanings as defined in formula (I).

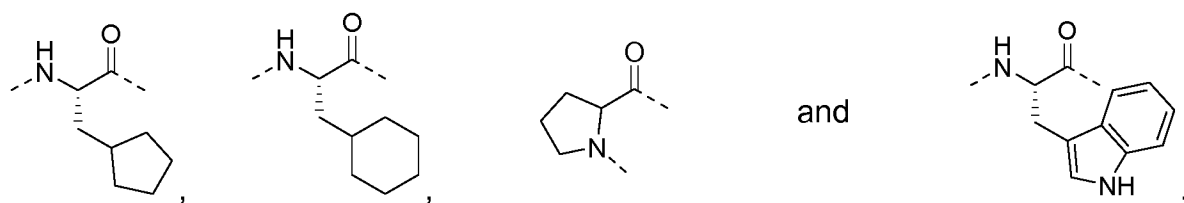
Moreover, in any general formula disclosed herein and especially in any one of the formulae (I), and (II-1) – (II-3), **A**¹ is preferably selected from



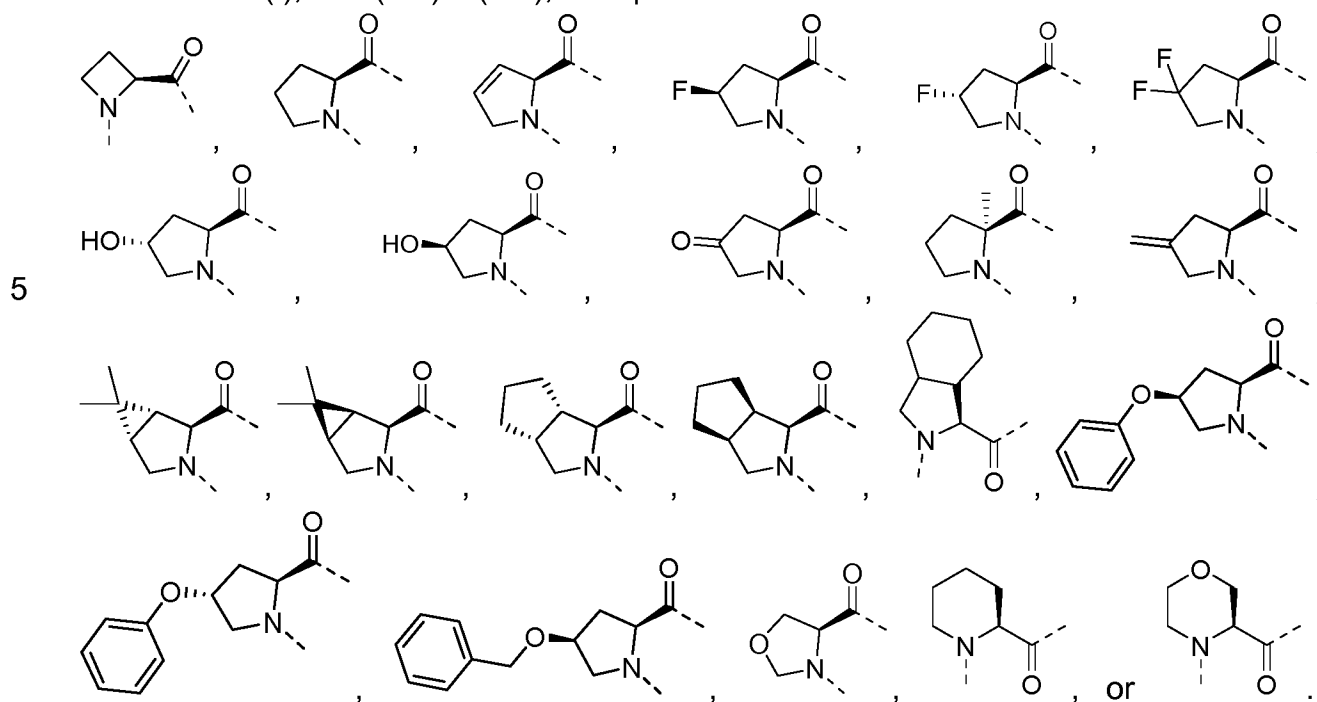
5

and/or **A**² is preferably selected from:

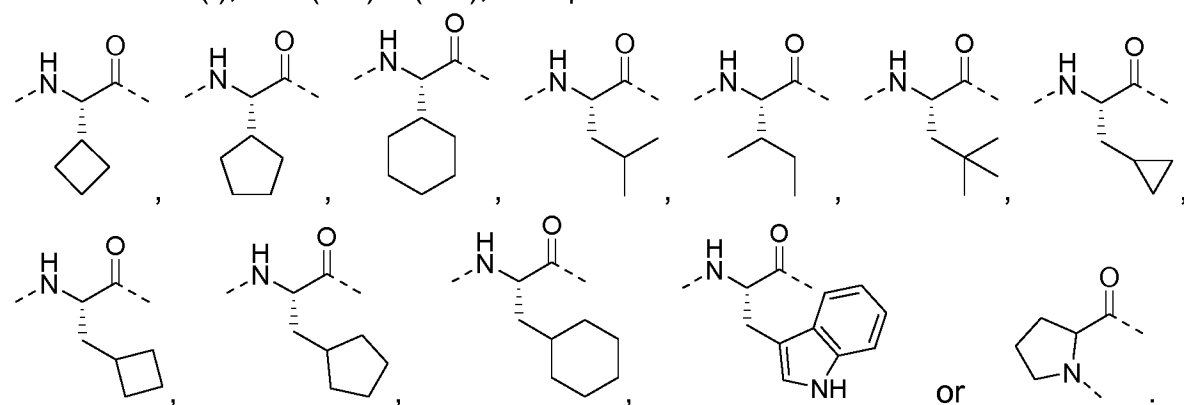




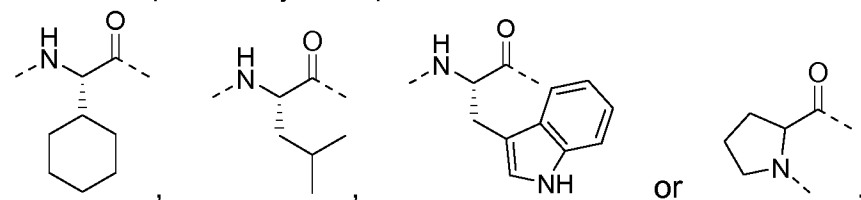
More preferably, in any general formula disclosed herein and especially in any one of the formulae (I), and (II-1) – (II-3), A^1 represents:



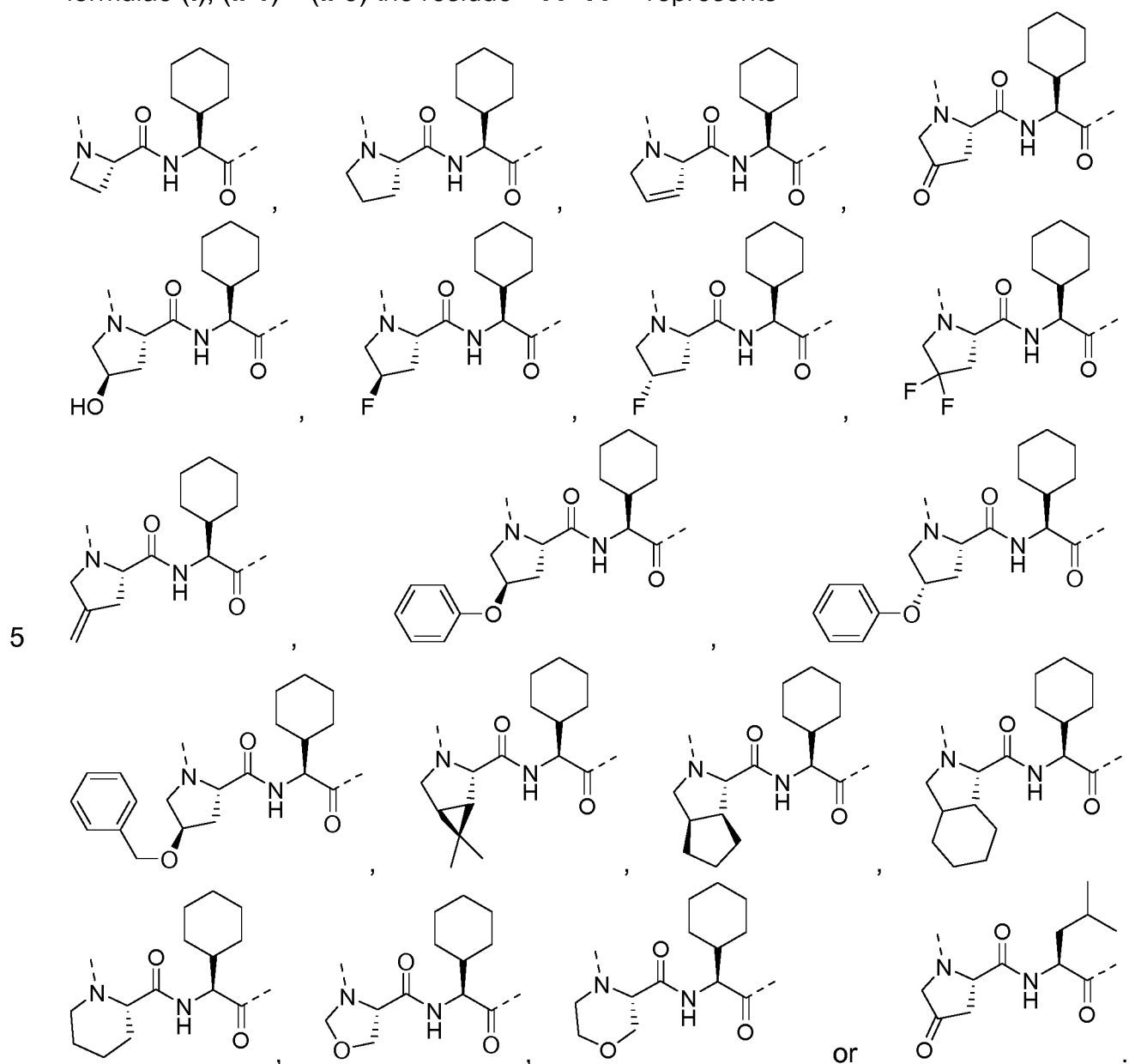
More preferably, in any general formula disclosed herein and especially in any one of the formulae (I), and (II-1) – (II-3), A^2 represents



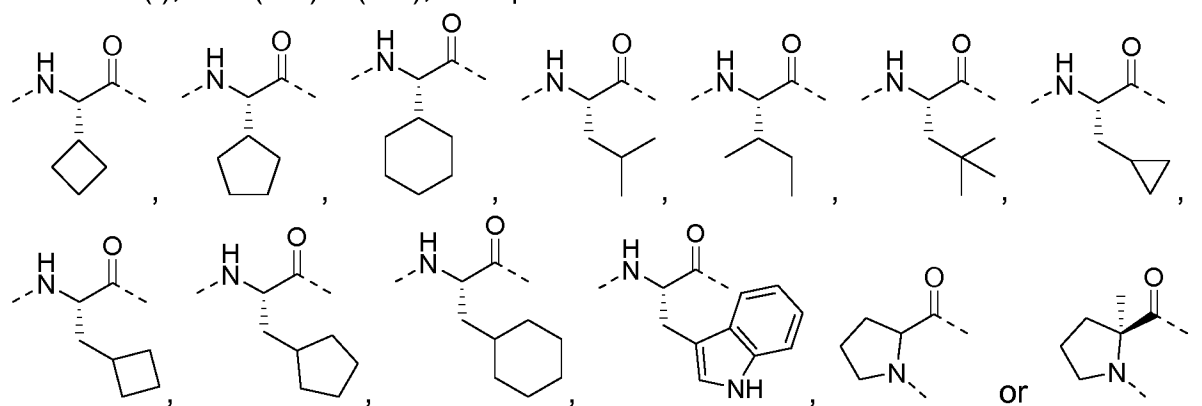
and most preferably A^2 represents



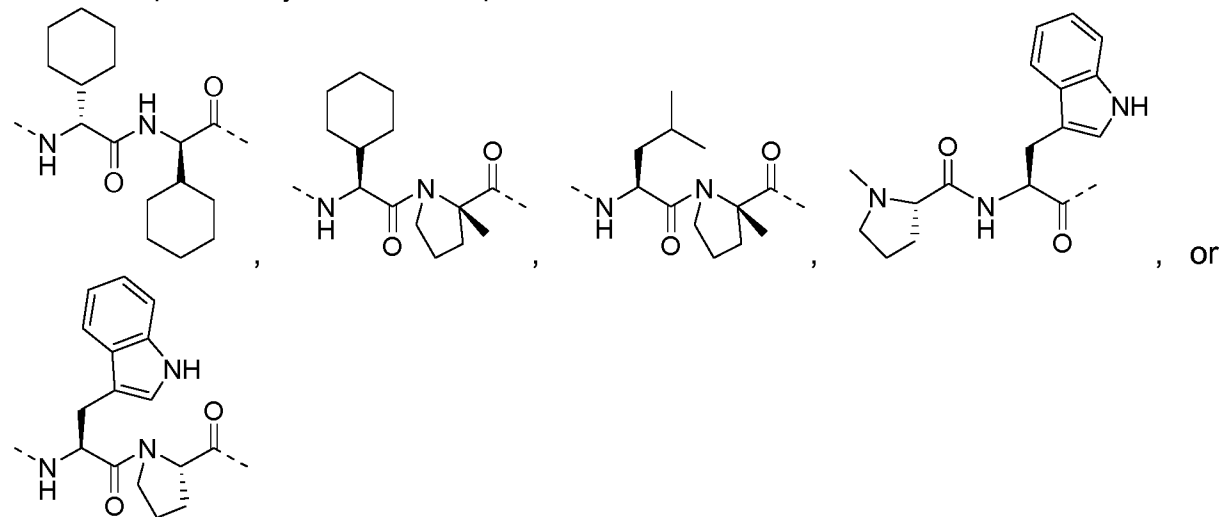
Also preferred is that in any general formula disclosed herein and especially in the formulae (I), (II-1) – (II-3) the residue $-A^1-A^2-$ represents



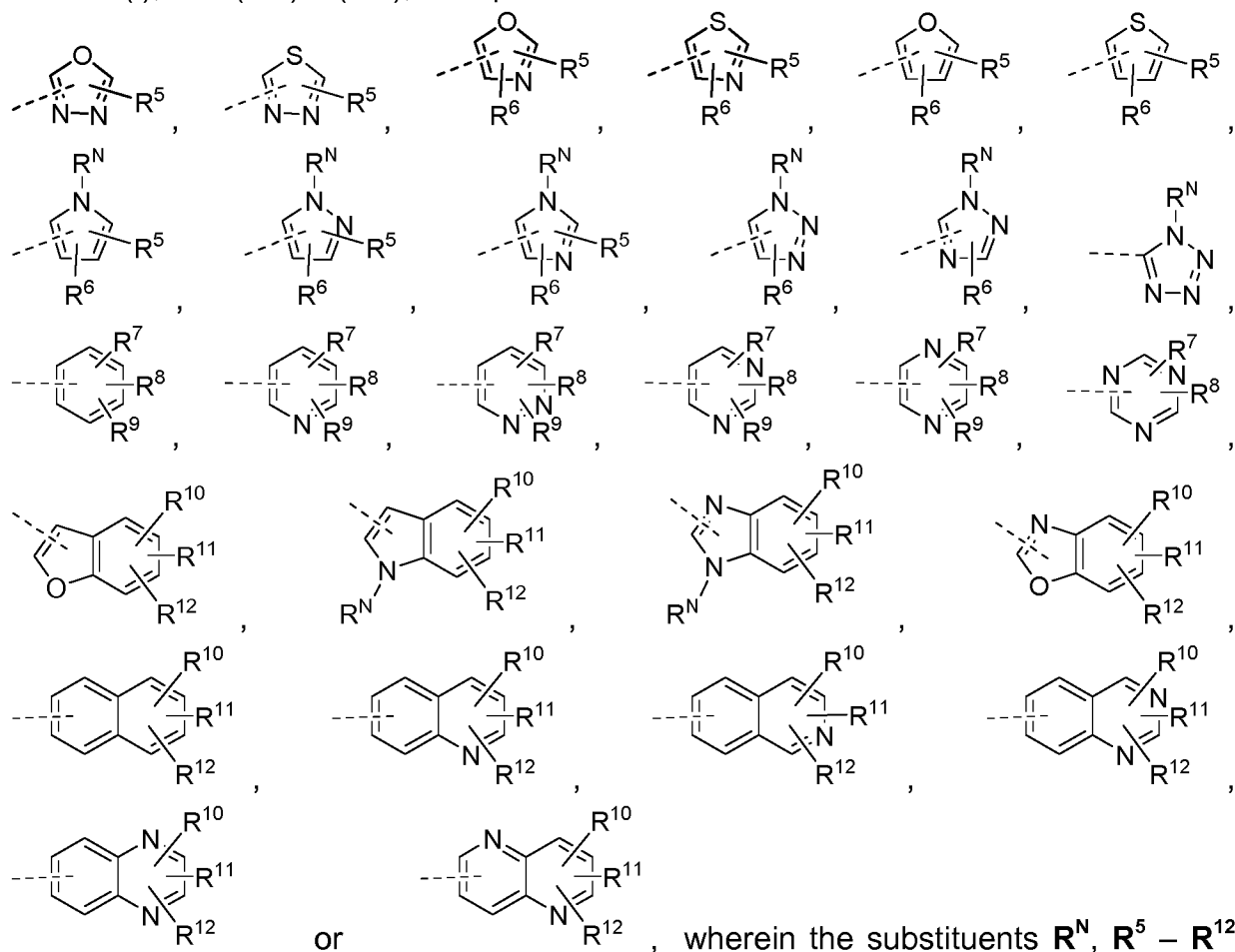
10 Preferably, in any general formula disclosed herein and especially in any one of the formulae (I), and (II-1) – (II-3), A^3 represents



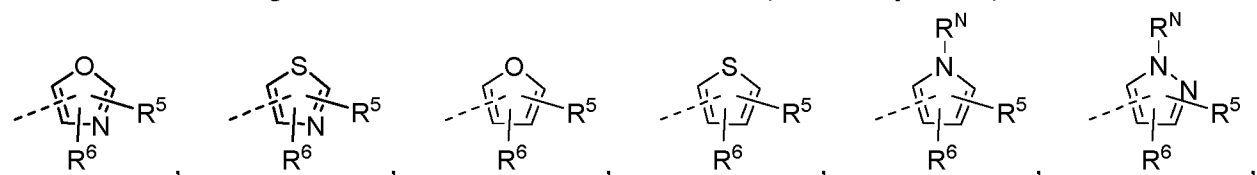
and more preferably $-A^2-A^3-$ represents

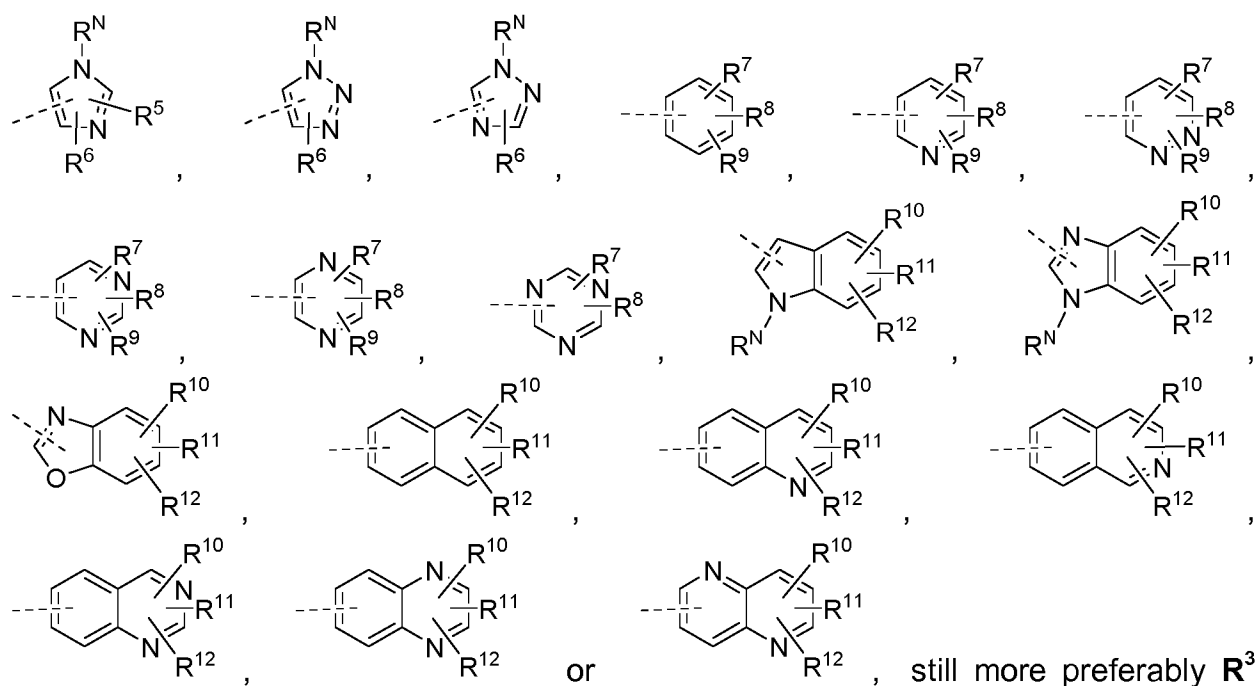


Preferably, in any general formula disclosed herein and especially in any one of the
5 formulae (I), and (II-1) – (II-3), R^3 represents

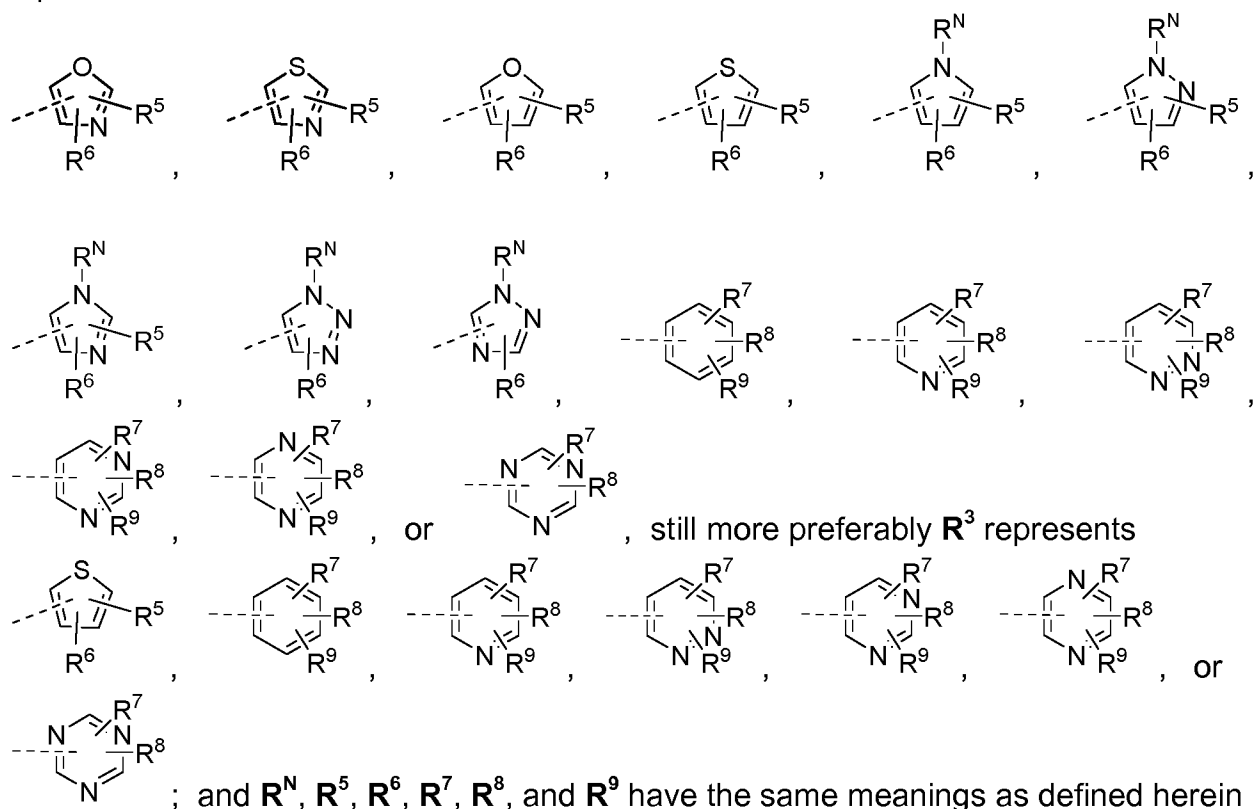


10 or , wherein the substituents R^N , $R^5 - R^{12}$ have the meanings as disclosed herein; and more preferably R^3 represents

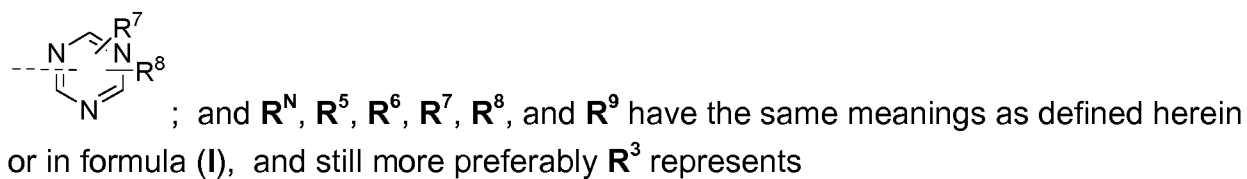




5 represents

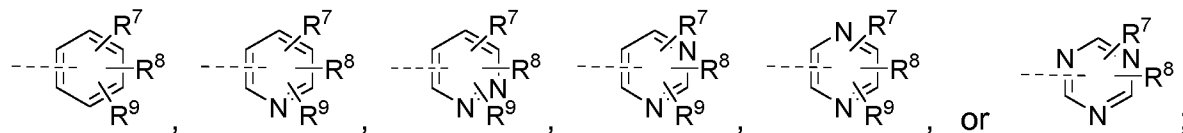


10

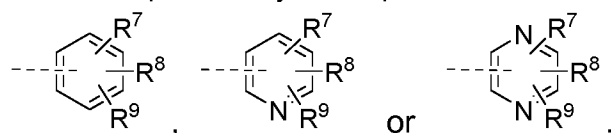


and R^N , R^5 , R^6 , R^7 , R^8 , and R^9 have the same meanings as defined herein

or in formula (I), and still more preferably R^3 represents

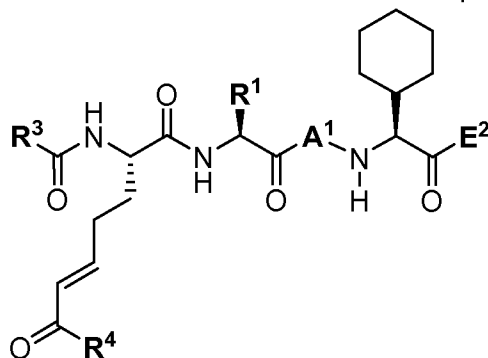


and most preferably, R^3 represents



15

More preferably, the present invention is directed to a compound of formula (III):

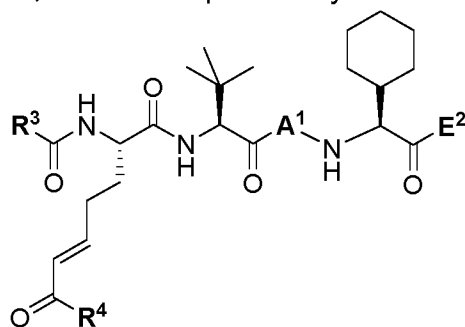


(III)

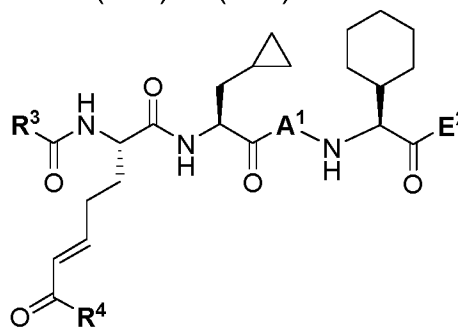
5 wherein

E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$, or $-A^3-A^4-A^5-E$; and

A^1 , A^3 , A^4 , A^5 , R^1 , R^3 , R^4 , and E have the meanings and preferred meanings as defined herein; or more specifically to a compound of formula (III-1) or (III-2):



(III-1)



(III-2)

wherein

10 E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$, or $-A^3-A^4-A^5-E$;

R^3 , represents

The structures shown for R^3 are: a thiophene ring with substituents R^5 and R^6 ; a pyrrolidine ring with substituents R^5 and R^N ; and three pyridine rings with substituents R^7 , R^8 , and R^9 at different positions. These are separated by commas, followed by "or".

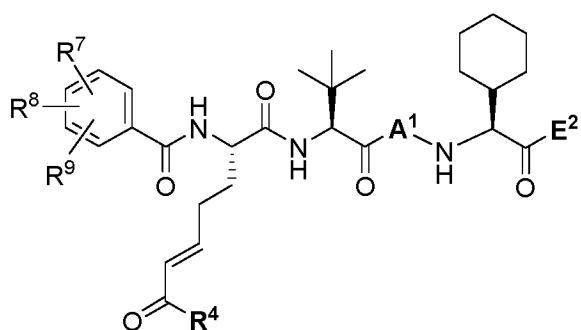
preferably

The structures shown for R^3 are: two pyridine rings with substituents R^7 , R^8 , and R^9 at different positions, and one pyrimidine ring with substituents R^7 , R^8 , and R^9 at different positions. These are separated by commas, followed by "or".

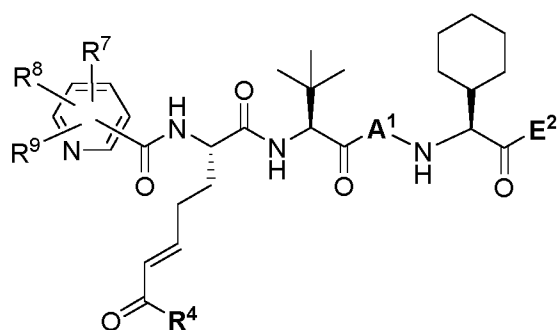
A^1 , A^3 , A^4 , A^5 , R^N , R^4 , R^5 , R^6 , R^7 , R^8 , R^9 and E have the same meanings as defined herein.

15

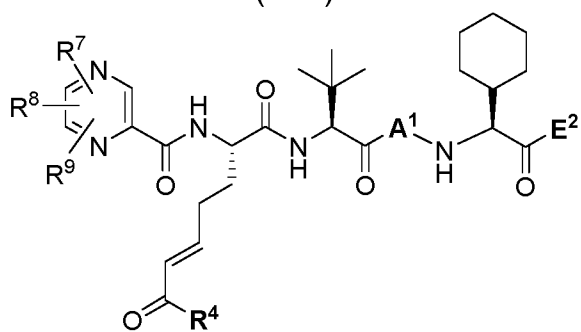
Still more preferably, the present invention is directed to a compound of any one of the formulae (IV-1) – (IV-5):



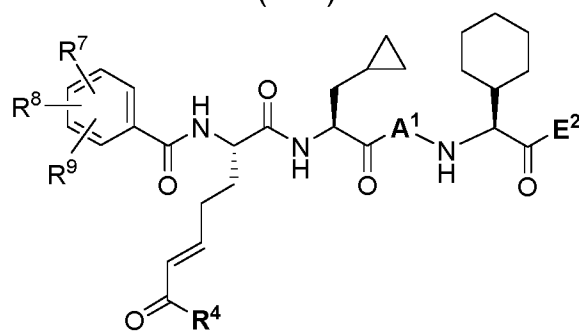
(IV-1)



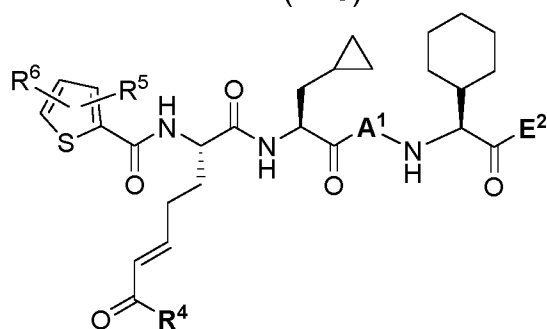
(IV-2)



(IV-3)



(IV-4)



(IV-5)

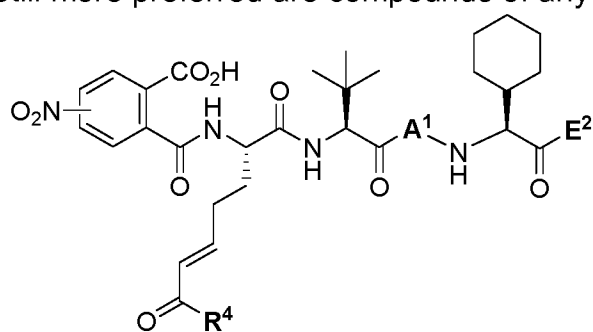
wherein

E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$, or $-A^3-A^4-A^5-E$;

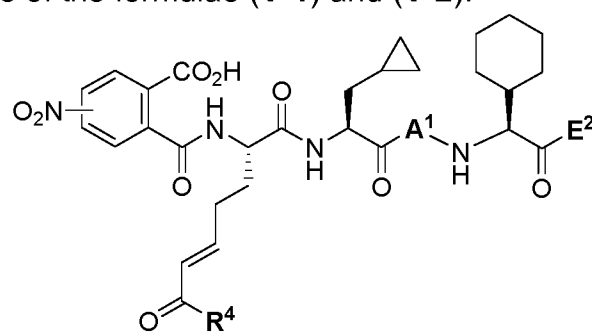
5 R^4 represents $-OCH_3$ or $-OC_2H_5$;

R^5 , R^6 , R^7 , R^8 , and R^9 represent independently of each other $-H$, $-Cl$, $-OH$, $-NO_2$ or $-CO_2H$; and A^1 , A^3 , A^4 , A^5 , and E have the same meanings as defined herein.

Still more preferred are compounds of any one of the formulae (V-1) and (V-2):



(V-1)



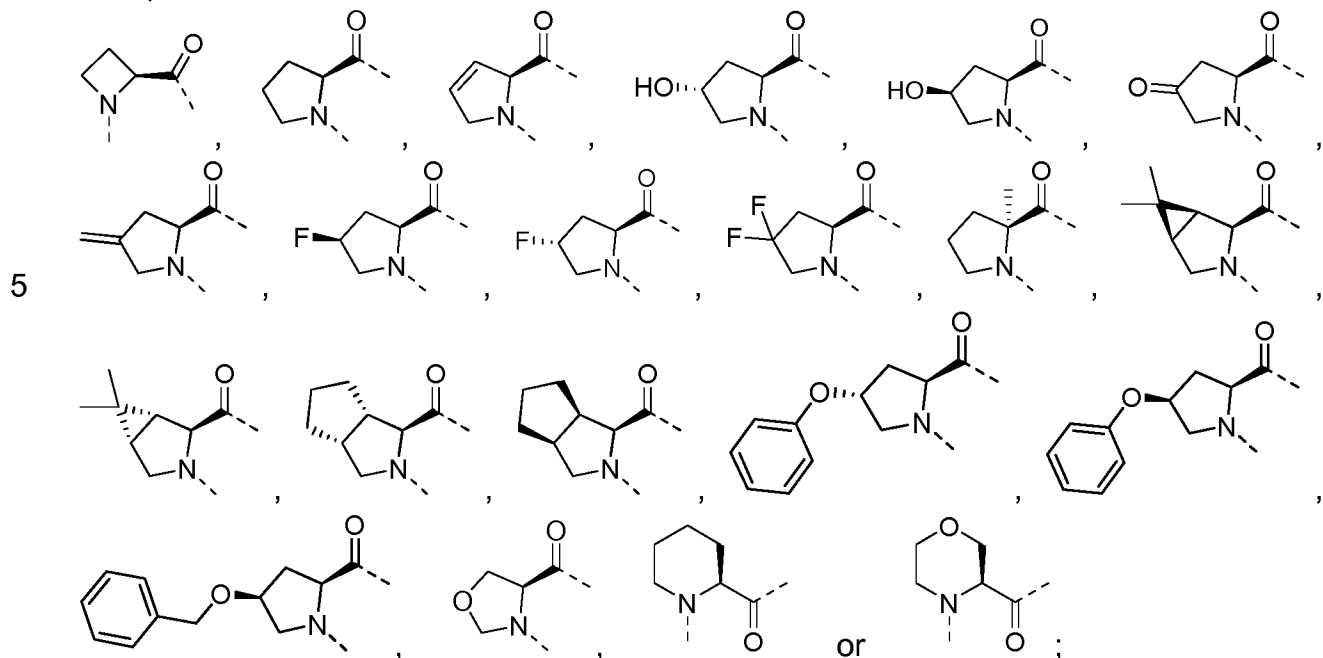
(V-2)

10 wherein

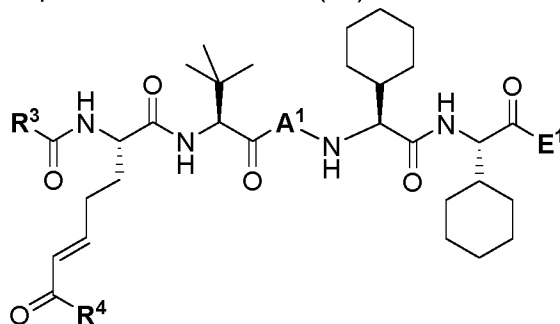
E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$, or $-A^3-A^4-A^5-E$;

R^4 represents $-OCH_3$ or $-OC_2H_5$;

A^1 represents



10 Still more preferred is a compound of a formula (VI):



(VI)

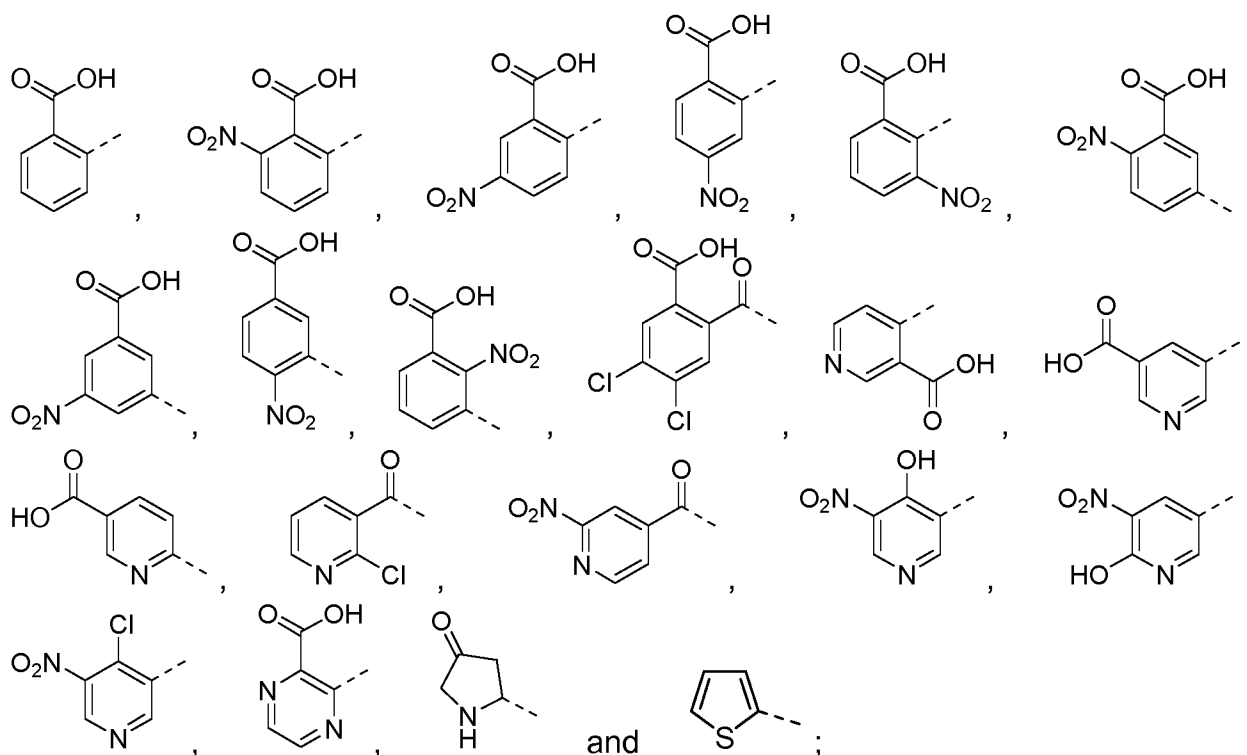
E^1 represents $-E$, $-A^4-E$, or $-A^4-A^5-E$;

R^3 represents

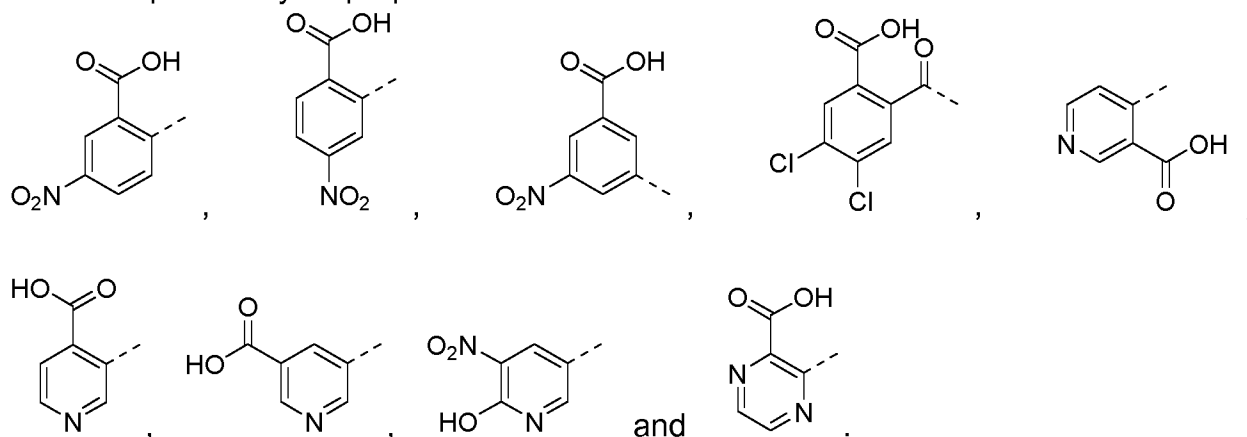
or

15 A^1 , A^4 , A^5 , R^4 , R^7 , R^8 , R^9 and E have the same meanings as defined herein or more preferably as defined in formula (V-1).

Preferably, in any general formula disclosed herein, R^3 is selected from the group consisting of:

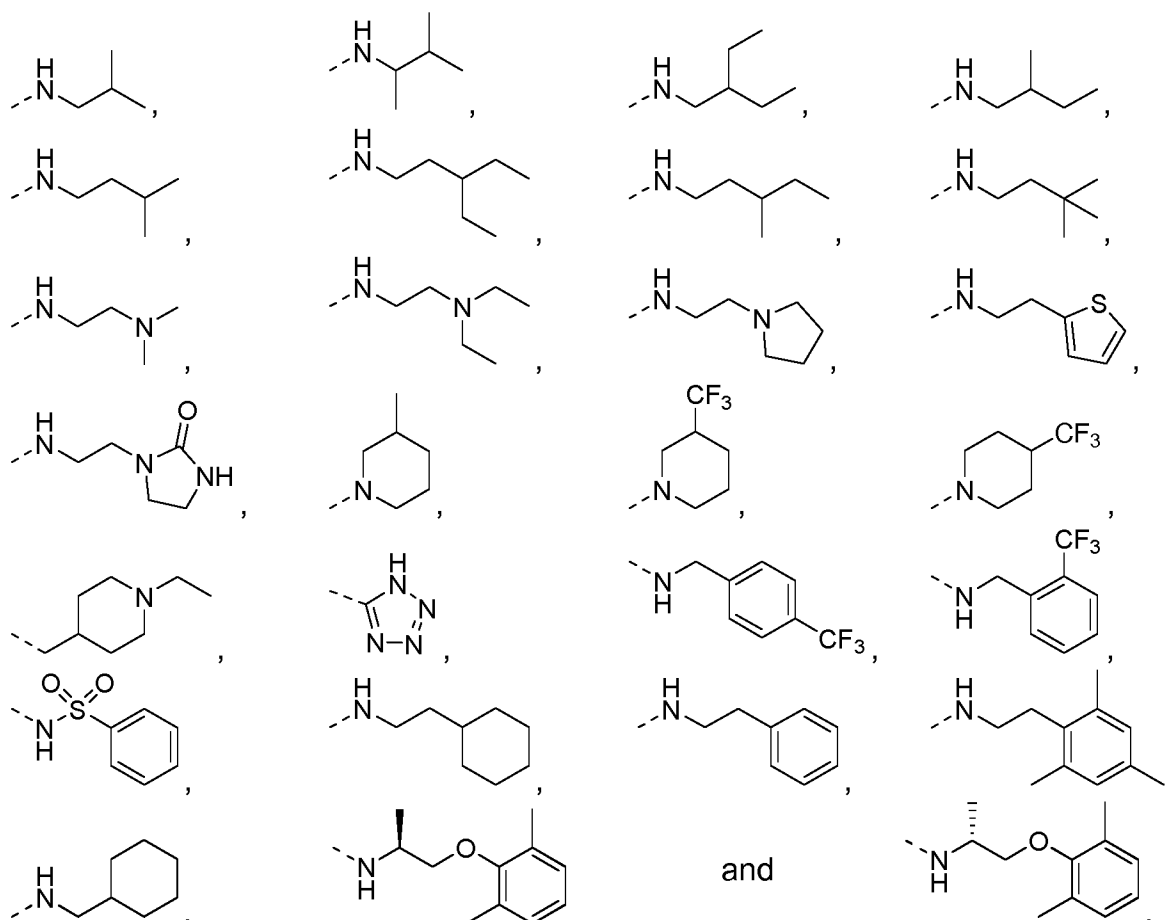


5 and more preferably R^3 represents

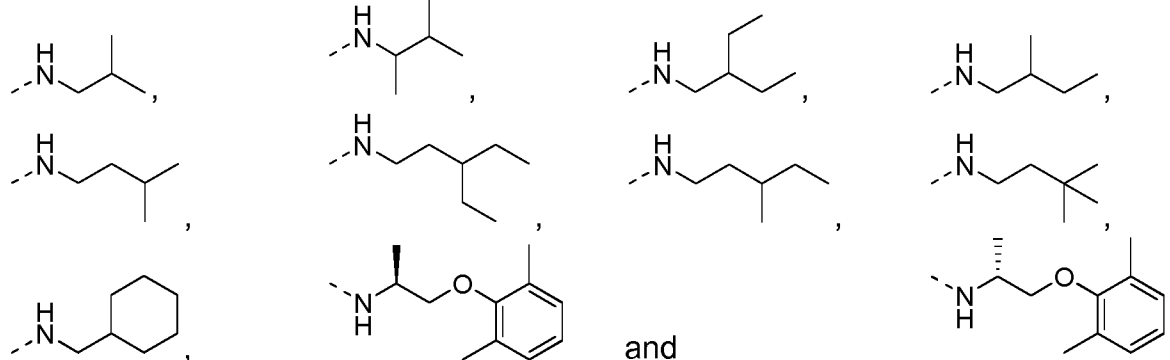


- 10 Preferably, in any general formula disclosed herein, $R^{4'}$, $R^{5'}$, $R^{6'}$, and $R^{7'}$ represent independently of each other: $-H$, $-F$, $-Cl$, $-Br$, $-I$, $-CH_3$, $-CH_2CH_3$, $-CH(CH_3)_2$, $-cyclo-C_3H_5$, $-OCH_3$, $-CF_3$, $-OCF_3$, $-OH$, $-CN$, $-COCH_3$, $-CO_2H$, $-CO_2Me$, $-OCOCH_3$, $-NH_2$, $-NHCH_3$, $-N(CH_3)_2$, $-NHCOCH_3$, $-NHCOCF_3$, $-NHSO_2CH_3$, $-NHSO_2CF_3$, $-SCH_3$, $-SO_2CH_3$, $-SO_2CF_3$, $-SO_2NH_2$, $-SO_2NHCH_3$, or
- 15 $-SO_2N(CH_3)_2$; more preferably $-H$, $-F$, $-Cl$, $-Br$, $-CH_3$, $-CH_2CH_3$, $-CH(CH_3)_2$, $-cyclo-C_3H_5$, $-OCH_3$, $-OH$, $-CO_2H$, $-CO_2Me$, $-NH_2$, $-NHCH_3$, $-N(CH_3)_2$; and most preferably $-H$.

- Preferably, in any general formula disclosed herein, E is selected from a C terminal group consisting of: $-OH$, $-OCH_3$, $-NH_2$, $-NHCH_3$, $-N(CH_3)_2$, $-N(CH_2CH_3)_2$,
- 20

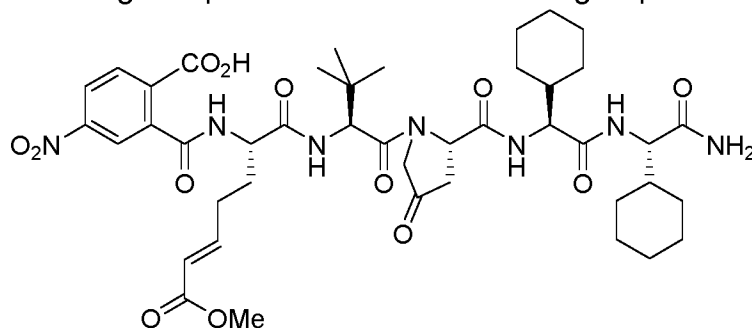


and more preferably **E** is selected from a C terminal group consisting of:
 $-\text{OH}$, $-\text{OCH}_3$, $-\text{NH}_2$, $-\text{NHCH}_3$, $-\text{N}(\text{CH}_3)_2$,

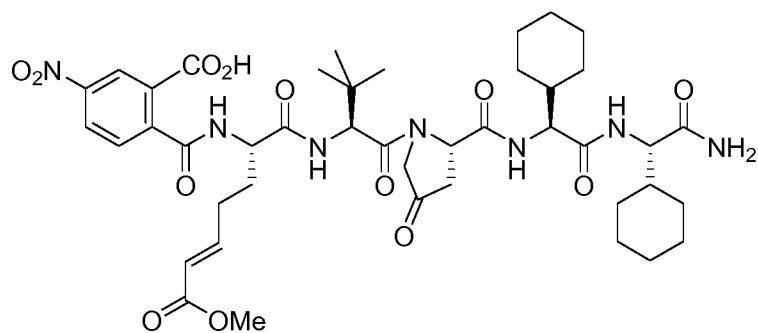


5 Also preferred are the following compounds selected from the group consisting of:

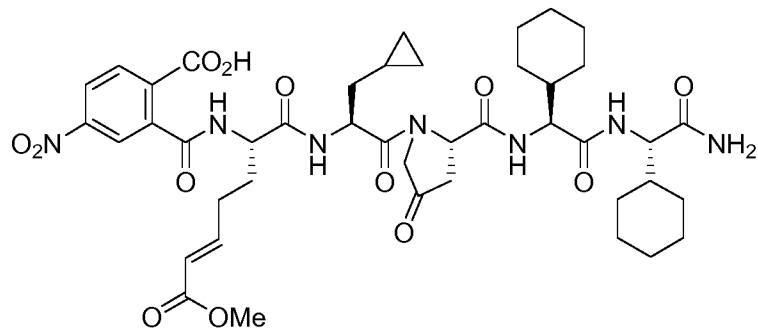
Compound 1a:



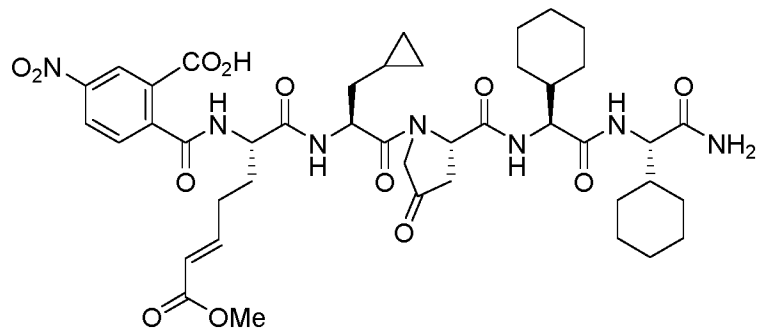
Compound 1b:



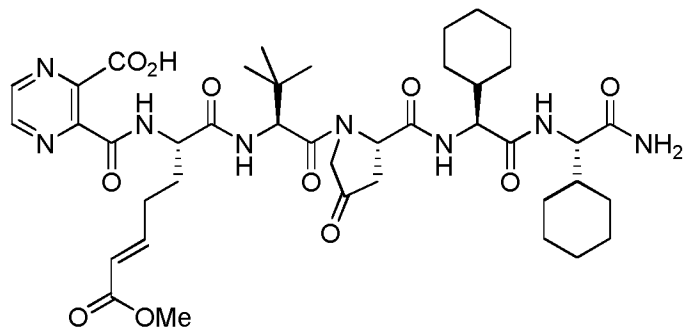
Compound 2a:



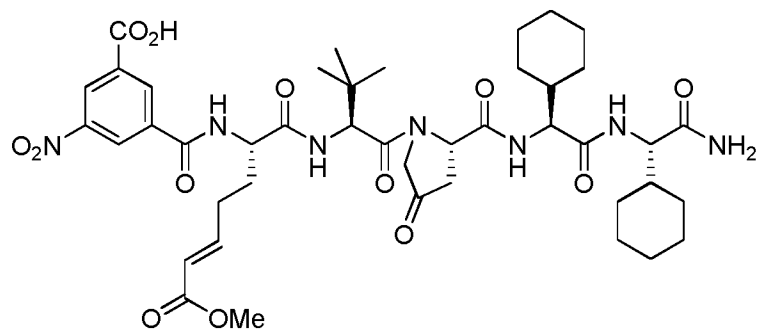
Compound 2b:



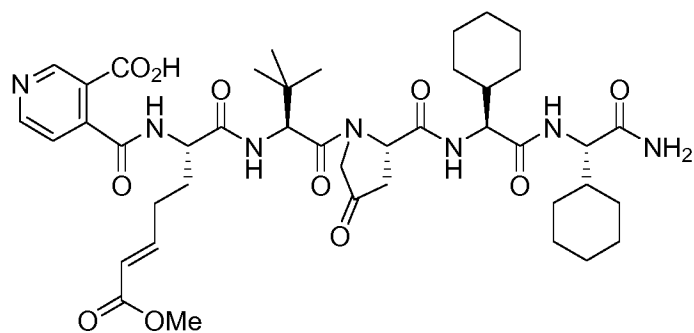
Compound 3:



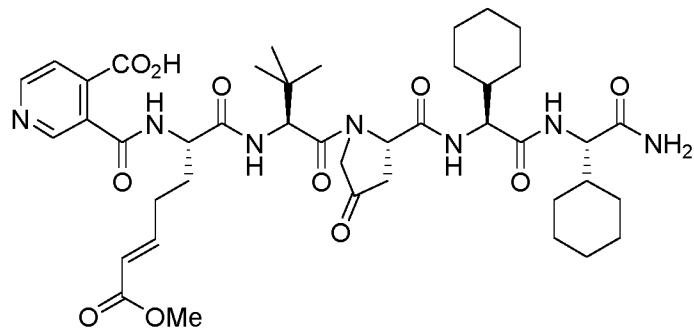
Compound 4:



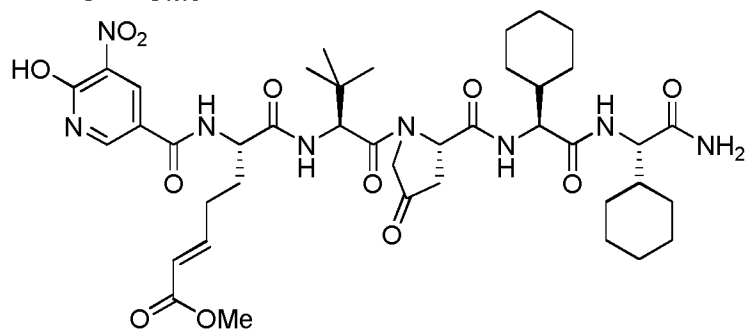
Compound 5a:



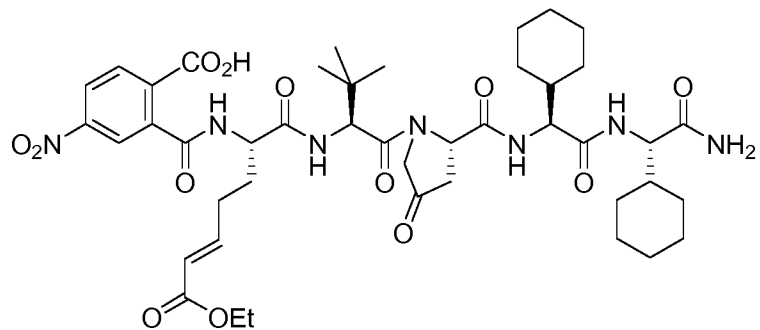
Compound 5b:



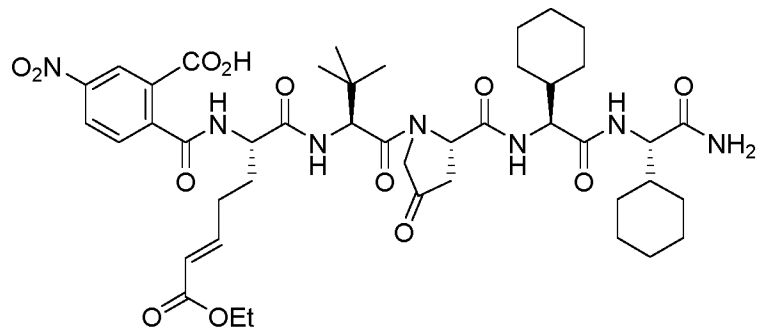
Compound 6:



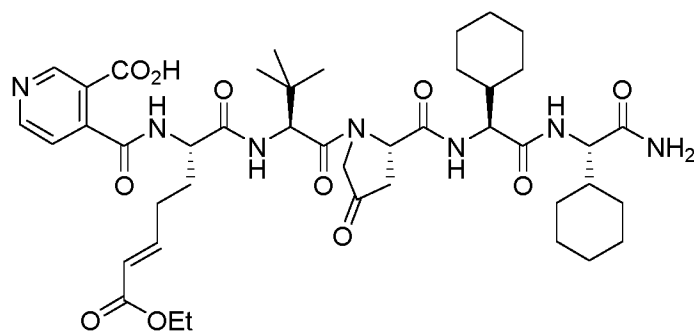
Compound 7a:



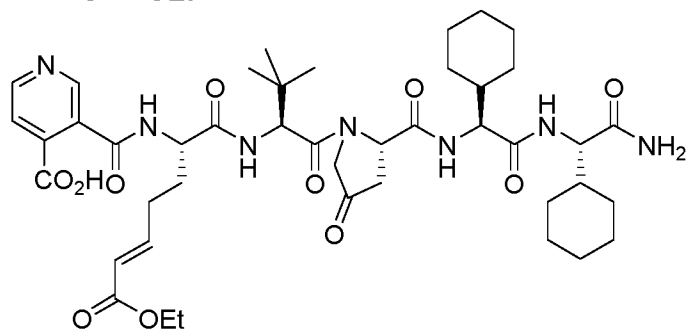
Compound 7b:



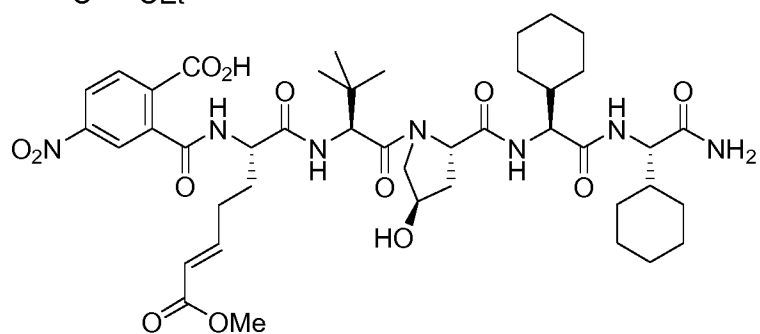
Compound 8a:



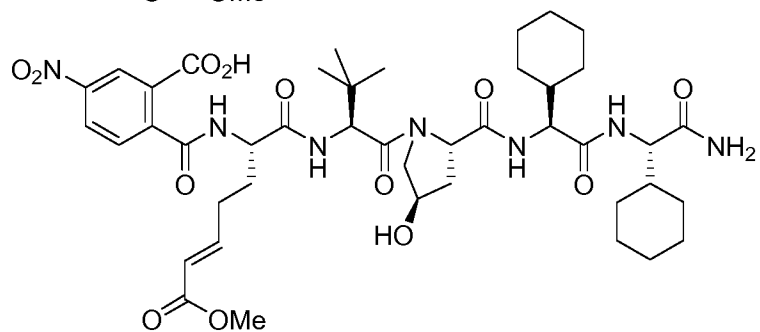
Compound 8b:



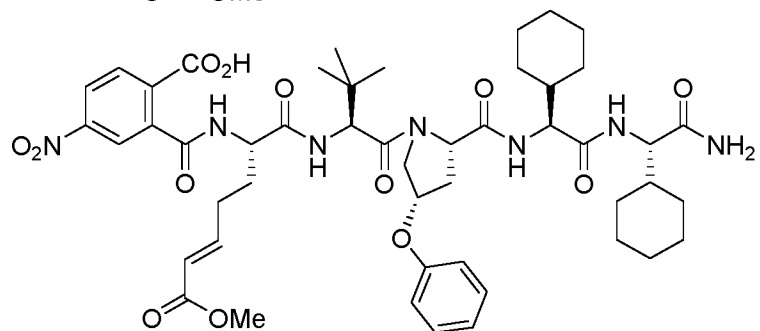
Compound 9a:



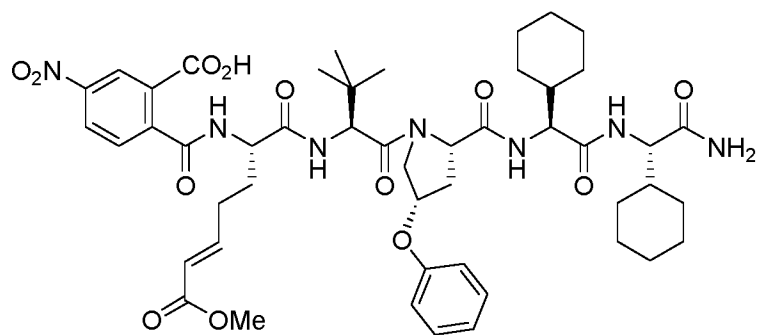
Compound 9b:



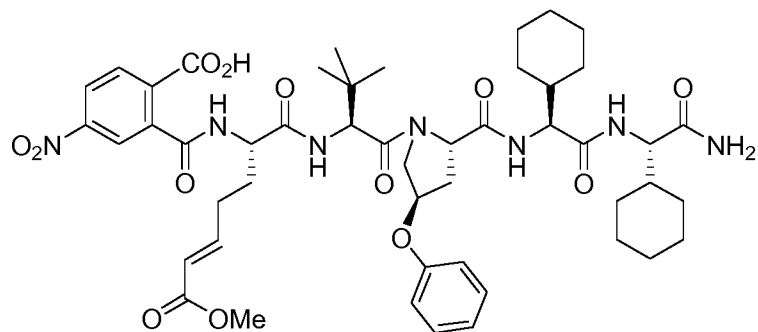
Compound 10a:



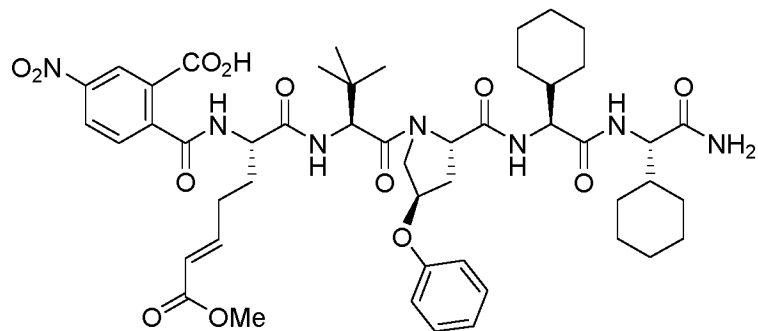
Compound 10b:



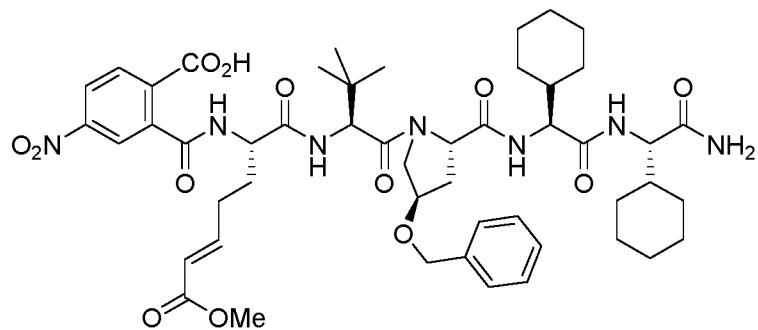
Compound 11a:



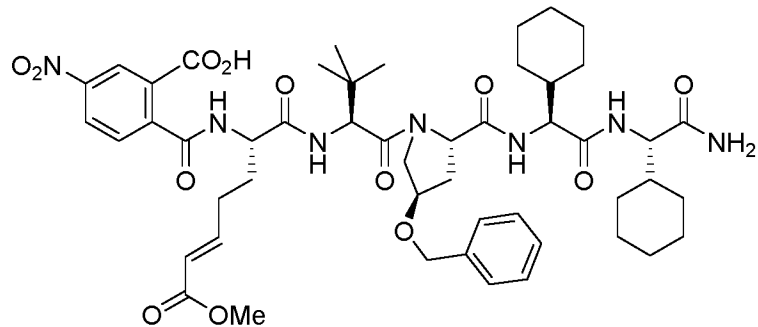
Compound 11b:



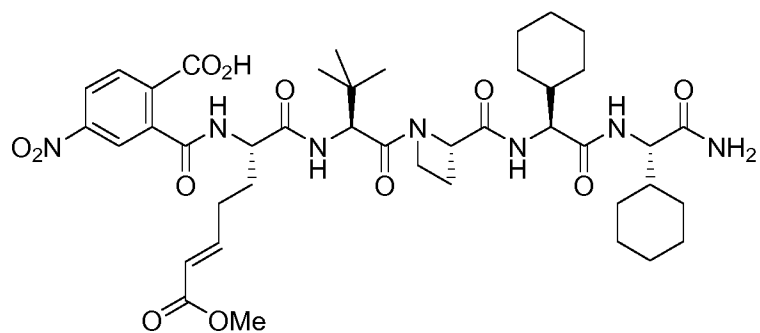
Compound 12a:



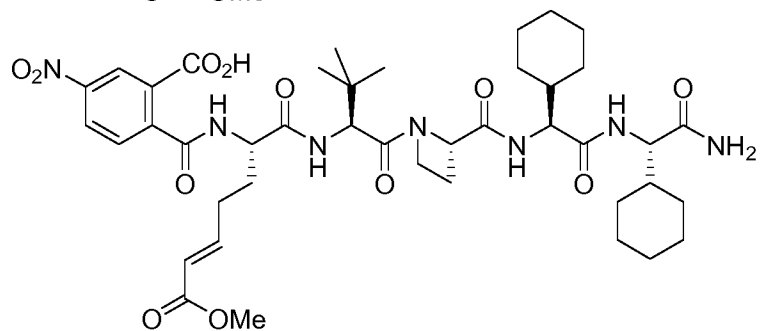
Compound 12b:



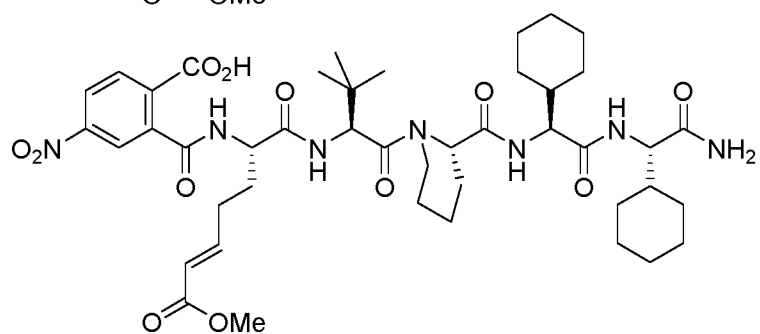
Compound 13a:



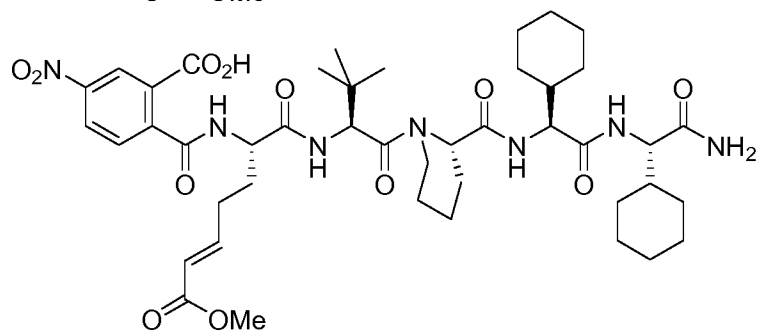
Compound 13b:



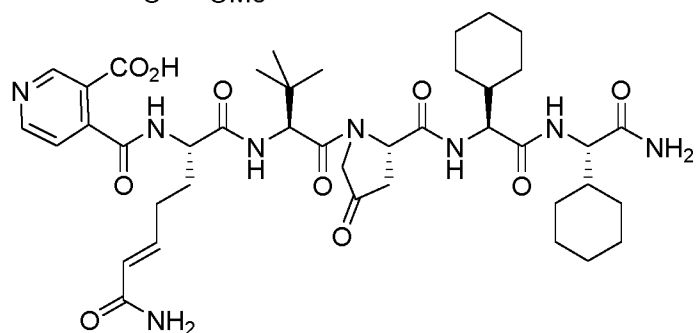
Compound 14a:



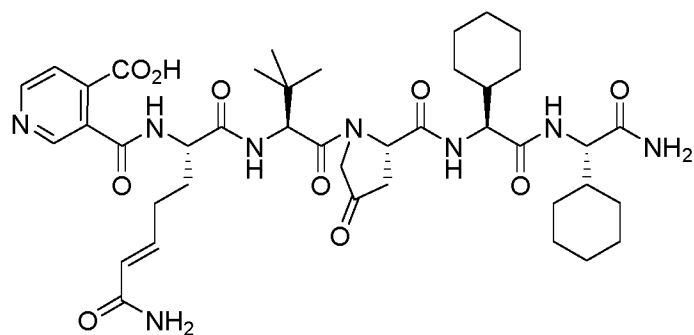
Compound 14b:



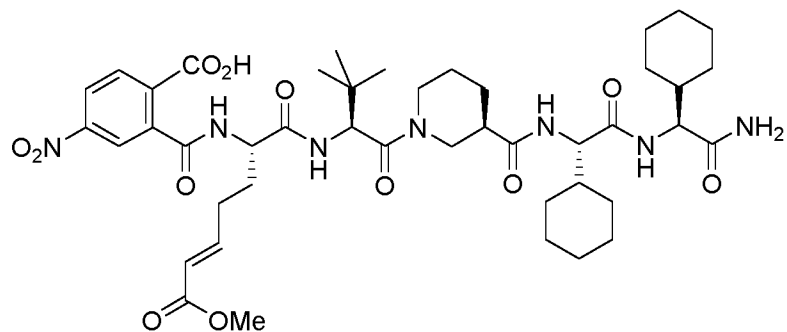
Compound 15a:



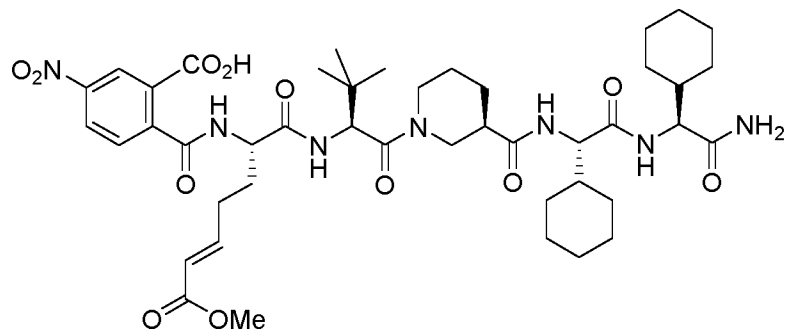
Compound 15b:



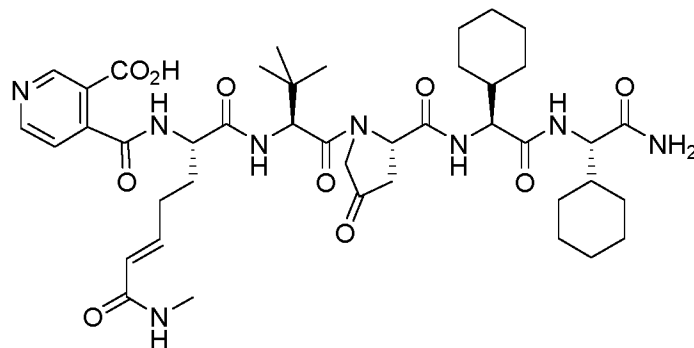
Compound 16a:



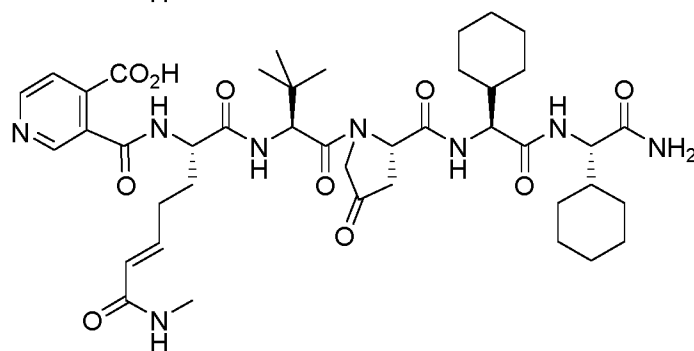
Compound 16b:



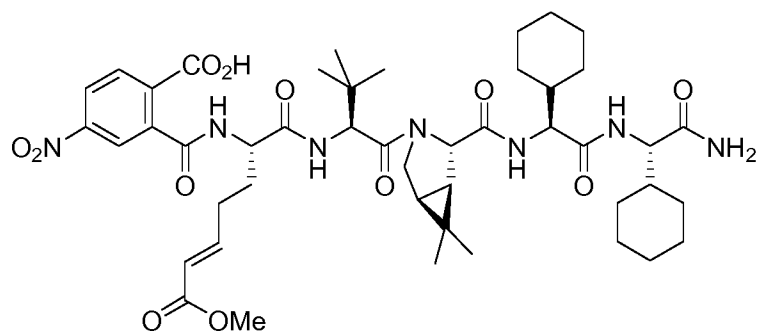
Compound 17a:



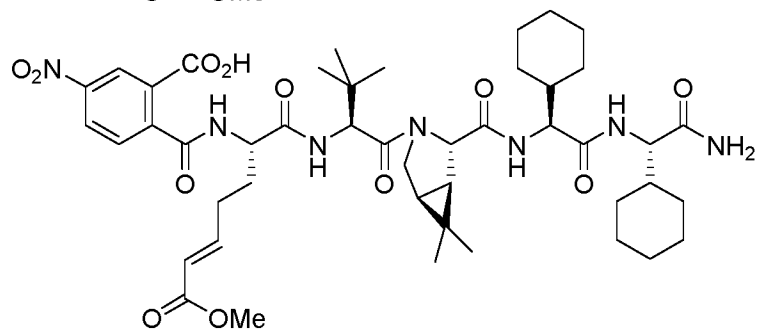
Compound 17b:



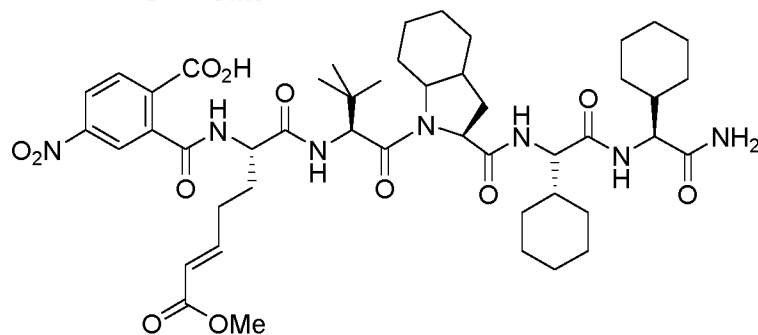
Compound 18a:



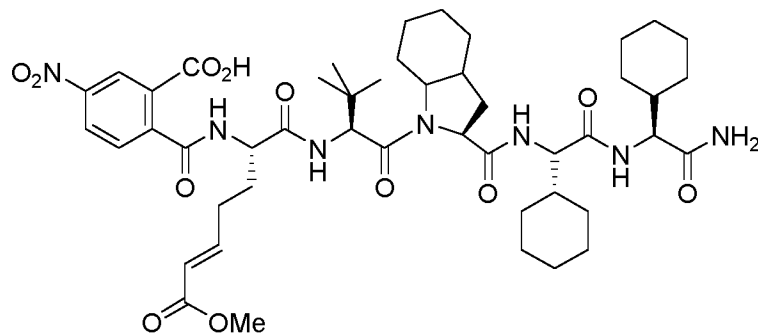
Compound 18b:



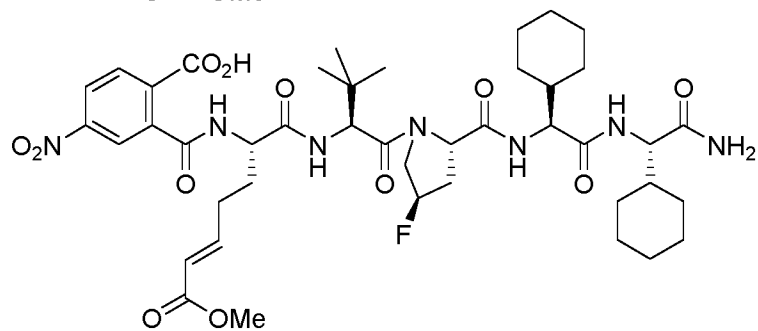
Compound 19a:



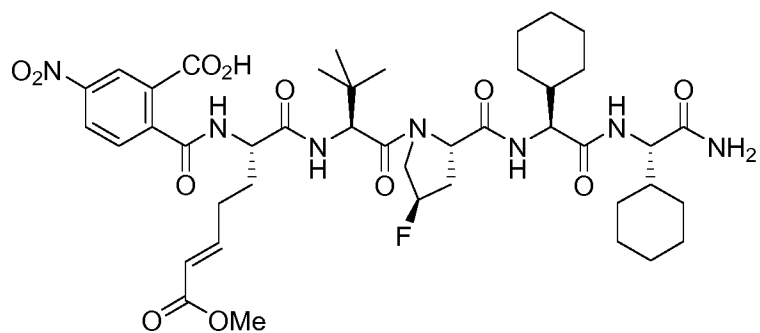
Compound 19b:



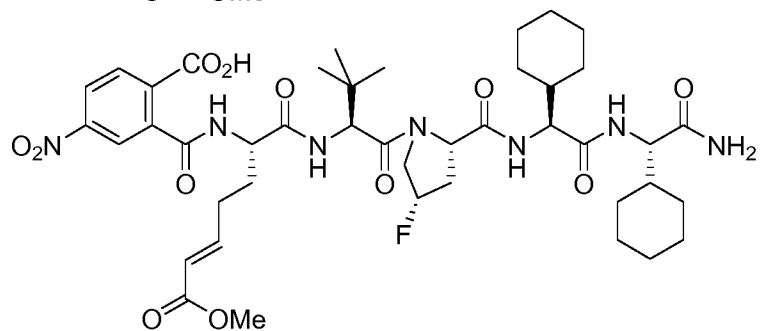
Compound 20a:



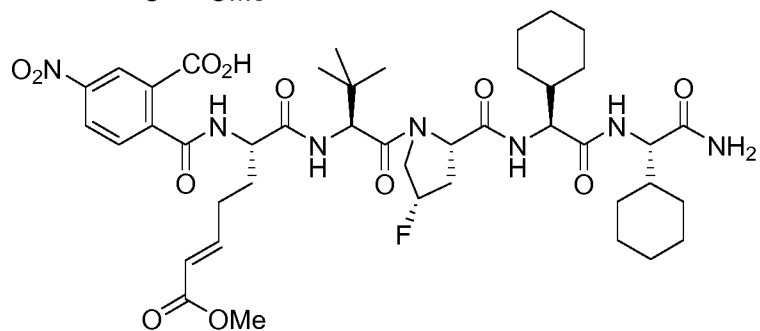
Compound 20b:



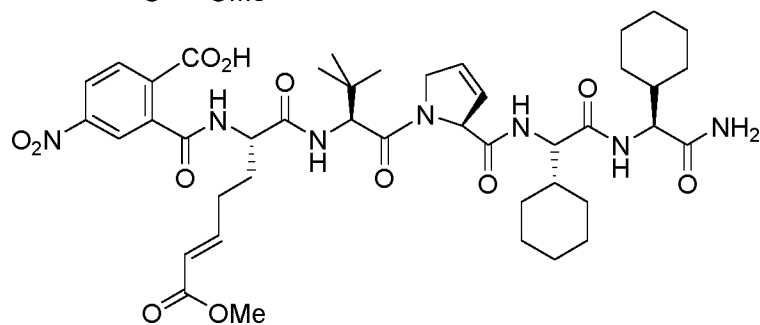
Compound 21a:



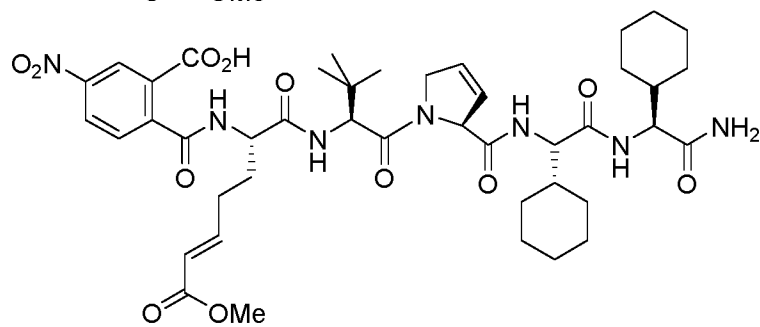
Compound 21b:



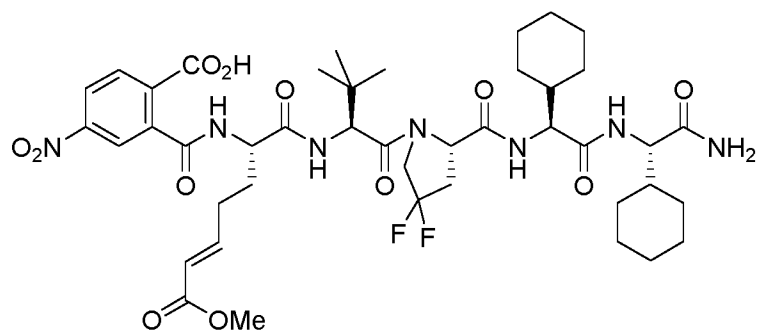
Compound 22a:



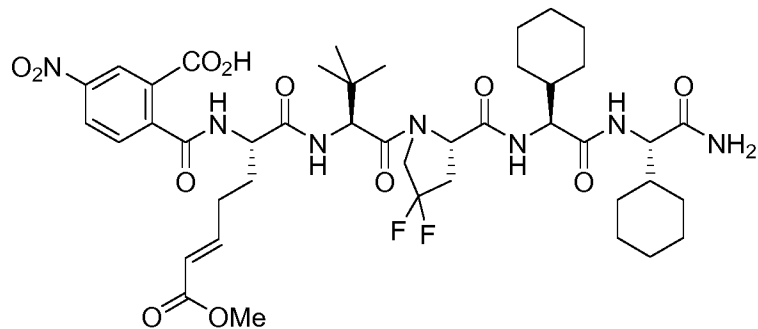
Compound 22b:



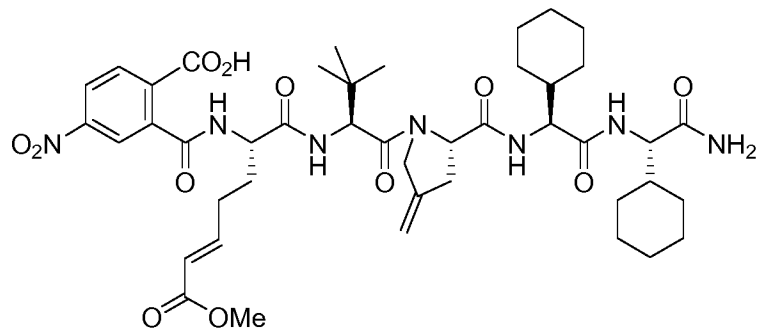
Compound 23a:



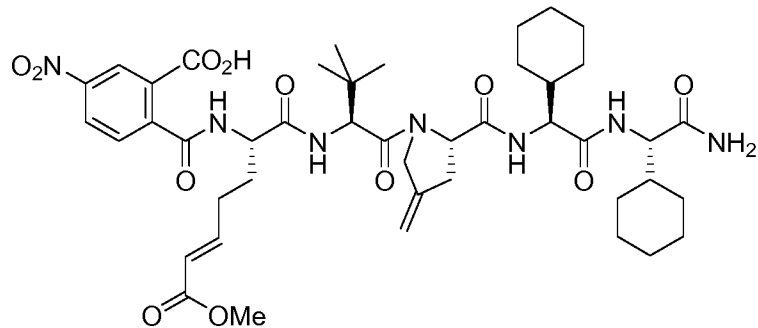
Compound 23b:



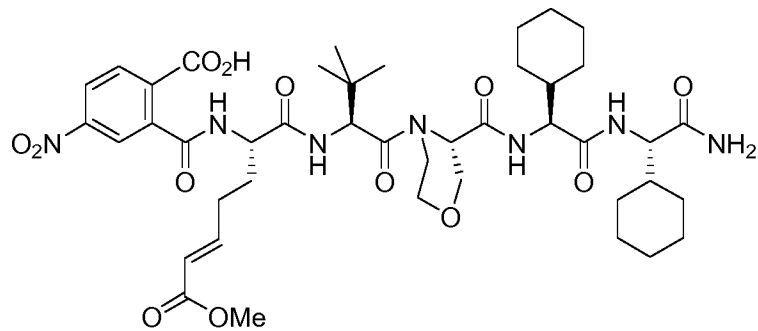
Compound 24a:



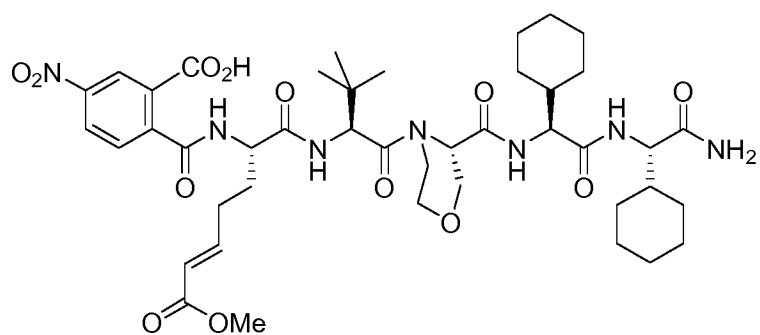
Compound 24b:



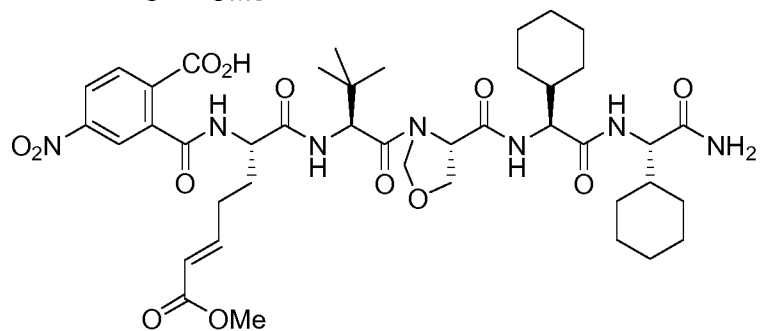
Compound 25a:



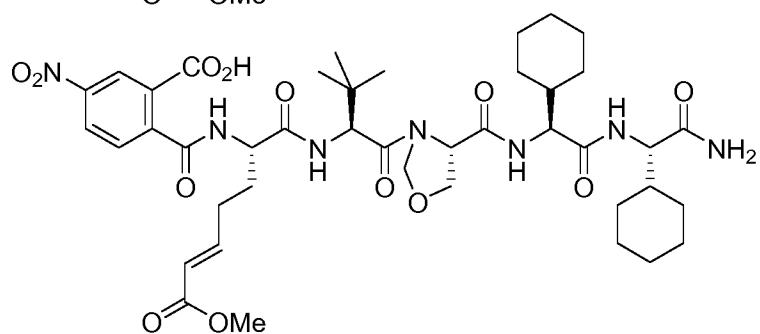
Compound 25b:



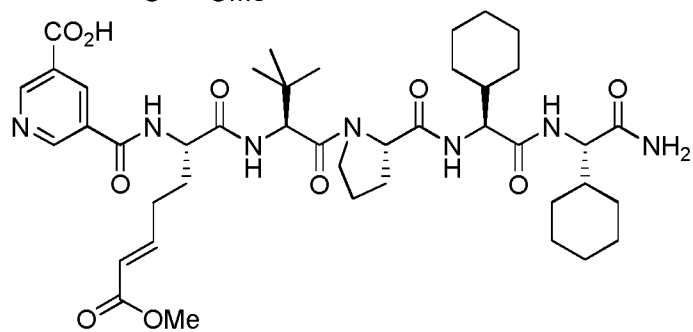
Compound 26a:



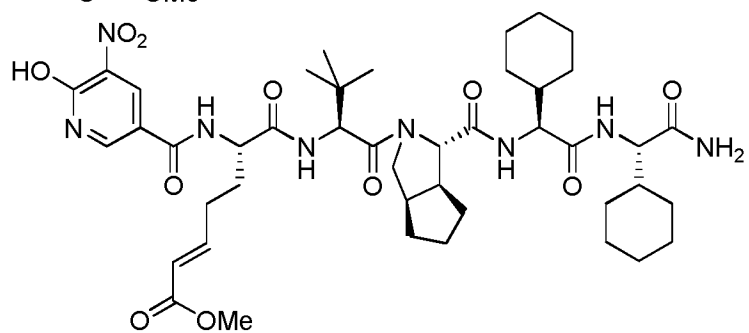
Compound 26b:



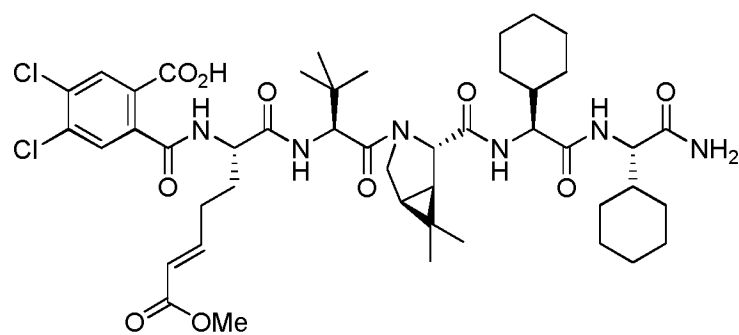
Compound 27:



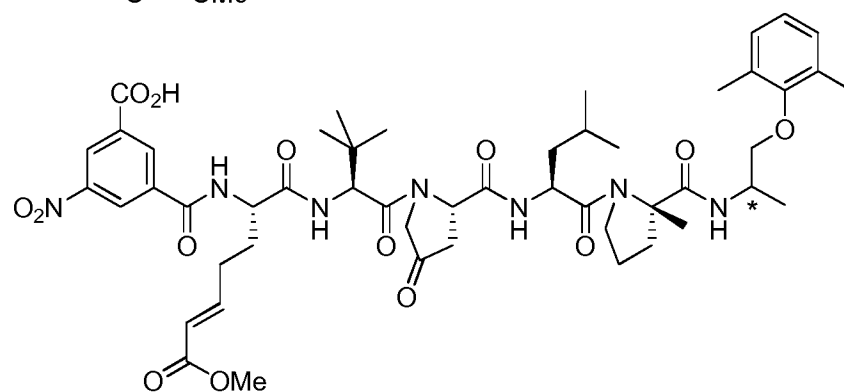
Compound 28:



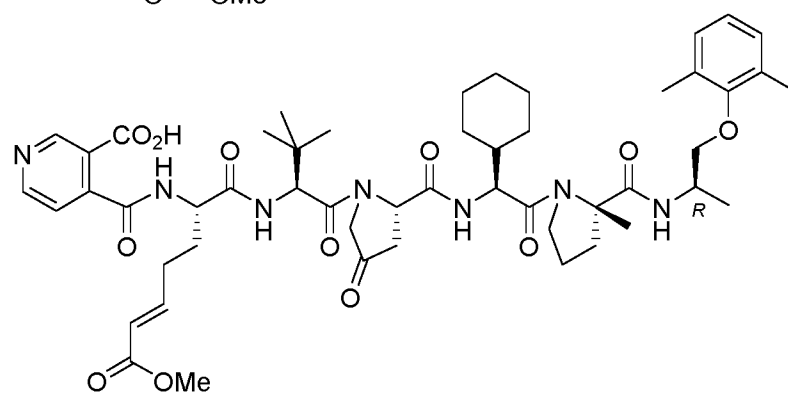
Compound 29:



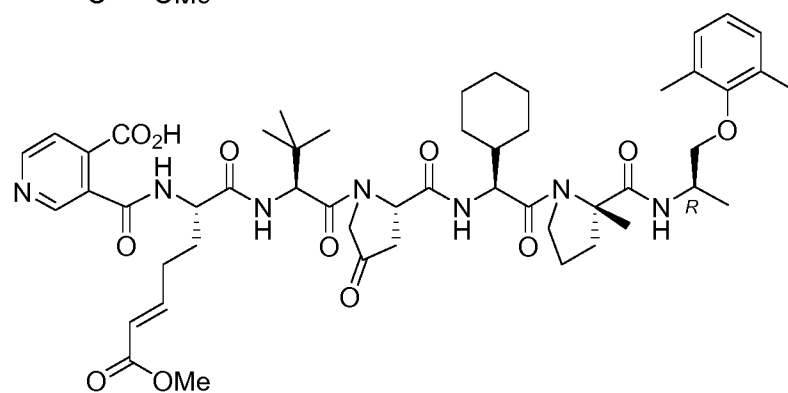
Compound 30:



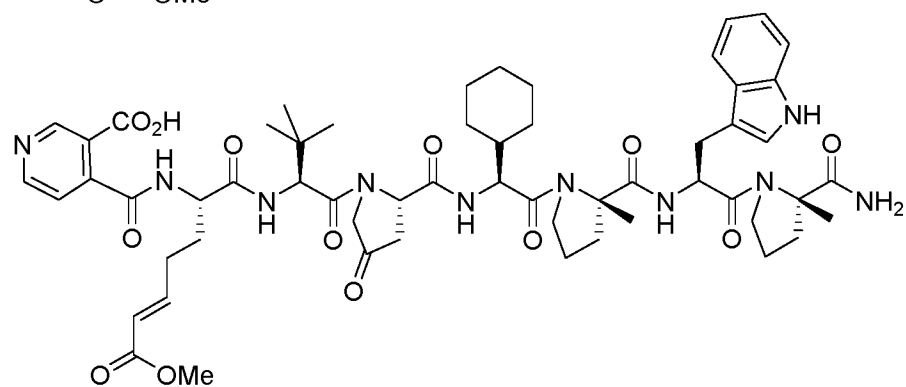
Compound 31a:



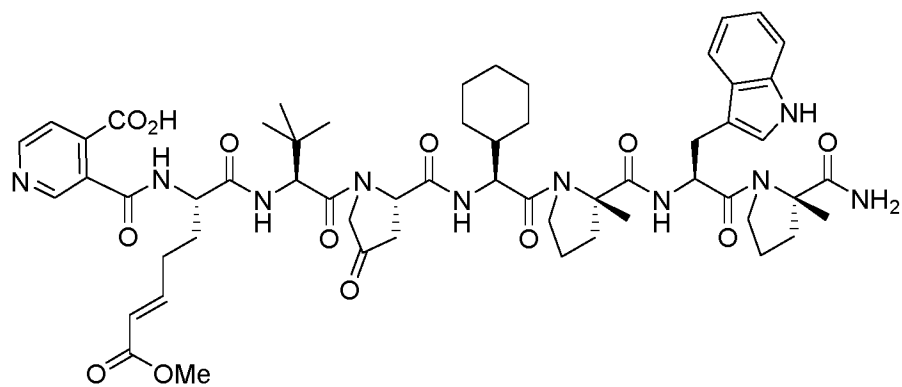
Compound 31b:



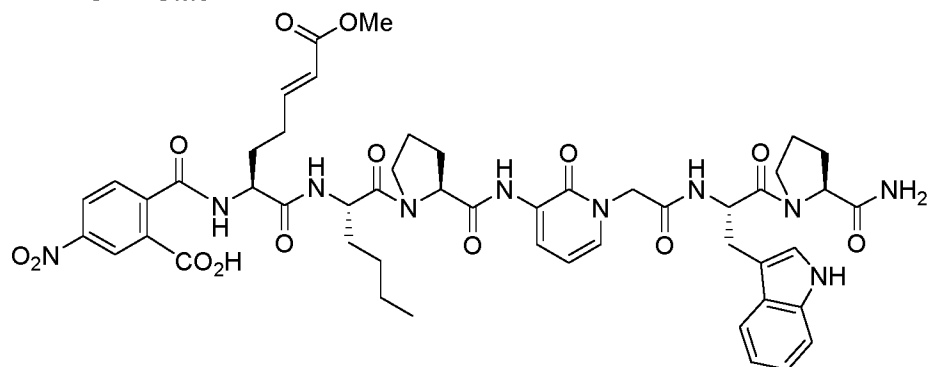
Compound 32a:



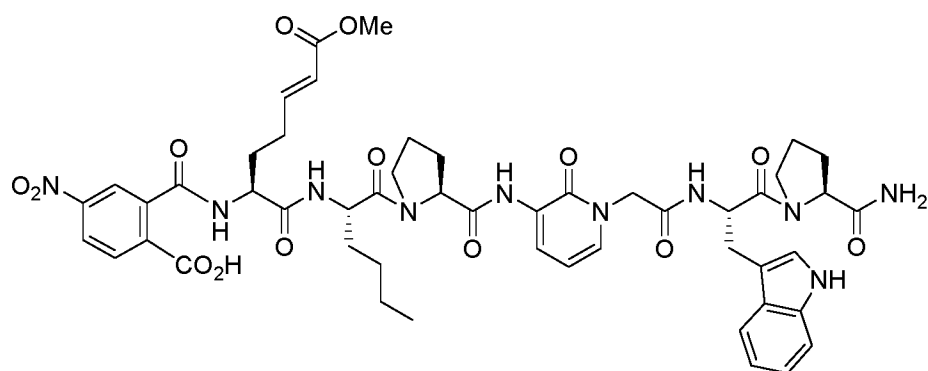
Compound 32b:



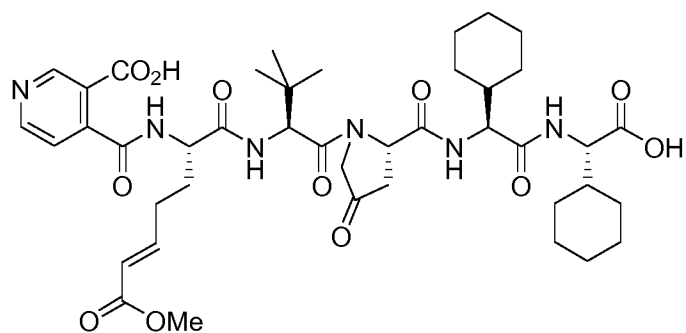
Compound 33a:



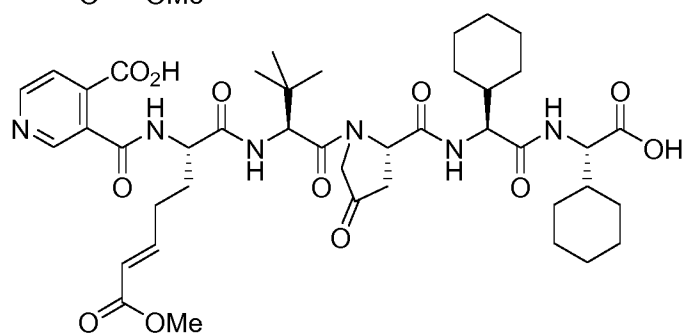
Compound 33b:



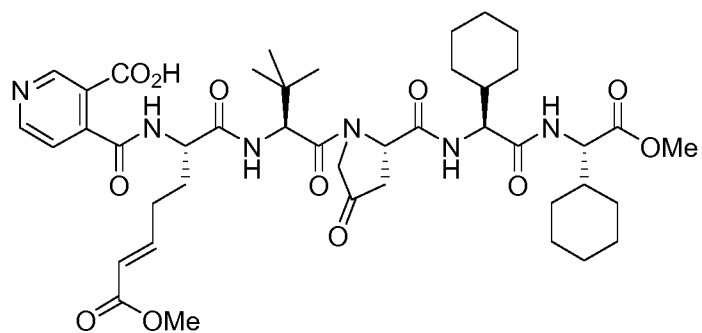
Compound 34a:



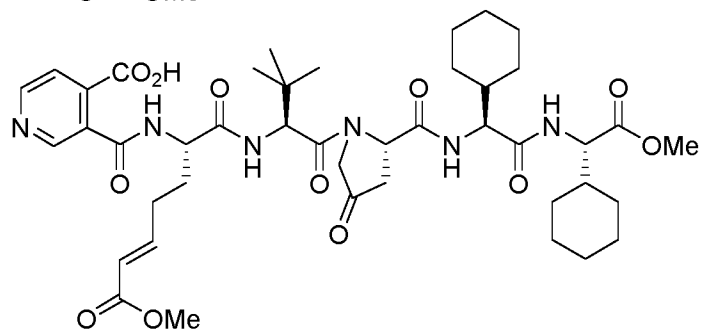
Compound 34b:



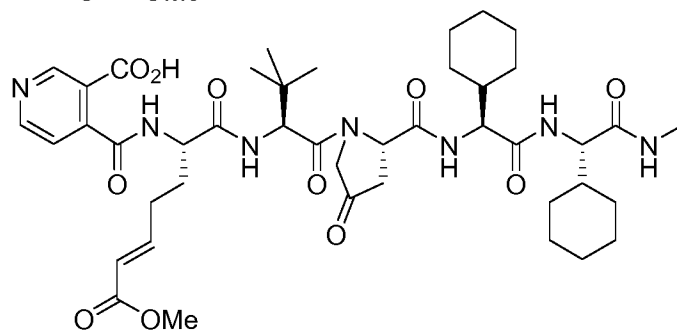
Compound 35a:



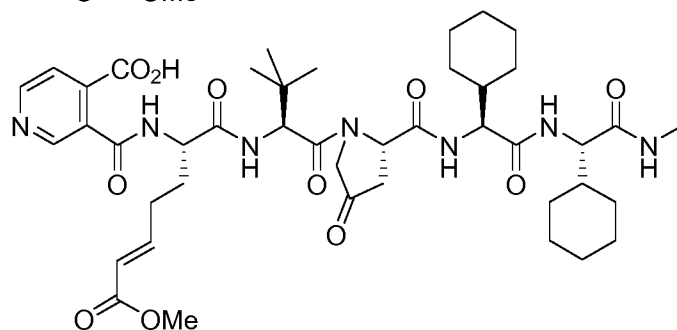
Compound 35b:



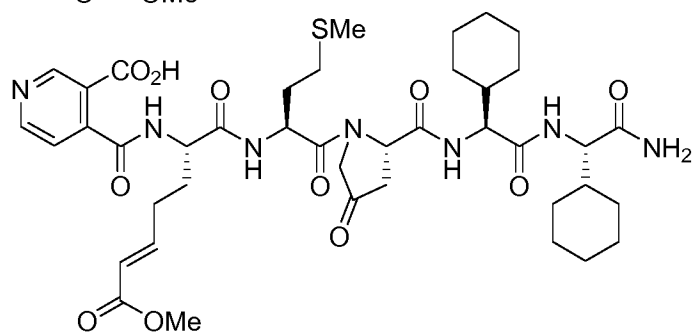
Compound 36a:



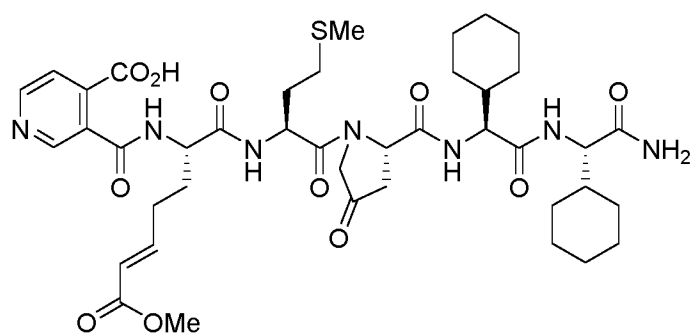
Compound 36b:



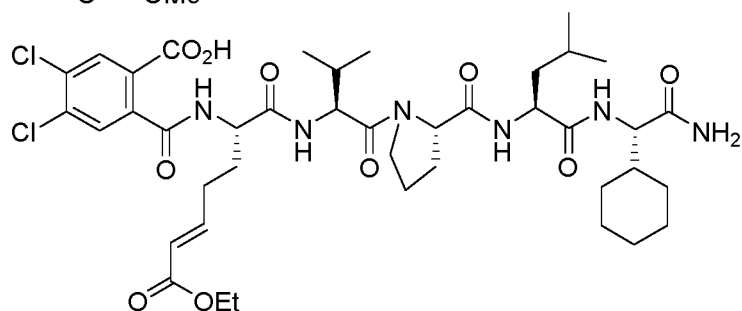
Compound 37a:



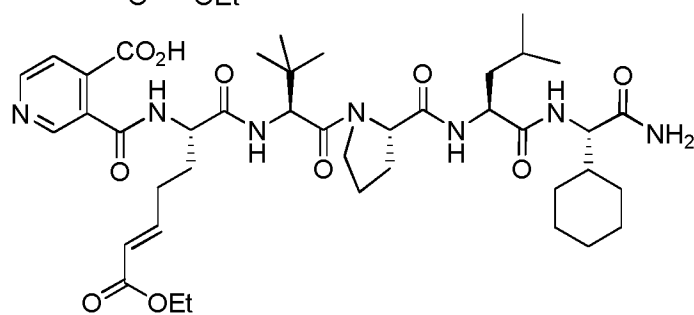
Compound 37b:



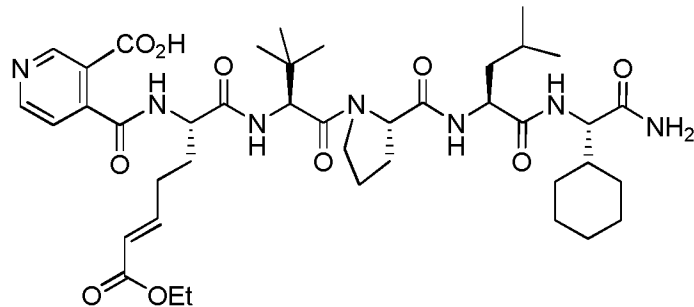
Compound 38:



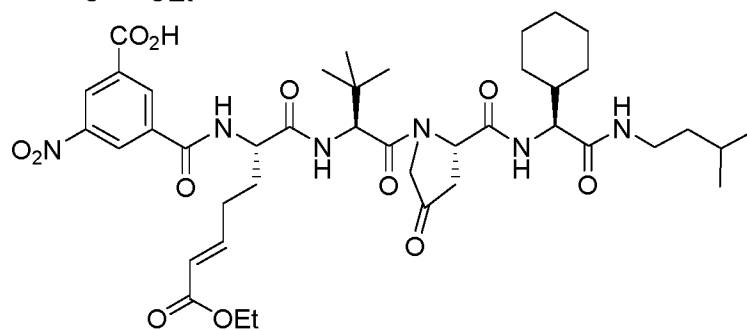
Compound 39a:



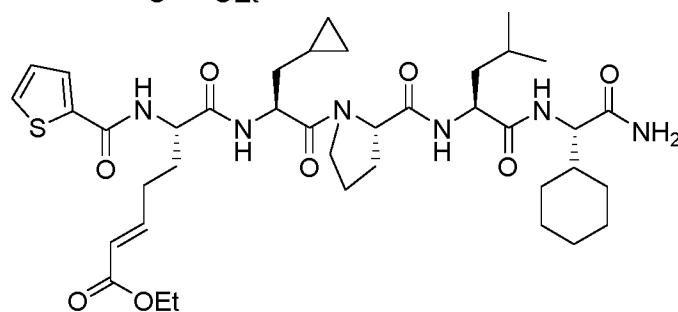
Compound 39b:



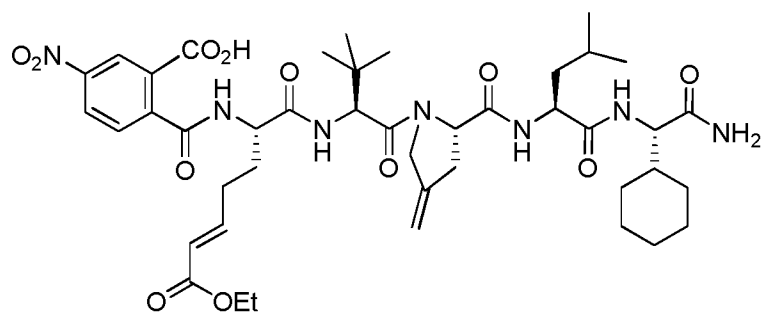
Compound 40:



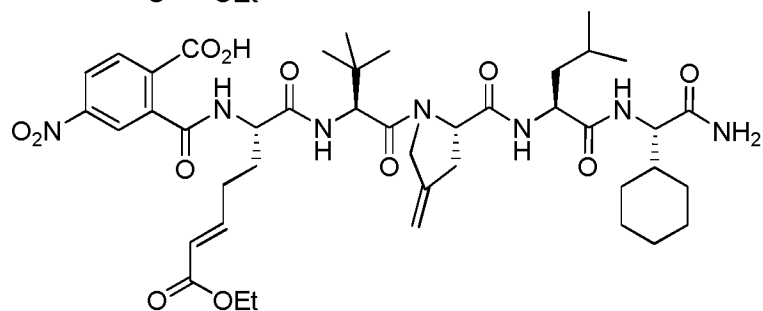
Compound 41:



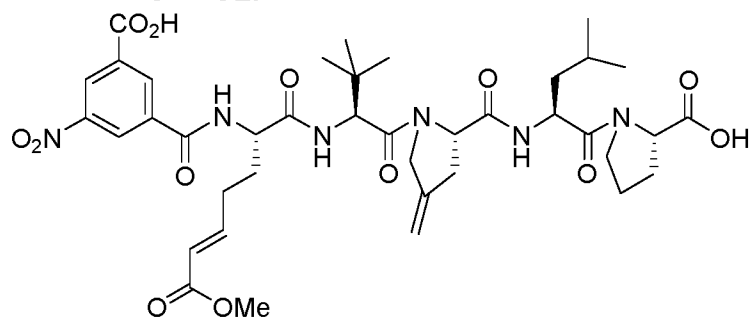
Compound 42a:



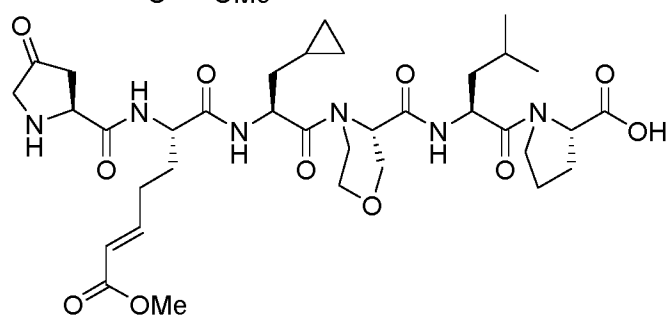
Compound 42b:



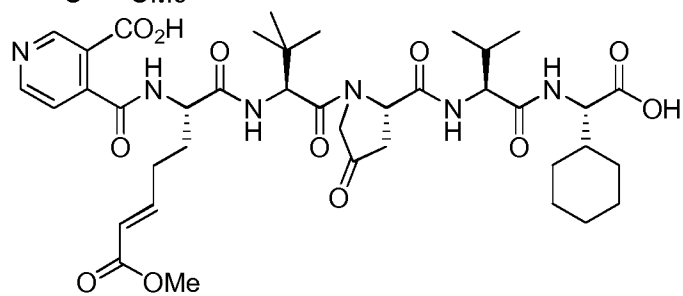
Compound 43



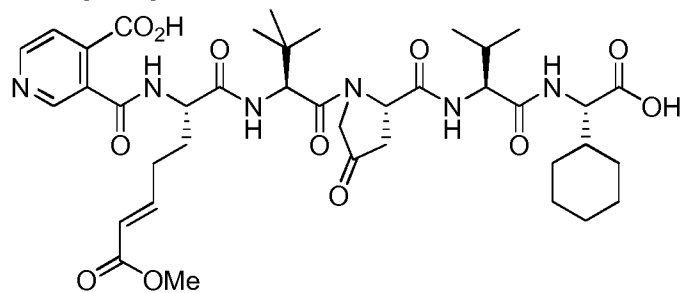
Compound 44



Compound 45a

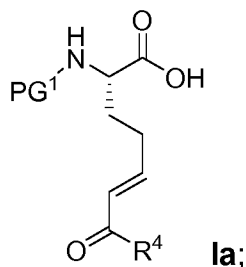


Compound 45b

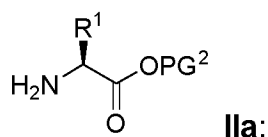


A further aspect of the present invention relates to the production of compound of the formula (I). As shown in Scheme 1, a method for producing the compound of the present invention comprises:

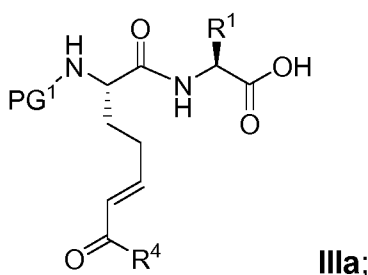
- 5 **Step (0):** providing a protected amino acid **Ia**



Step 1: (a) performing coupling reaction of the protected amino acid **Ia** with an amino acid building block **Ila**

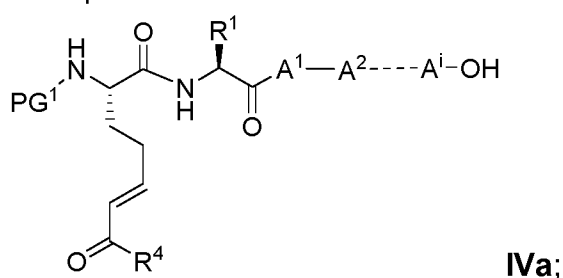


- 10 (b) deprotecting an amino protecting group PG² of a resulting compound after Step (a);
to obtain an intermediate compound **3a**

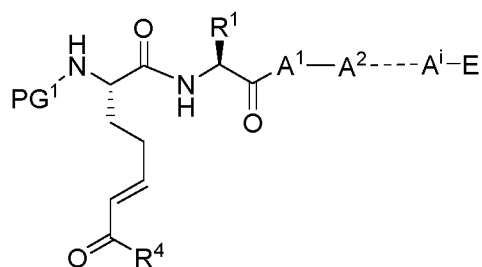


Step 2: (a) performing coupling reaction of the intermediate compound **IIIa** of Step 1 with a corresponding C-terminal amino acid building block H₂-Aⁱ-OPG³;

- 15 (b) deprotecting the protecting group PG³ of a resulting compound after Step (a);
(c) repeating the steps (a) and (b) *i* times, wherein *i* is 1-5,
to obtain an intermediate compound **IVa**

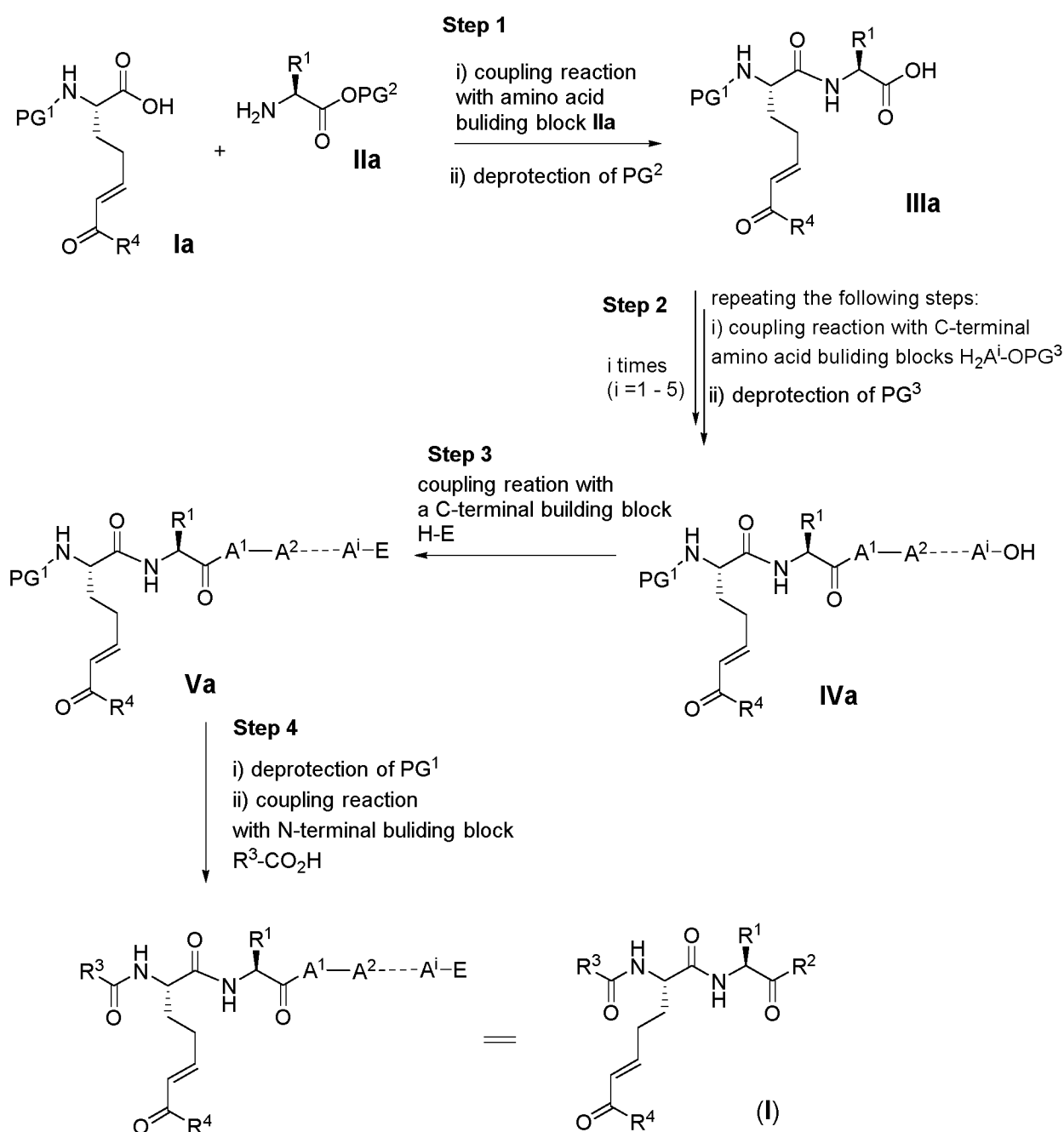


Step 3: performing coupling reaction of the intermediate compound **IVa** of Step 2 with a corresponding C-terminal building block H-**E**;
20 to obtain an intermediate compound **Va**

**Va;**

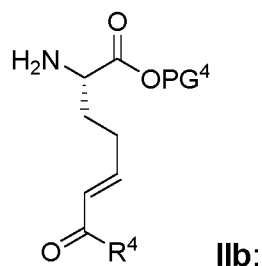
Step 4: (a) deprotecting the protecting group PG¹ of the intermediate compound **Va**;
 (b) performing coupling reaction of a resulting compound after Step (a) with a N-terminal building block R³-CO₂H to produce the compound of the formula (I).

5

Scheme 1

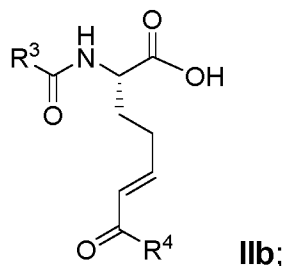
As shown in Scheme 2, an alternative method for producing the compound of the present invention comprises:

Step (0): providing a protected amino acid **IIb**

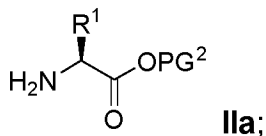


Step 1A: (a) performing coupling reaction of the protected amino acid **IIb** with a N-terminal building block R^3 -CO₂H,

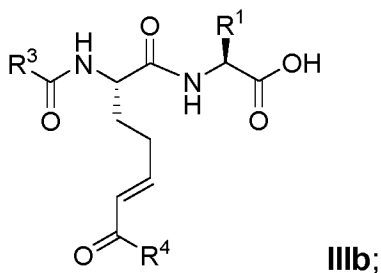
(b) deprotecting an amino protecting group PG⁴ of a resulting compound after Step (a), to obtain an intermediate compound **IIb**



Step 2A: (a) performing coupling reaction of the intermediate compound **IIb** with an amino acid building block **Ila**



(b) deprotecting an amino protecting group PG² of a resulting compound after Step (a); to obtain an intermediate compound **IIIb**

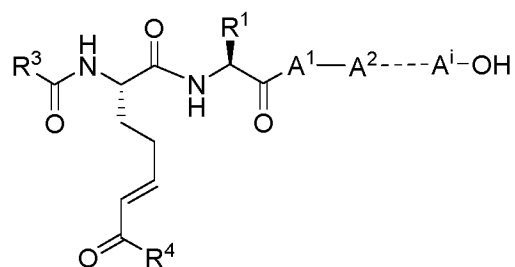


Step 3A: (a) performing coupling reaction of the intermediate compound **IIIb** with a corresponding C-terminal amino acid building block H₂-Aⁱ-OPG³;

(b) deprotecting the protecting group PG³ of a resulting compound after Step (a);

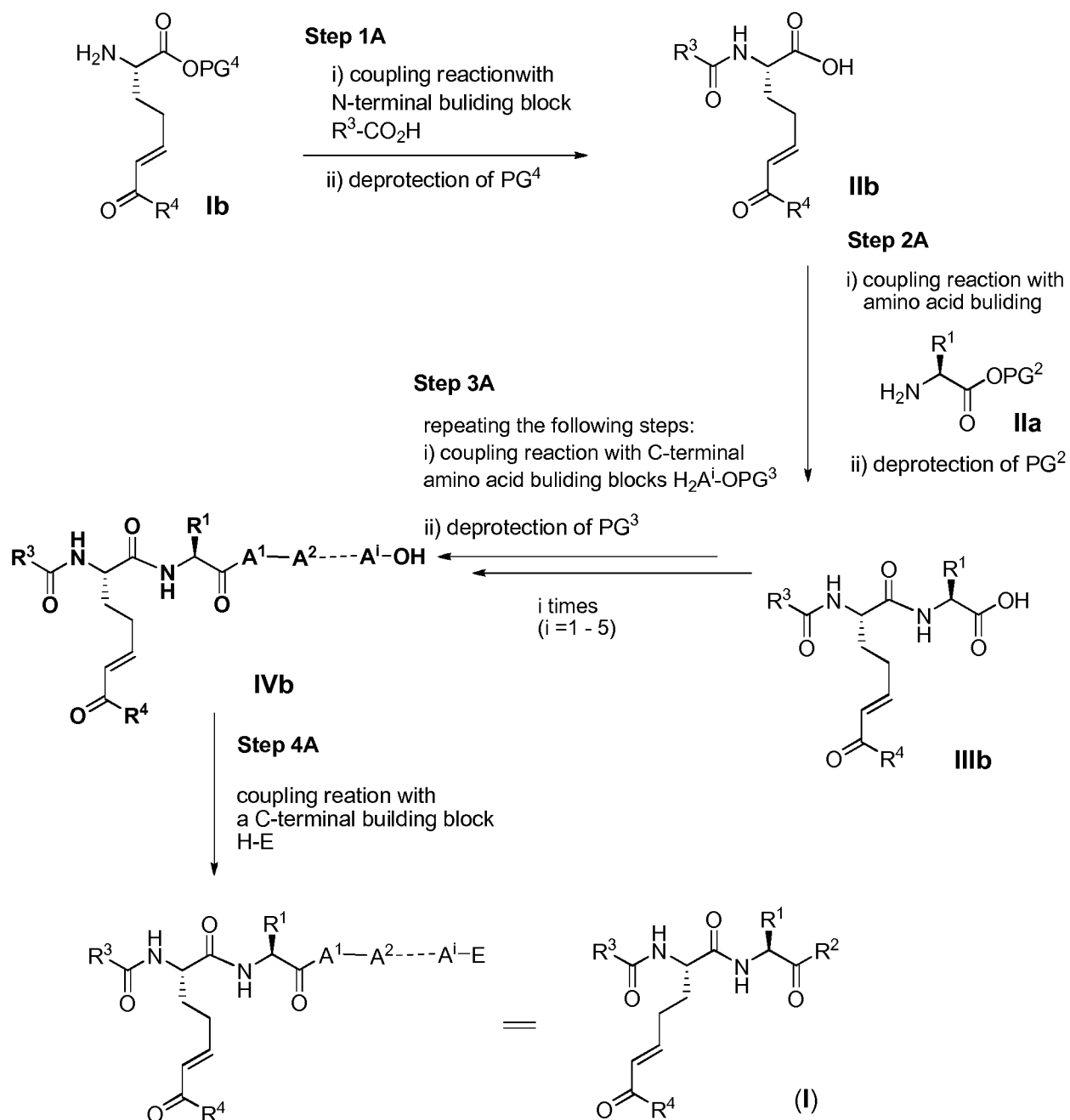
(c) repeating the steps (a) and (b) *i* times, wherein *i* is 1-5,

to obtain an intermediate compound **IVb**

**IVb;**

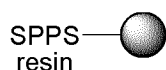
Step 4A: performing coupling reaction of the intermediate compound **IVb** with a corresponding C-terminal building block H-E to produce the compound of the formula (I).

5

Scheme 2

As shown in Scheme 3, an alternative method for producing the compound of the present invention comprises:

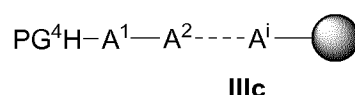
- 5 **Step (0B)**: providing a resin, suitable for solid-phase peptide synthesis (SPPS).



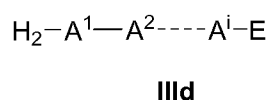
Step (1B) (a): performing coupling reaction of the corresponding C-terminal amino acid building block $\text{PG}^4\text{NH-A}^i\text{-OH}$.

(b) deprotecting the protecting group PG^4 of a resulting compound after Step (a);

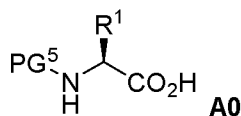
- 10 (c) repeating the steps (a) and (b) i times, wherein i is 1-5,
to obtain a resin bound intermediate compound (**IIIc**).



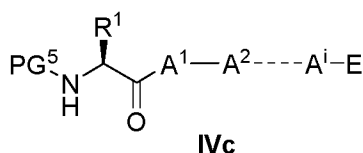
Step (2B): cleavage from resin and deprotecting the protecting group PG^4 to obtain an intermediate compound (**IIId**).



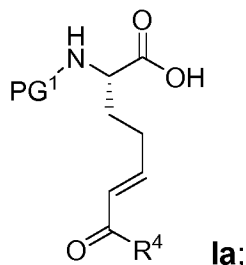
Step (3B): performing coupling reaction of the intermediate compound **IIId** with an amino acid building block **A0**



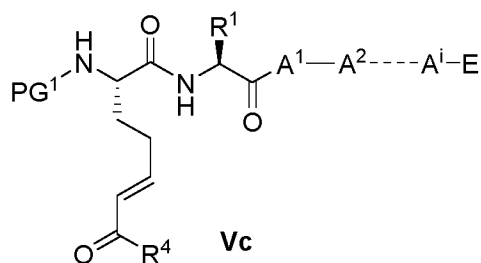
to obtain a compound **IVc**.



Step (4B): deprotecting the protecting group PG^5 and subsequent coupling reaction with protected amino acid **la**

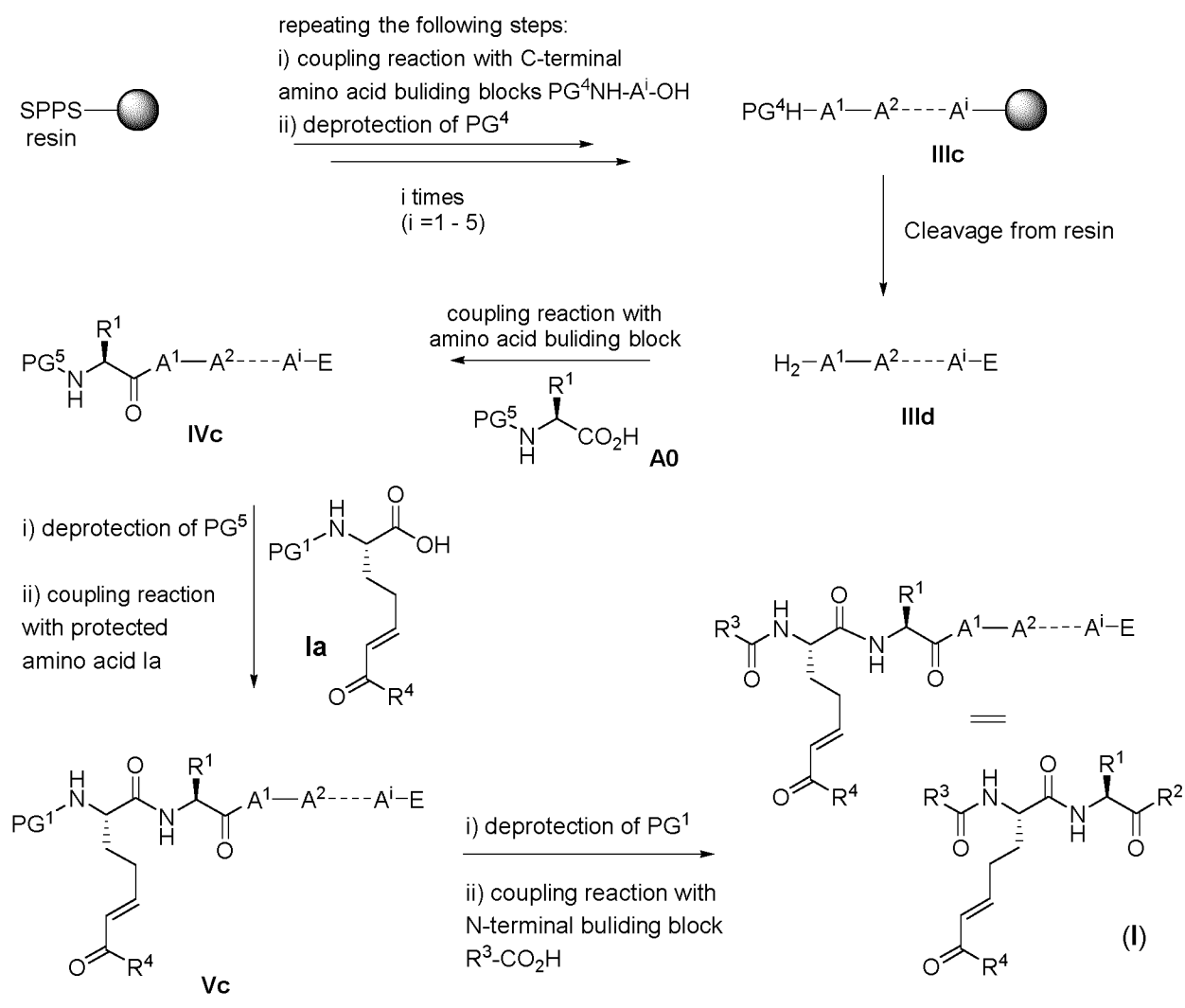


to obtain compound **Vc**



Step (5B): deprotecting the protecting group PG¹ and subsequent coupling reaction with a N-terminal building block R³-CO₂H to produce the compound of the formula (I).

Scheme 3



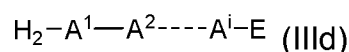
As shown in Scheme 4, an alternative method for producing the compound of the present invention comprises:

Step (0C): providing a N-deprotected C-terminal building block H-E or H-Aⁱ-E.

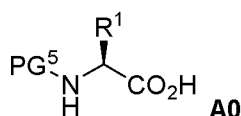
Step (1C): (a) performing coupling reaction of the corresponding C-terminal amino acid building block PG⁴NH-Aⁱ-OH or PG⁴NH-Aⁱ⁻¹-OH.

(b) deprotecting the protecting group PG⁴ of a resulting compound after Step (a);

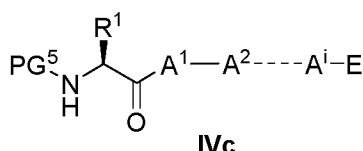
(c) repeating the steps (a) and (b) *i* times, wherein *i* is 1-5 or 1-4, to obtain intermediate compound (IIId).



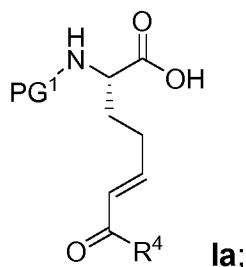
Step (3B): performing coupling reaction of the intermediate compound IIId with an amino acid building block A0



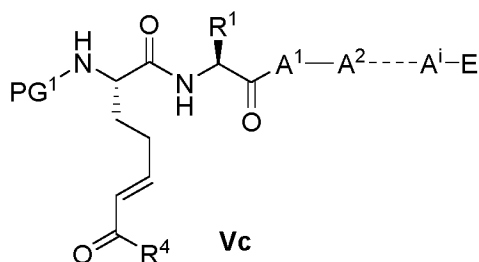
to obtain a compound IVc.



Step (4B): deprotecting the protecting group PG⁵ and subsequent coupling reaction with protected amino acid Ia

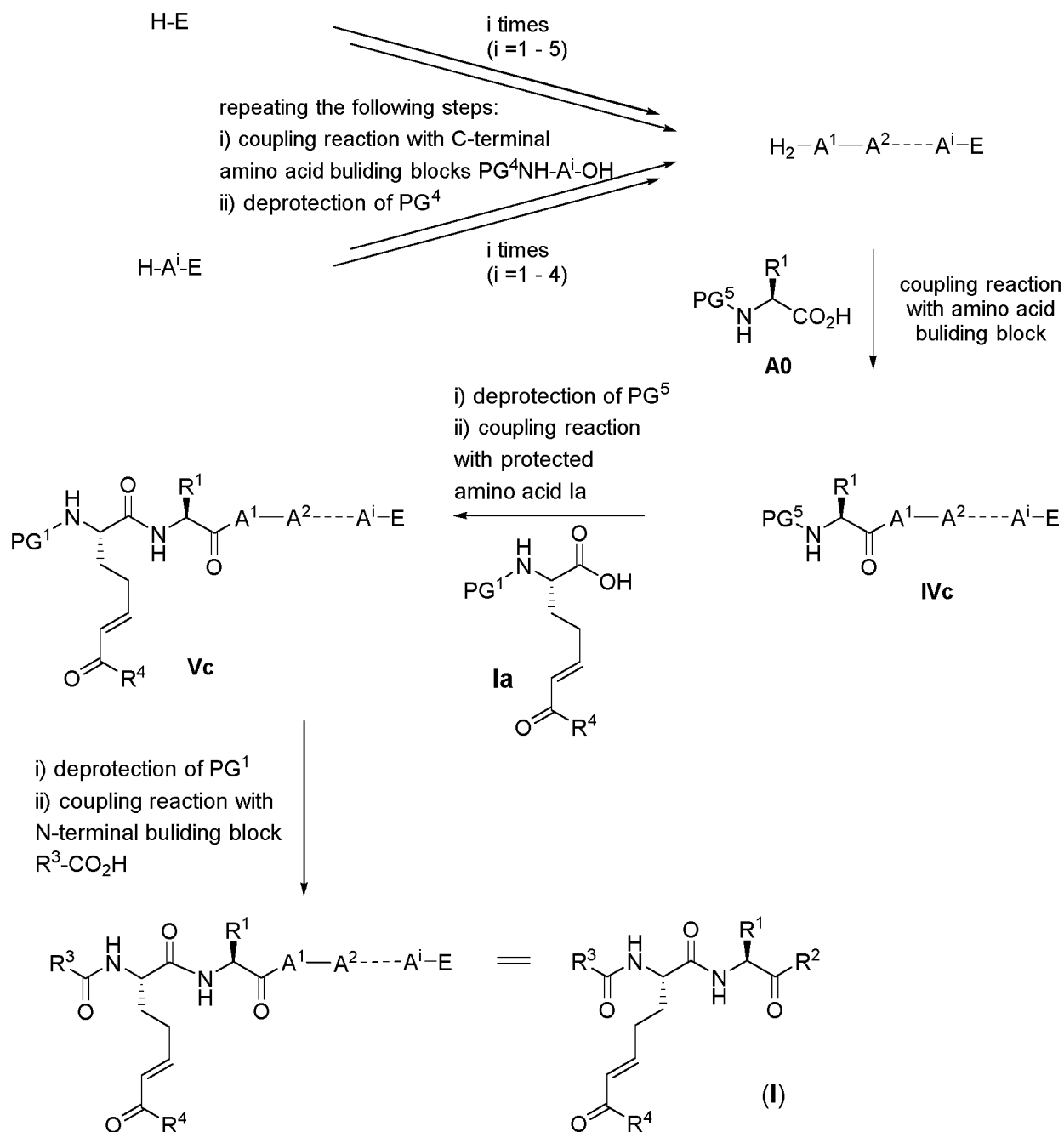


to obtain compound Vc



Step (5B): deprotecting the protecting group PG¹ and subsequent coupling reaction with a N-terminal building block R³-CO₂H to produce the compound of the formula (I).

Scheme 4

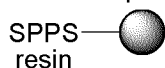


5

The above-described methods in schemes 3 and 4 may be also combined as follows:

A method for producing the compound of the present invention comprises:

- 10 **Step (0B):** providing a resin, suitable for solid-phase peptide synthesis (SPPS).

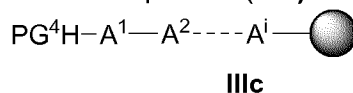


Step (1B) (a): performing coupling reaction of the corresponding C-terminal amino acid building block $\text{PG}^4\text{NH-A}^i\text{-OH}$.

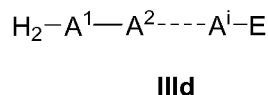
(b) deprotecting the protecting group PG^4 of a resulting compound after Step (a);

(c) repeating the steps (a) and (b) i times, wherein i is 1-5,

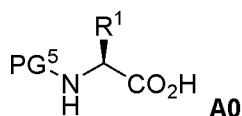
5 to obtain a resin bound intermediate compound (**IIIc**).



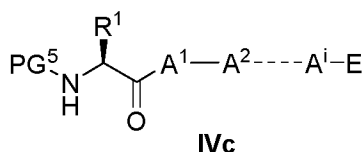
Step (2B): cleavage from resin and deprotecting the protecting group PG^4 to obtain an intermediate compound (**IIId**).



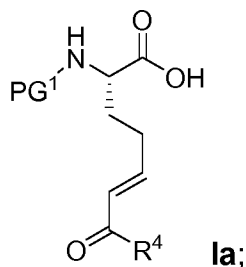
10 **Step (3B):** performing coupling reaction of the intermediate compound **IIId** with an amino acid building block **A0**



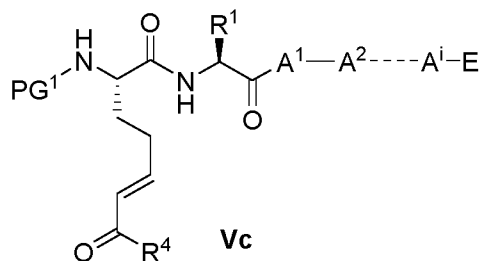
to obtain a compound **IVc**.



15 **Step (4B):** deprotecting the protecting group PG^5 and subsequent coupling reaction with protected amino acid **la**



to obtain compound **Vc**



20 **Step (5B):** deprotecting the protecting group PG^1 and subsequent coupling reaction with a N-terminal building block $\text{R}^3\text{-CO}_2\text{H}$ to produce the compound of the formula (I);

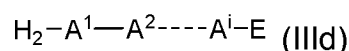
or

Step (0C): providing a N-deprotected C-terminal building block H-E or H-Aⁱ-E.

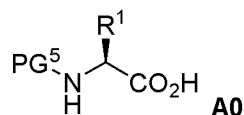
Step (1C): (a) performing coupling reaction of the corresponding C-terminal amino acid building block PG⁴NH-Aⁱ-OH or PG⁴NH-Aⁱ⁻¹-OH.

5 **(b)** deprotecting the protecting group PG⁴ of a resulting compound after Step (a);

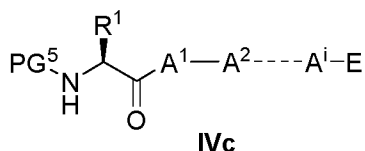
(c) repeating the steps (a) and (b) *i* times, wherein *i* is 1-5 or 1-4,
to obtain intermediate compound (III_d).



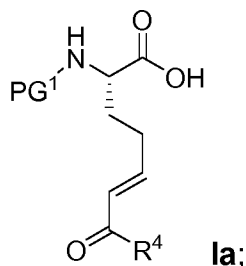
10 **Step (3B):** performing coupling reaction of the intermediate compound III_d with an amino acid building block A₀



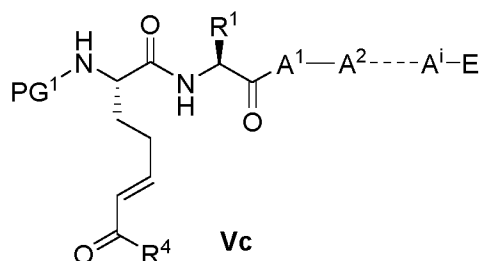
to obtain a compound IV_c.



15 **Step (4B):** deprotecting the protecting group PG⁵ and subsequent coupling reaction with protected amino acid Ia



to obtain compound V_c



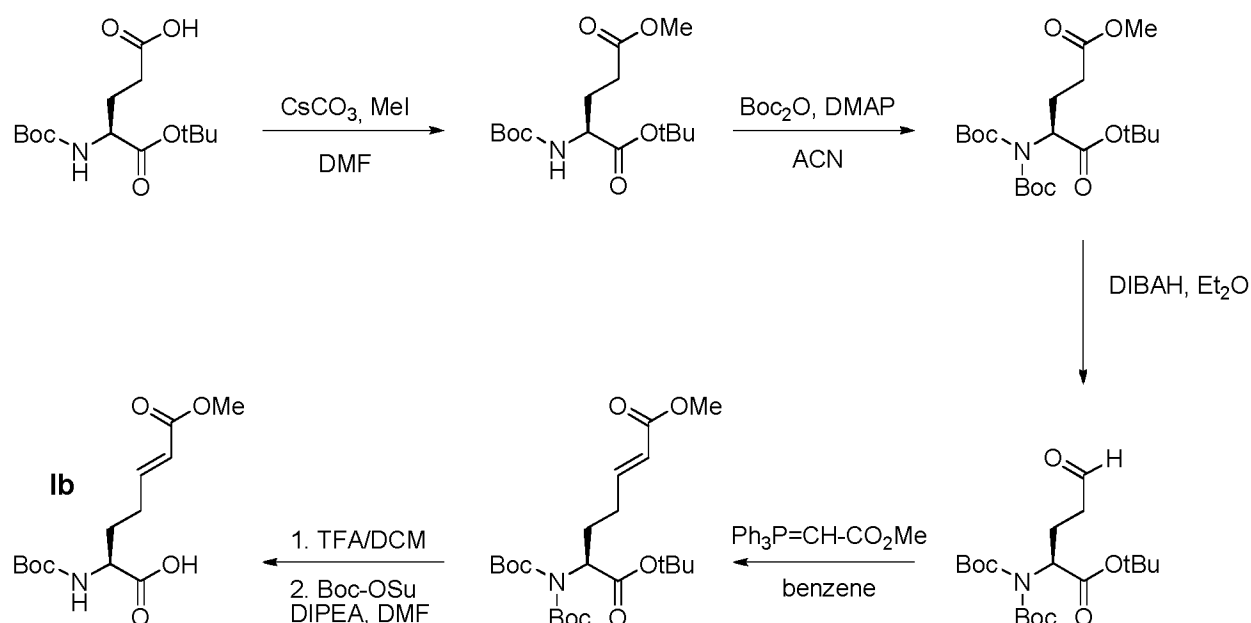
20 **Step (5B):** deprotecting the protecting group PG¹ and subsequent coupling reaction with a N-terminal building block R³-CO₂H to produce the compound of the formula (I).

25 Herein, Aⁱ represent one of A¹, A², A³, A⁴, and A⁵. H₂-Aⁱ-OPG³ means amino acid having Aⁱ (one of A¹ – A⁵) backbone and unprotected free amino (H₂N-) group and carboxyl moiety protected by PG³ group.

- The term “protecting groups” as used herein refers to commonly used protection groups in organic synthesis, preferably for amino and carboxyl groups. PG¹ and PG⁵ are suitable protecting group for amino group. PG², PG³ and PG⁴ are suitable protecting groups for carboxyl groups. Preferably, PG¹ may be selected from the group consisting of or comprising: acetyl, benzoyl, benzyloxycarbonyl (Cbz), tert-butylcarbonyl, tert-butylloxycarbonyl (Boc), and fluorenylmethylenoxy group (Fmoc). PG², PG³ and PG⁴ may be selected from the group consisting of or comprising: methoxy, ethoxy, isobutoxy, tert-butoxy, benzyloxy; preferably, tert-butoxy group.
- For the coupling reaction performed in Steps 1-4, 1A – 4A, 1B, 1C, 3B – 5B, the coupling reaction as used herein refers to commonly used in peptide synthesis. For performing the coupling reaction, firstly carboxylic acid group is activated by introducing an activating group and promote the coupling reaction with amino group of amino acid building block. The activating group of carboxylic acid may be introduced by a separate reaction or *in situ* reaction. Preferably, the activating group may be selected from the group consisting of or comprising: halides such as –F, –Br, –Cl, –I, anhydride group such as –OCOCH₃, N-oxy-benzotriazol group and N-oxy-succinimide. Preferably, the activating group is introduced *in situ* and it is well-known in peptide chemistry. Any of the following coupling reagent can be used to introduce activating group: BOP, PyBOP, AOP, PyAOP, TBTU, EEDQ, Polyphosphoric Acid (PPA), DPPA, HATU, HOBT, HOAt, DCC, EDCI, BOP-Cl, TFFH, Brop, PyBrop, and CIP.

The warhead was synthesized following the route shown in Scheme 5.

Scheme 5: Synthesis of Michael acceptor warhead Ib



The pharmaceutically acceptable salts of the compound of the present invention may be formed with organic or inorganic acids or bases. Examples of suitable acids for such acid addition salt formation are hydrochloric acid, hydrobromic acid, sulfuric acid, phosphoric acid, acetic acid, citric acid, oxalic acid, malonic acid, salicylic acid, p-aminosalicylic acid, malic acid, fumaric acid, succinic acid, ascorbic acid, maleic acid, sulfonic acid, phosphonic acid, perchloric acid, nitric acid, formic acid, propionic acid, gluconic acid, lactic acid, tartaric acid, hydroxymaleic acid, pyruvic acid, phenylacetic acid, benzoic acid, p-aminobenzoic acid, p-hydroxybenzoic acid, methanesulfonic acid, ethanesulfonic acid, nitrous acid, hydroxyethanesulfonic acid, ethylenesulfonic acid, p-toluenesulfonic acid, naphthylsulfonic acid, sulfanilic acid, camphorsulfonic acid, china acid, mandelic acid, o-methylmandelic acid, hydrogen-benzenesulfonic acid, picric acid, adipic acid, d-o-tolytartaric acid, tartronic acid, (o, m, p)-toluic acid, naphthylamine sulfonic acid, trifluoroacetic acid, and other mineral or carboxylic acids well known to those skilled in the art. The salts are prepared by contacting the free base form with a sufficient amount of the desired acid to produce a salt in the conventional manner.

In the case the inventive compounds bear acidic groups, salts could also be formed with inorganic or organic bases. Examples for suitable inorganic or organic bases are, for example, NaOH, KOH, NH_4OH , tetraalkylammonium hydroxide, lysine or arginine and the like. Salts may be prepared in a conventional manner using methods well known in the art, for example by treatment of a solution of the compound of the general formula (I) with a solution of an acid, selected out of the group mentioned above.

Therefore another aspect of the present invention relates to compound according to the general formula (I) for use as medicament as well as use thereof in medicine. Especially preferred is the use in anticoagulation and as an inhibitor of transglutaminases, in particular factor XIII.

The compounds according to general formula (I) described herein are especially suitable for the treatment and prophylaxis of diseases associated with and/or caused by transglutaminases, in particular factor XIII.

Therefore, another aspect of the present invention is the use of the inventive compounds of the general formula (I) for the treatment or prophylaxis of cardiovascular diseases, atherosclerosis, thrombosis, autoimmune diseases, neurodegenerative diseases, fibrotic disorders, dermatological diseases, wound healing and inflammatory diseases.

In particular, the compound of any one of the formulae (I), (II-1)–(II-3), (III), (III-1)–(III-2), (IV-1)–(IV-5), (V-1)–(V-2) and (VI) is useful for the treatment or prophylaxis of coeliac disease, Duhning-Brocq-disease, gluten ataxia, tissue fibrosis, cystic fibrosis, kidney fibrosis and diabetic nephropathy, liver fibrosis, cataract, ichthyosis, acne, psoriasis, skin aging, candidosis, neurodegenerative disorders including Huntington's disease, Parkinson's disease and Alzheimer's disease as well as atherosclerosis, thrombosis, thrombocytopenia and thrombopreventive indications and for use as anticoagulant in the treatment of sepsis, stroke, recurrent occlusion and acute care setting including acute kidney injury, acute lung injury and acute coronary syndrome.

Preferred potential indications for the compounds of the present invention mainly include thrombopreventive indications in groups of risk patients showing permanent plasmatic clotting activation. These groups include patients suffering from tumour diseases and, first and foremost, patients who need to undergo regular haemodialysis therapy. Preferred is anticoagulation using FXIII-inhibitors in patients with a high risk for bleeding and/or side-effects like heparin induced thrombocytopenia.

Further indications include older, multimorbid patients suffering from cardiac arrest and/or dysrhythmia, which are frequently associated with discrete vascular clotting diseases as well as progressive chronic renal diseases. Due to the unique mode-of-action, the compounds are preferred anticoagulants in the acute care setting like acute kidney injury, acute lung injury and acute coronary syndrome. Further indications include sepsis, stroke, and recurrent occlusion also in combination with plasminogen activators (e.g. tPA and uPA). However the most important indications are the prevention and treatment of atherosclerosis and thrombosis.

Due to the possible inactivation of other transglutaminase isoenzymes at least of some compounds also treatment or prophylaxis of, coeliac disease, Duhning-Brocq-disease, gluten ataxia, tissue fibrosis, cystic fibrosis, kidney fibrosis and diabetic nephropathy, liver fibrosis, cataract, ichthyosis, acne, psoriasis, skin aging and candidosis is claimed. Further blood brain barrier permeable compounds may be used for the treatment of neurodegenerative disorders including Huntington's disease, Parkinson's disease and Alzheimer's disease.

The term „transglutaminase dependent diseases“ comprises all diseases, dysfunctions or other impairments of the health, which are caused by or in connection with a dysfunction, perturbation or hyperactivity of transglutaminases in the body. Alternatively, it might be of benefit for certain at risk patients to prophylactically block a transglutaminase like FXIII e.g. in thrombophilic patients.

The particular suitability of the inventive compounds of the general formula (I) is connected to the sterical and electronical properties which result from the molecule structure. The electrophilic warhead group appears to be an essential unit of the irreversible transglutaminase inhibitors, and especially in combination with the certain peptidomimetic backbone with certain kinds of amino acids at defined positions (like the position of the conformationally constrained proline or the unnatural proline-based amino acids called herein proline derivatives or proline analogues) results in potent transglutaminase inhibitors, especially blood coagulation factor XIII and transglutaminase 2. Selectivity is obtained by implementing said components at selected positions within the backbone.

The pharmaceutical compositions according to the present invention comprise at least one compound according to the present invention. Preferably, the pharmaceutical compositions according to the present invention comprise at least one compound according to the present invention as an active ingredient together with at least one pharmaceutically acceptable (i.e. non-toxic) carrier, excipient and/or diluent.

The Pharmaceutical composition according to the present invention is useful for the treatment or prophylaxis of coeliac disease, Duhring-Brocq-disease, gluten ataxia, tissue fibrosis, cystic fibrosis, kidney fibrosis and diabetic nephropathy, liver fibrosis, cataract, ichthyosis, acne, psoriasis, skin aging, candidosis, neurodegenerative disorders including Huntington's disease, Parkinson's disease and Alzheimer's disease as well as atherosclerosis, thrombosis, thrombocytopenia and thrombopreventive indications and for use as anticoagulant in the treatment of sepsis, stroke, recurrent occlusion and acute care setting including acute kidney injury, acute lung injury and acute coronary syndrome.

The present invention also includes pharmaceutical preparations for parenteral application, including dermal, intradermal, intragastral, intracutaneous, intravasal, intravenous, intramuscular, intraperitoneal, intranasal, intravaginal, intrabuccal, percutan, rectal, subcutaneous, sublingual, topical, or transdermal application, which preparations in addition to typical vehicles and/or diluents contain at least one compound according to the present invention and/or a pharmaceutical acceptable salt thereof as active ingredient.

Liquid form preparations include solutions, suspensions, and emulsions. As an example, there may be mentioned water or water/propylene glycol solutions for parenteral injections or addition of sweeteners and opacifiers for oral solutions, suspensions, and emulsions. Liquid form preparations may also include solutions for intranasal administration. Aerosol preparations suitable for inhalation may include

solutions and solids in powder form, which may be present in combination with a pharmaceutically acceptable carrier such as an inert, compressed gas, e.g. nitrogen.

The following abbreviations are used for the common and modified amino acids referred to herein.

5

Abbreviation	Amino acid
Ala	Alanine
Arg	Arginine
Asn	Asparagine
Asp	Aspartic acid (Aspartate)
Chg	Cyclohexylglycin
Cys	Cysteine
Gln	Glutamine
Glu	Glutamic acid (Glutamate)
Gly	Glycine
His	Histidine
Ile	Isoleucine
Leu	Leucine
Lys	Lysine
Met	Methionine
Nle	Norleucine
Phe	Phenylalanine
Pro	Proline
Ser	Serine
Sec	Selenocysteine
Thr	Threonine
Trp	Tryptophan
Tyr	Tyrosine
Val	Valine

Description of the Figures

Figure 1:

A: Gel permeation chromatography of hydrolyzed fibrin-clots. Inhibition of cFXIII by compound 5 (dashed line) during fibrin clotting resulted in a shift of the main peak towards lower molecular weight products compared to control without inhibitor (solid line). Void volume (V_0) and total volume (V_t) of the GPC column as well as the apparent molecular mass of the (x)FDPs are indicated.

B: SDS-PAGE and Western blot analysis of human fibrinogen (FGN) and the main peak fractions (xFDPs/FDPs) of the gel permeation chromatography. Samples were analyzed under non-reducing conditions. SDS-PAGE revealed either the most characteristic “D-dimer” band or the “D-domain” degradation products (Fragments D). The monoclonal antibody against the fibrin γ -chain showed a pattern similar to the Coomassie staining while the novel “DD-XLink-mab” (Zedira, A076) specifically recognized the isopeptide bond in the D-dimer product.

Figure 2 shows the thromboelastogram of whole human blood spiked with compound 5. Graphs represent concentrations [μM] of 0, 0.63, 2.5, 20 μM from high MCF [mm] to low.

Figure 3: two graphs (A) and (B) show the reduction of maximum clot firmness compared to inhibitor-free control (MCFc) and the increase in clot lysis at 60 minutes compared to control (LI60c).

Figure 4:

A: Experimental schedule of the rabbit model of venous stasis and reperfusion. B.S.: Blood sample; BL: Baseline; TEG: Thromboelastography.

B: The in vivo experiment proves significantly higher flow rates after compound 5 infusion compared to PBS control animals. Data is depicted as mean $\pm$ S.E.M. ($n=6-7$)

C: The area under the curve of flow rate is in accordance to the vein flow rate. In the compound 5 group the mean areas under the curve (AUC) of the jugular flow rate normalized to baseline between time points 35 and 135 minutes are significantly higher. Data is depicted as mean $\pm$ S.E.M. ($n=6-7$).

D: The Thrombus wet weight is significantly reduced in the compound 5 group. Thrombus wet weight was determined after 135 min of infusion. Data is depicted as dot plot with mean $\pm$ S.E.M. ($n=6-7$, $p=0.0265$).

E: Most importantly the template skin bleeding time is not influenced. Template skin bleeding time was determined after 60 min of infusion. No difference between PBS and compound 5 was observed. Maximal observation time was pre-defined at 300 seconds. Data is depicted as dot plot with mean $\pm$ S.E.M. ($n=7-8$).

Examples

Following abbreviations used in the examples have the following meaning.

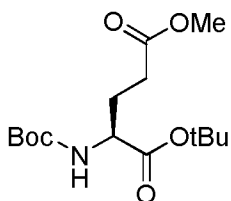
5	DMAP:	4-(Dimethylamino)-pyridine
	TEA:	Triethylamine
	DMF:	Dimethylformamide
	DIPEA:	N-Ethyldiisopropylamine
	TFA:	Trifluoroacetic acid
10	EtOAc	Ethyl acetate
	HATU	1-[Bis(dimethylamino)methylene]-1H-1,2,3-triazolo[4,5-b]pyridinium 3-oxid hexafluorophosphate
	PyAOP	(7-Azabenzotriazol-1-yloxy)tripyrrolidinophosphonium hexafluorophosphate

15

Chemical Examples

The following examples are intended to illustrate the invention with selected compounds without limiting the protecting scope of the present intellectual property right on these concrete examples. It is clear for a person skilled in the art that analogous compounds and compounds produced according to analogous synthetic ways fall under the protecting scope of the present intellectual property right.

25 Preparation of compound ZED788



(S)-1-*tert*-butyl 5-methyl 2-(*tert*-butoxycarbonylamino)pentanedioate

Chemical Formula: C₁₅H₂₇NO₆

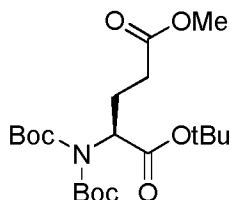
Exact Mass: 317,18

Molecular Weight: 317,38

12.0 g of Boc-L-Glu-OtBu (39.6 mmol) and 7.09 g of cesium carbonate (21.8 mmol, 0.55 eq) were suspended in 100 ml of DMF and stirred for 1 h at room temperature. 2.47 ml iodomethane (39.6 mmol) we added and the mixture was stirred at room temperature over night. The solvent was evaporated and the residue was dissolved in ethyl acetate and washed with twice with each citric acid solution (10 %), NaHCO₃ solution (10 %) and brine. The organic phase was dried over Na₂SO₄, filtered and the solvent was evaporated. The raw product was used without further purification.

Yield: 13.4 g, >100 %; ESI-MS: 318.3 [M+H]⁺

Preparation of compound ZED720



(S)-1-*tert*-butyl 5-methyl 2-(bis(*tert*-butoxycarbonyl)amino)pentanedioate

Chemical Formula: C₂₀H₃₅NO₈

Exact Mass: 417,24

Molecular Weight: 417,49

5

13.4 g of ZED788 (~39,6 mmol) and 986 mg of N,N-dimethyl-4-aminopyridine (DMAP) were dissolved in 30 ml of acetonitrile. 17.6 g of di-*tert*-butyl bicarbonate (77.1 mmol) in 100 ml of acetonitrile was added and the solution was stirred at room temperature over night. The solvent was evaporated and the residue was dissolved in ethyl acetate and washed with twice with each citric acid solution (10 %), NaHCO₃ solution (10 %) and brine. The organic phase was dried over Na₂SO₄, filtered and the solvent was evaporated. The raw product was used without further purification.

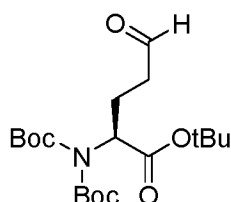
10

Yield: 13.7 g, 83 %

ESI-MS: 418.3 [M+H]⁺

15

Preparation of compound ZED721



(S)-*tert*-butyl 2-(bis(*tert*-butoxycarbonyl)amino)-5-oxopentanoate

Chemical Formula: C₁₉H₃₃NO₇

Exact Mass: 387,23

Molecular Weight: 387,47

20

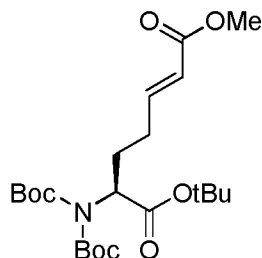
13.7 g of ZED720 (32.8 mmol) were dissolved in 200 ml of dry diethyl ether and cooled to -78°C under argon atmosphere. 36.1 ml of diisobutylaluminum hydride (1M in hexane) were added dropwise and the solution was stirred for 30 min at -78° C before being quenched with potassium sodium tartrate (Rochelle salt) solution. The organic layer was separated, dried over Na₂SO₄, filtered and concentrated to dryness. The raw

25

product was used without further purification.

Yield: 13.3 g, >100 %

ESI-MS: 388.3 [M+H]⁺

Preparation of compound ZED755

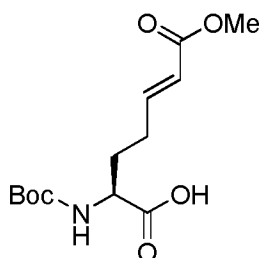
(*S,E*)-7-*tert*-butyl 1-methyl 6-(bis(*tert*-butoxycarbonyl)amino)hept-2-enedioate

Chemical Formula: $C_{22}H_{37}NO_8$

Exact Mass: 443,25

Molecular Weight: 443,53

- 5 13.3 g of ZED721 (~32.8 mmol) were dissolved in 60 ml of benzene and 11.2 g of (carbmethoxymethylene)-triphenylphosphorane (1 eq) was added portionwise. After stirring overnight, the solvent was evaporated. The residue was purified by flash chromatography.
- Yield: 12.0 g, 83 %
- 10 ESI-MS: 444.3 $[M+H]^+$

Preparation of compound Ib

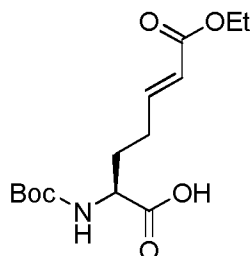
(*S,E*)-2-(*tert*-butoxycarbonylamino)-7-methoxy-7-oxohept-5-enoic acid

Chemical Formula: $C_{13}H_{21}NO_6$

Exact Mass: 287,14

Molecular Weight: 287,31

- 15 12.0 g of ZED755 (27.1 mmol) are dissolved in 100 ml DCM/TFA (1:1) and stirred at room temperature for 1 h. The solvent was evaporated and the residue was dissolved in 100 ml DMF and 9.23 ml DIPEA (2 eq). 7.15 g of N-(*tert*-Butoxycarbonyloxy)succinimide were added and the reaction was stirred at room temperature overnight. The solvent was evaporated and the residue was dissolved in ethyl acetate and washed with twice with each citric acid solution (10 %) and brine. The organic phase was dried over Na_2SO_4 , filtered and the solvent was evaporated. The residue was purified by flash chromatography.
- Yield: 5.89 g, 76 %
- ESI-MS: 288.3 $[M+H]^+$

Preparation of compound 1c

(*S,E*)-2-(*tert*-butoxycarbonylamino)-7-ethoxy-7-oxohept-5-enoic acid

Chemical Formula: C₁₄H₂₃NO₆

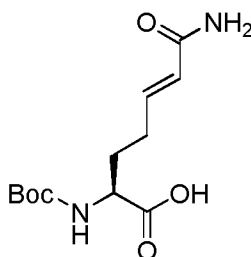
Exact Mass: 301,15

Molecular Weight: 301,34

The synthesis of **1c** was performed according to **1b**, using (carbethoxymethylene)-triphenylphosphorane in step 4.

Yield: 3.27 g, 59 % (last step)

ESI-MS: 302.3 [M+H]⁺

Preparation of compound 1d

(*S,E*)-7-amino-2-(*tert*-butoxycarbonylamino)-7-oxohept-5-enoic acid

Chemical Formula: C₁₂H₂₀N₂O₅

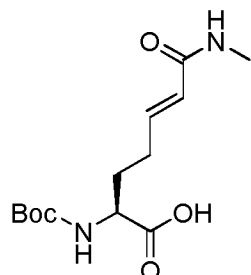
Exact Mass: 272,14

Molecular Weight: 272,30

The synthesis of **1d** was performed according to **1b**, using triphenylphosphonium carbamoylmethylide in step 4.

Yield: 623 mg, 36 % (last step)

ESI-MS: 273.3 [M+H]⁺

Preparation of compound 1e

(*S,E*)-2-(*tert*-butoxycarbonylamino)-7-(methylamino)-7-oxohept-5-enoic acid

Chemical Formula: C₁₃H₂₂N₂O₅

Exact Mass: 286,15

Molecular Weight: 286,32

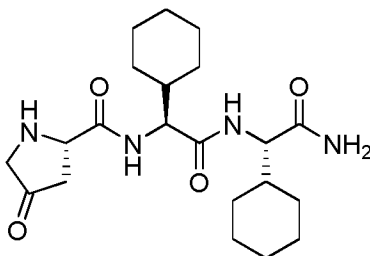
The synthesis of **1e** was performed according to **1b**, using N-methyl-triphenylphosphonium carbamoylmethylide in step 4.

Yield: 241 mg, 32 % (last step)

ESI-MS: 287.3 [M+H]⁺

5

Preparation of compound ZED3478



(S)-N-((S)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethyl)-4-oxopyrrolidine-2-carboxamide

Chemical Formula: C₂₁H₃₄N₄O₄

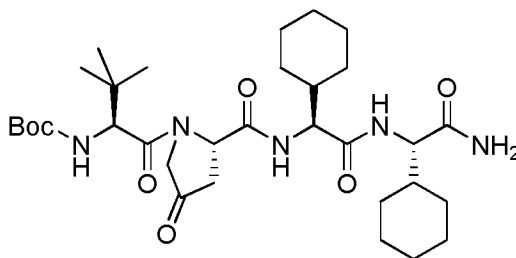
Exact Mass: 406,26

Molecular Weight: 406,52

ZED3478 was synthesized by standard Fmoc solid-phase peptide chemistry (reactions in DMF, coupling with TBTU/HOBt/DIPEA, deprotection with piperidine) using 0.41 g (0.28 mmol) Rink Amide MBHA resin as starting material. Coupling of N- α -(9-Fluorenylmethyloxycarbonyl)-L-cyclohexylglycine (twice), followed by (S)-N-Boc-4-oxopyrrolidine-2-carboxylic acid led to Boc-protected resin bound "Boc-ZED3478-resin". Subsequently, ZED3478 was cleaved from the resin (using 95% TFA / 2.5 % water / 2.5 % triisopropylsilane). The solution was reduced and the raw product (TFA salt) was precipitated from diethyl ether.

Yield: 124 mg, 85 %; ESI-MS: 407.3 [M+H]⁺

Preparation of compound ZED3480



tert-butyl (S)-1-((S)-2-((S)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylcarbamate

Chemical Formula: C₃₂H₅₃N₅O₇

Exact Mass: 619,39

Molecular Weight: 619,79

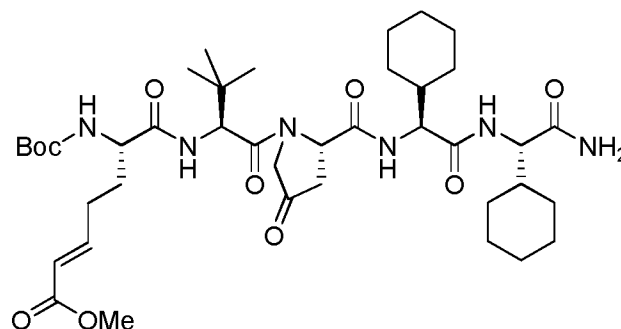
124 mg (0.24 mmol) of ZED3478 were dissolved in 5 ml DMF. 55.5 mg (1 eq) Boc-L-tert-leucine, 91.3 mg (1 eq) HATU and 81.6 μ l (2 eq) DIPEA were added and the reaction was stirred at room temperature overnight. The solvent was evaporated and the residue was dissolved in ethyl acetate and washed with twice with each citric acid

solution (10 %), NaHCO₃ solution (10 %) and brine. The organic phase was dried over Na₂SO₄, filtered and the solvent was evaporated. The raw product was used without further purification.

Yield: 119 mg, 80 %; ESI-MS: 620.5 [M+H]⁺

5

Preparation of compound ZED3481



(*S,E*)-methyl 7-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-6-(*tert*-butoxycarbonylamino)-7-oxohept-2-enoate

Chemical Formula: C₄₀H₆₄N₆O₁₀

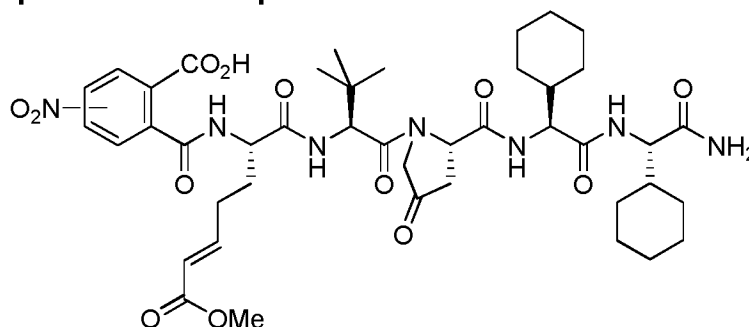
Exact Mass: 788,47

Molecular Weight: 788,97

119 mg (0.19 mmol) of ZED3480 were dissolved in 6 ml DCM/TFA (1:1) and stirred at room temperature for 1 h. The solvent was evaporated and the residue was dissolved in 5 ml DMF. 54.6 mg (1 eq) **1b**, 72.2 mg (1 eq) HATU and 64.6 μl (2 eq) DIPEA were added and the reaction was stirred at room temperature overnight. The solvent was evaporated and the residue was dissolved in ethyl acetate and washed with twice with each citric acid solution (10 %), NaHCO₃ solution (10 %) and brine. The organic phase was dried over Na₂SO₄, filtered and the solvent was evaporated. The raw product was used without further purification.

Yield: 86 mg, 57 %; ESI-MS: 789.6 [M+H]⁺

Example 1-1. Preparation of compounds 1a/b:



2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₃H₅₉N₇O₁₃

Exact Mass: 881,42

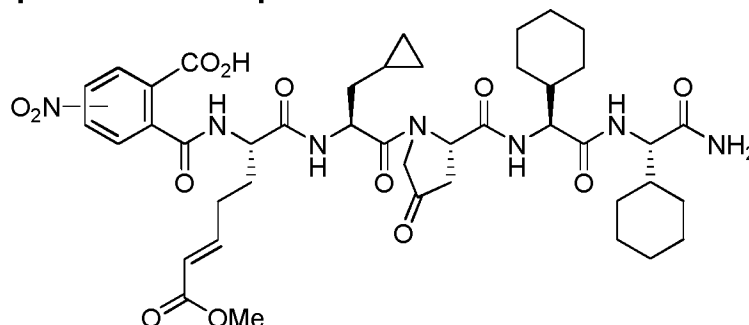
Molecular Weight: 881,97

86 mg (0.11 mmol) of ZED3481 were dissolved in 5 ml DCM/TFA (1:1) and stirred at room temperature for 1 h. The solvent was evaporated and the residue was dissolved in 3 ml DMF. 19.6 mg (1 eq) 4-nitrophthalic anhydride and 37 μ l (2 eq) DIPEA were added and the reaction was stirred at room temperature overnight. The solvent was evaporated and the residue was purified by HPLC.

Yield: 26 mg, 27 %, ratio of regioisomers: approximately 1:1

ESI-MS: 882.5 $[M+H]^+$

Example 1-2. Preparation of compounds 2a/b:



2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3-cyclopropyl-1-oxopropan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{43}H_{57}N_7O_{13}$

Exact Mass: 879,40

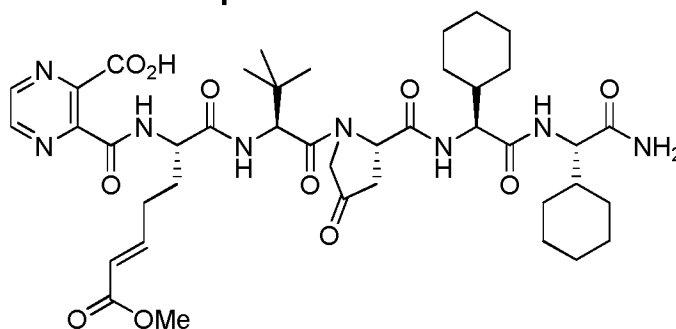
Molecular Weight: 879,95

The synthesis of example 1-2 was performed according to example 1-1, using the corresponding amino acids.

Yield: 21 mg, 36 %, ratio of regioisomers: approximately 1:1

ESI-MS: 880.5 $[M+H]^+$

Example 1-3. Preparation of compound 3:



3-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)pyrazine-2-carboxylic acid

Chemical Formula: $C_{41}H_{58}N_8O_{11}$

Exact Mass: 838,42

Molecular Weight: 838,95

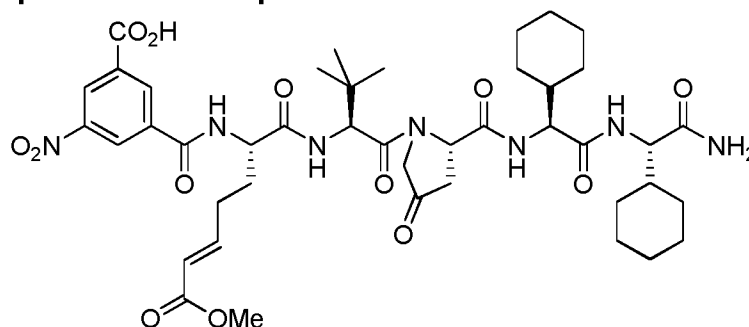
The synthesis of example 1-3 was performed according to example 1-1, using the corresponding anhydride.

Yield: 39 mg, 49 %

ESI-MS: 839.5 [M+H]⁺

5

Example 1-4. Preparation of compound 4:



3-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-5-nitrobenzoic acid

Chemical Formula: C₄₃H₅₉N₇O₁₃

Exact Mass: 881,42

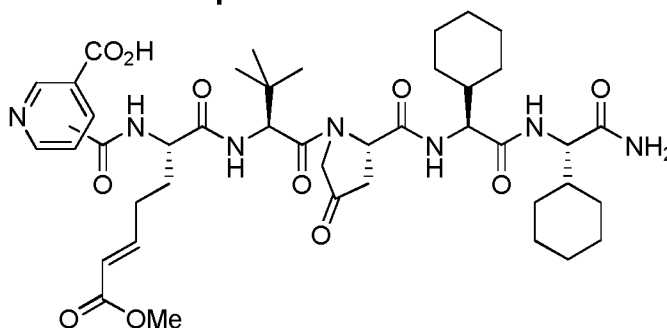
Molecular Weight: 881,97

The synthesis of example 1-4 was performed according to example 1-1, using the corresponding carboxylic acid.

10 Yield: 18 mg, 26 %

ESI-MS: 882.5 [M+H]⁺

Example 1-5. Preparation of compounds 5a/b:



3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: C₄₂H₅₉N₇O₁₁

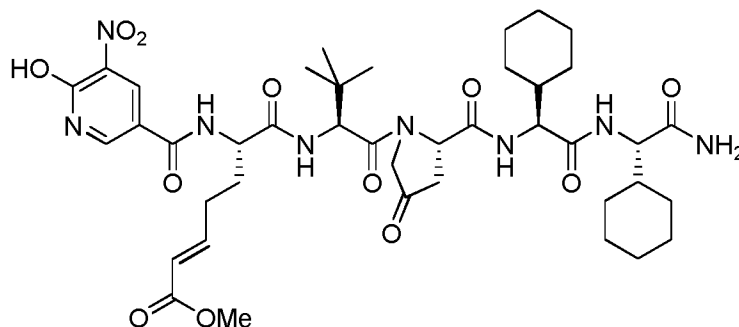
Exact Mass: 837,43

Molecular Weight: 837,96

15 The synthesis of example 1-5 was performed according to example 1-1, using the corresponding anhydride.

Yield: 1.03 g, 48 %, ratio of regioisomers: approximately 1:1

ESI-MS: 838.6 [M+H]⁺

Example 1-6. Preparation of compound 6:

(*S,E*)-methyl 7-(((*S*)-1-(((*S*)-2-(((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-6-(6-hydroxy-5-nitronicotinamido)-7-oxohept-2-enoate

Chemical Formula: $C_{41}H_{58}N_8O_{12}$

Exact Mass: 854,42

Molecular Weight: 854,95

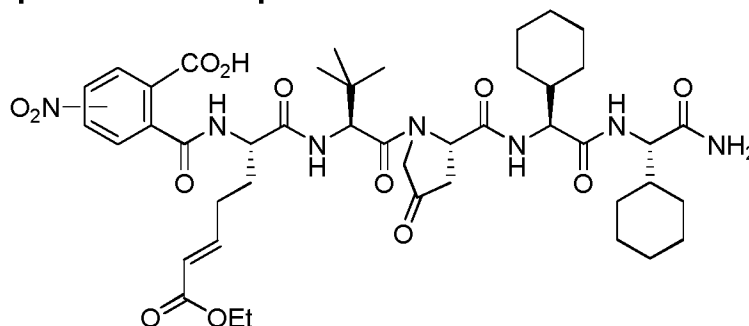
5

The synthesis of example 1-6 was performed according to example 1-1, using the corresponding carboxylic acid.

Yield: 12 mg, 18 %

ESI-MS: 855.5 $[M+H]^+$

10

Example 1-7. Preparation of compounds 7a/b:

2-(((*S,E*)-1-(((*S*)-1-(((*S*)-2-(((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-ethoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{44}H_{61}N_7O_{13}$

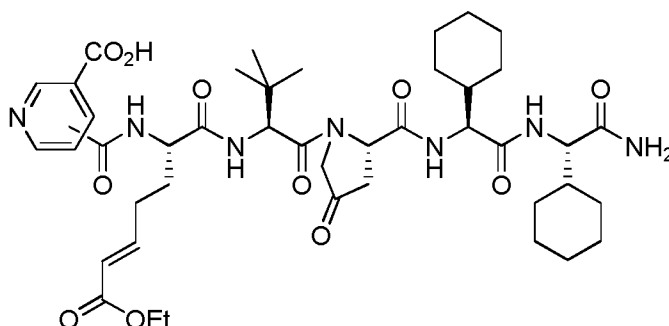
Exact Mass: 895,43

Molecular Weight: 895,99

15 The synthesis of example 1-7 was performed according to example 1-1, using the corresponding building block **1c**.

Yield: 63 mg, 52 %, ratio of regioisomers: approximately 1:1

ESI-MS: 896.6 $[M+H]^+$

Example 1-8. Preparation of compounds 8a/b:

3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-ethoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: $C_{43}H_{61}N_7O_{11}$

Exact Mass: 851,44

Molecular Weight: 851,98

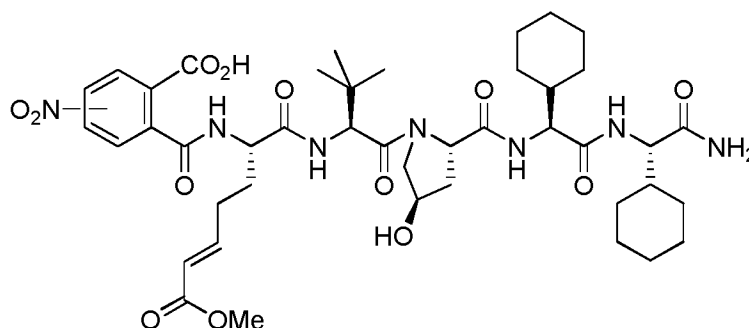
5

The synthesis of example 1-8 was performed according to example 1-1, using the corresponding anhydride and building block **1c**.

Yield: 46 mg, 49 %, ratio of regioisomers: approximately 1:1

ESI-MS: 852.6 $[M+H]^+$

10

Example 1-9. Preparation of compounds 9a/b:

2-((*S,E*)-1-((*S*)-1-((2*S,4R*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-hydroxypyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{43}H_{61}N_7O_{13}$

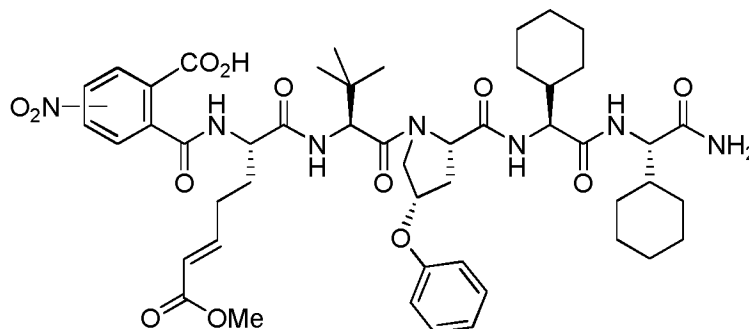
Exact Mass: 883,43

Molecular Weight: 883,98

15 The synthesis of example 1-9 was performed according to example 1-1, using the corresponding amino acids.

Yield: 79 mg, 56 %, ratio of regioisomers: approximately 1:1

ESI-MS: 884.6 $[M+H]^+$

Example 1-10. Preparation of compounds 10a/b:

2-((*S,E*)-1-((*S*)-1-((2*S,4S*)-2-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-phenoxy-2-oxo-1,3-dioxolane-5-carbamoyl)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{49}H_{65}N_7O_{13}$

Exact Mass: 959,46

Molecular Weight: 960,08

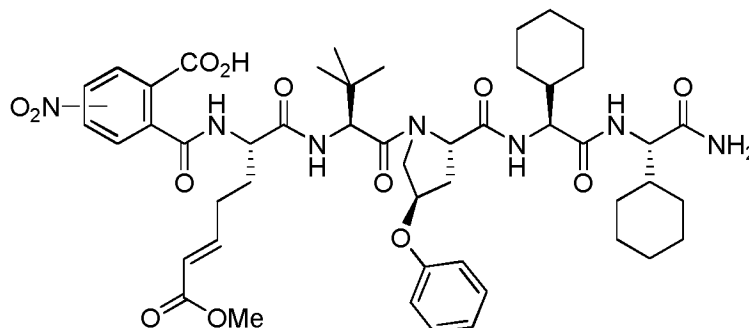
5

The synthesis of example 1-10 was performed according to example 1-1, using the corresponding amino acids.

Yield: 21 mg, 32 %, ratio of regioisomers: approximately 1:1

ESI-MS: 960.6 $[M+H]^+$

10

Example 1-11. Preparation of compounds 11a/b:

2-((*S,E*)-1-((*S*)-1-((2*S,4R*)-2-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-phenoxy-2-oxo-1,3-dioxolane-5-carbamoyl)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{49}H_{65}N_7O_{13}$

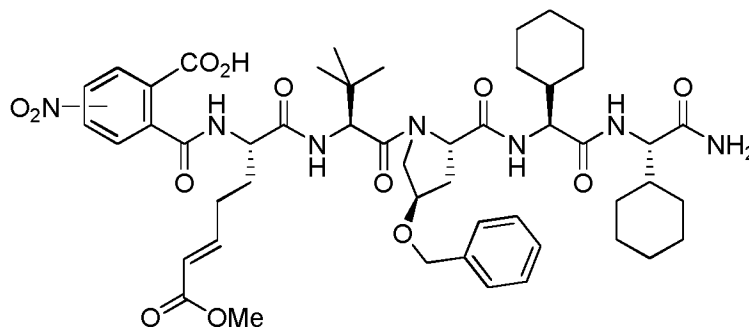
Exact Mass: 959,46

Molecular Weight: 960,08

15 The synthesis of example 1-11 was performed according to example 1-1, using the corresponding amino acids.

Yield: 36 mg, 43 %, ratio of regioisomers: approximately 1:1

ESI-MS: 960.6 $[M+H]^+$

Example 1-12. Preparation of compounds 12a/b:

2-((*S,E*)-1-((*S*)-1-((2*S,4R*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-(benzyloxy)pyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₅₀H₆₇N₇O₁₃

Exact Mass: 973,48

Molecular Weight: 974,11

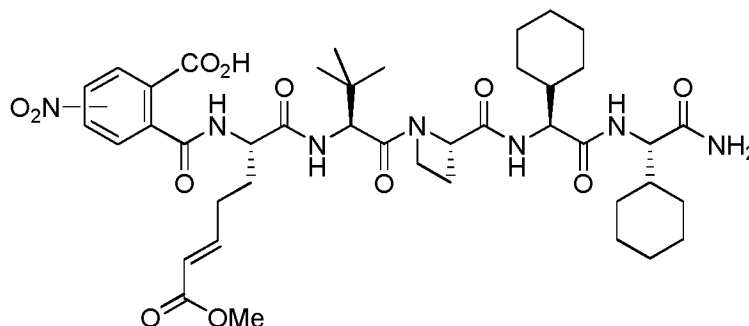
5

The synthesis of example 1-12 was performed according to example 1-1, using the corresponding amino acids.

Yield: 13 mg, 23 %, ratio of regioisomers: approximately 1:1

ESI-MS: 974.6 [M+H]⁺

10

Example 1-13. Preparation of compounds 13a/b:

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)azetidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₂H₅₉N₇O₁₂

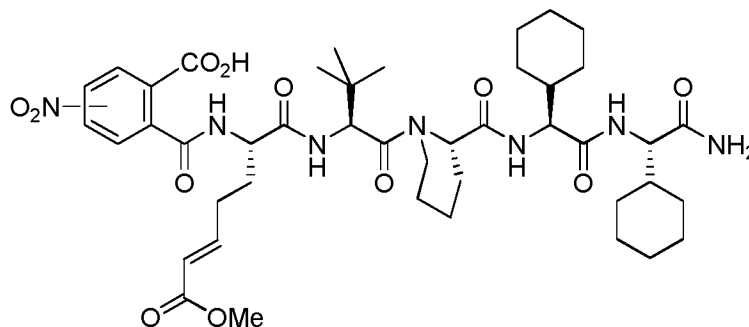
Exact Mass: 853,42

Molecular Weight: 853,96

15 The synthesis of example 1-13 was performed according to example 1-1, using the corresponding amino acids.

Yield: 36 mg, 56 %, ratio of regioisomers: approximately 1:1

ESI-MS: 854.5 [M+H]⁺

Example 1-14. Preparation of compounds 14a/b:

2-((S,E)-1-((S)-1-((R)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)piperidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{44}H_{63}N_7O_{12}$

Exact Mass: 881,45

Molecular Weight: 882,01

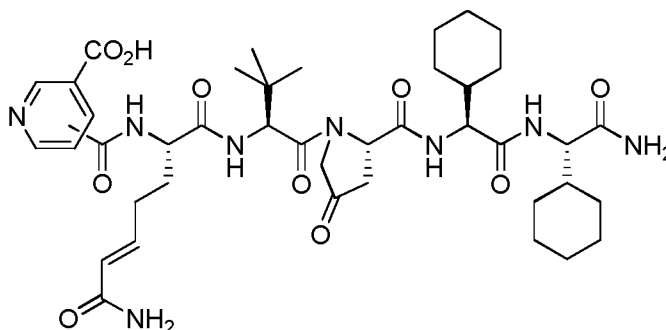
5

The synthesis of example 1-14 was performed according to example 1-1, using the corresponding amino acids.

Yield: 26 mg, 41 %, ratio of regioisomers: approximately 1:1

ESI-MS: 882.5 $[M+H]^+$

10

Example 1-15. Preparation of compounds 15a/b:

3/4-((S,E)-7-amino-1-((S)-1-((S)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: $C_{41}H_{58}N_8O_{10}$

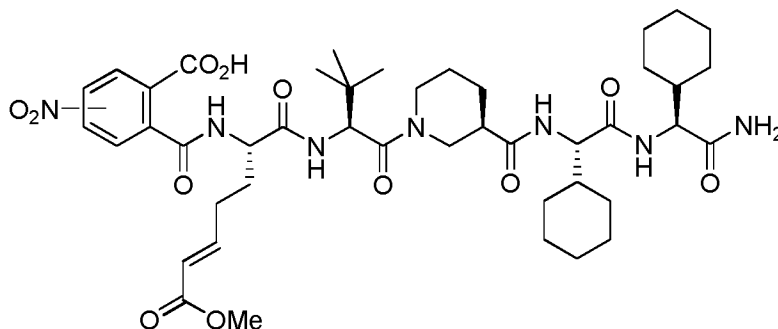
Exact Mass: 822,43

Molecular Weight: 822,95

15 The synthesis of example 1-15 was performed according to example 1-1, using the corresponding anhydride and building block **Id**.

Yield: 18 mg, 26 %, ratio of regioisomers: approximately 1:1

ESI-MS: 823.6 $[M+H]^+$

Example 1-16. Preparation of compounds 16a/b:

2-((*S,E*)-1-((*S*)-1-((*R*)-3-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)piperidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₄H₆₃N₇O₁₂

Exact Mass: 881,45

Molecular Weight: 882,01

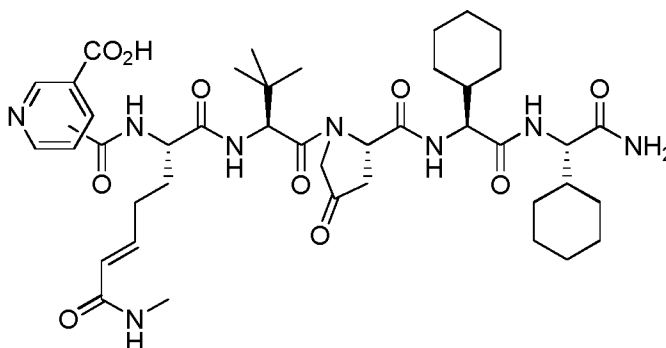
5

The synthesis of example 1-16 was performed according to example 1-1, using the corresponding amino acids.

Yield: 39 mg, 56 %, ratio of regioisomers: approximately 1:1

ESI-MS: 882.6 [M+H]⁺

10

Example 1-17. Preparation of compounds 17a/b:

3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-(methylamino)-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: C₄₂H₆₀N₈O₁₀

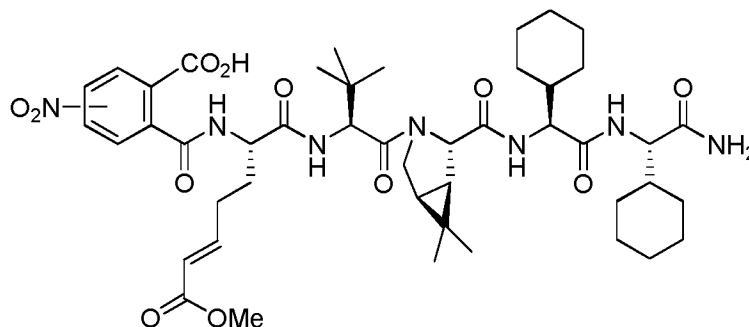
Exact Mass: 836,44

Molecular Weight: 836,97

15 The synthesis of example 1-17 was performed according to example 1-1, using the corresponding anhydride and building block **1e**.

Yield: 9 mg, 23 %, ratio of regioisomers: approximately 1:1

ESI-MS: 837.6 [M+H]⁺

Example 1-18. Preparation of compounds 18a/b:

2-((*S,E*)-1-((*S*)-1-((1*R*,2*S*,5*S*)-2-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-6,6-dimethyl-3-azabicyclo[3.1.0]hexan-3-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{46}H_{65}N_7O_{12}$

Exact Mass: 907,47

Molecular Weight: 908,05

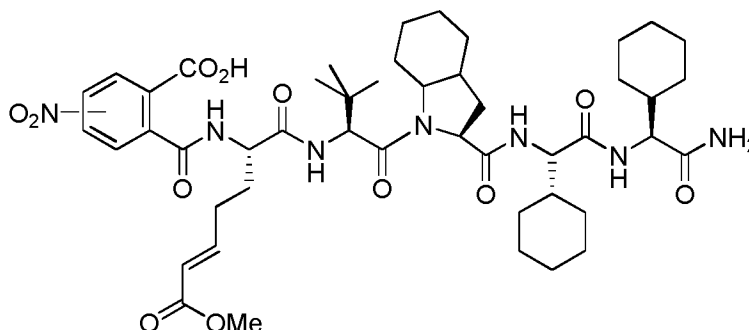
5

The synthesis of example 1-18 was performed according to example 1-1, using the corresponding amino acids.

Yield: 17 mg, 31 %, ratio of regioisomers: approximately 1:1

ESI-MS: 908.6 $[M+H]^+$

10

Example 1-19. Preparation of compounds 19a/b:

2-((2*S,E*)-1-((2*S*)-1-((2*S*)-2-((*R*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)octahydro-1*H*-indol-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{47}H_{67}N_7O_{12}$

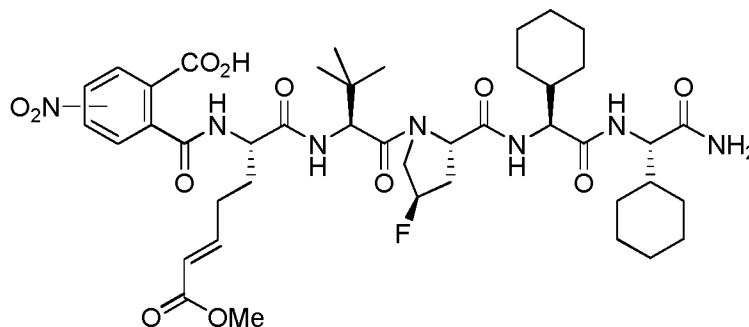
Exact Mass: 921,48

Molecular Weight: 922,07

15 The synthesis of example 1-19 was performed according to example 1-1, using the corresponding amino acids.

Yield: 25 mg, 36 %, ratio of regioisomers: approximately 1:1

ESI-MS: 922.7 $[M+H]^+$

Example 1-20. Preparation of compounds 20a/b:

2-((*S,E*)-1-((*S*)-1-((2*S,4R*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-fluoropyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₃H₆₀FN₇O₁₂

Exact Mass: 885,43

Molecular Weight: 885,97

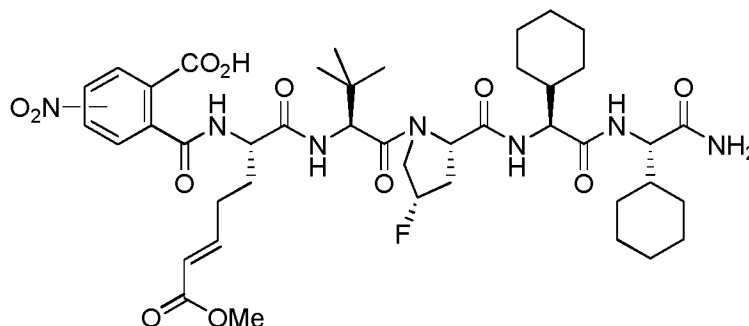
5

The synthesis of example 1-20 was performed according to example 1-1, using the corresponding amino acids.

Yield: 12 mg, 29 %, ratio of regioisomers: approximately 1:1

ESI-MS: 886.6 [M+H]⁺

10

Example 1-21. Preparation of compounds 21a/b:

2-((*S,E*)-1-((*S*)-1-((2*S,4S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-fluoropyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₃H₆₀FN₇O₁₂

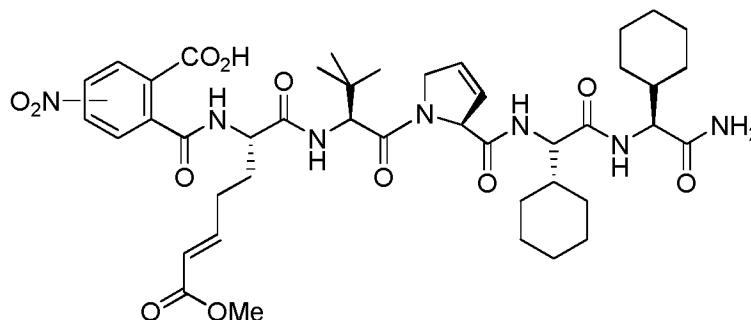
Exact Mass: 885,43

Molecular Weight: 885,97

15 The synthesis of example 1-21 was performed according to example 1-1, using the corresponding amino acids.

Yield: 19 mg, 36 %, ratio of regioisomers: approximately 1:1

ESI-MS: 886.6 [M+H]⁺

Example 1-22. Preparation of compounds 22a/b:

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*R*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-2,5-dihydro-1*H*-pyrrol-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₃H₅₉N₇O₁₂

Exact Mass: 865,42

Molecular Weight: 865,97

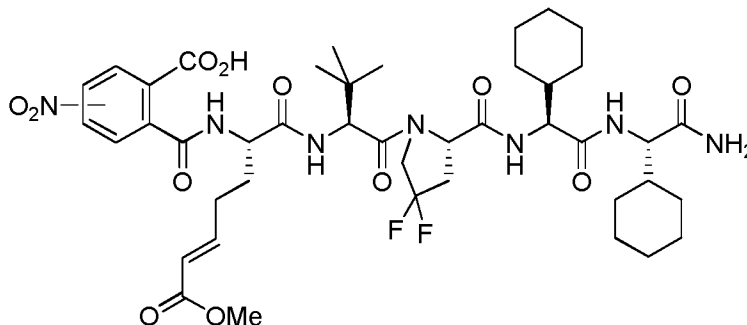
5

The synthesis of example 1-22 was performed according to example 1-1, using the corresponding amino acids.

Yield: 36 mg, 53 %, ratio of regioisomers: approximately 1:1

ESI-MS: 866.6 [M+H]⁺

10

Example 1-23. Preparation of compounds 23a/b:

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4,4-difluoropyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₃H₅₉F₂N₇O₁₂

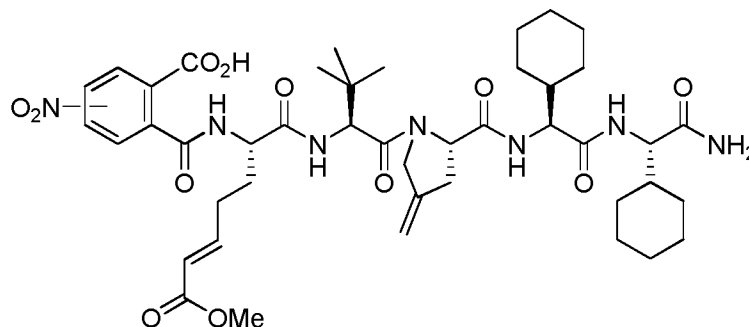
Exact Mass: 903,42

Molecular Weight: 903,97

15 The synthesis of example 1-23 was performed according to example 1-1, using the corresponding amino acids.

Yield: 14 mg, 26 %, ratio of regioisomers: approximately 1:1

ESI-MS: 904.5 [M+H]⁺

Example 1-24. Preparation of compounds 24a/b:

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-methylenepyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{44}H_{61}N_7O_{12}$

Exact Mass: 879,44

Molecular Weight: 879,99

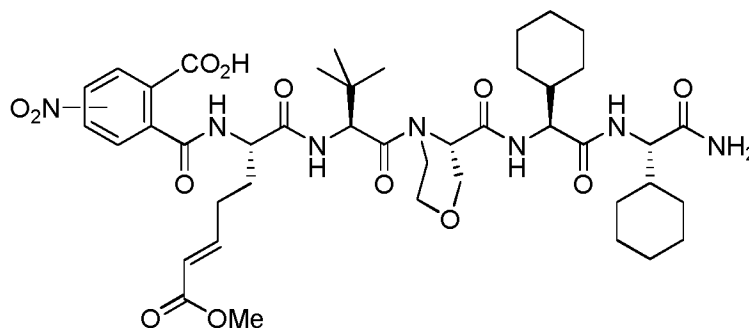
5

The synthesis of example 1-24 was performed according to example 1-1, using the corresponding amino acids.

Yield: 23 mg, 32 %, ratio of regioisomers: approximately 1:1

ESI-MS: 880.6 $[M+H]^+$

10

Example 1-25. Preparation of compounds 25a/b:

2-((*S,E*)-1-((*S*)-1-((*R*)-3-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)morpholino)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{43}H_{61}N_7O_{13}$

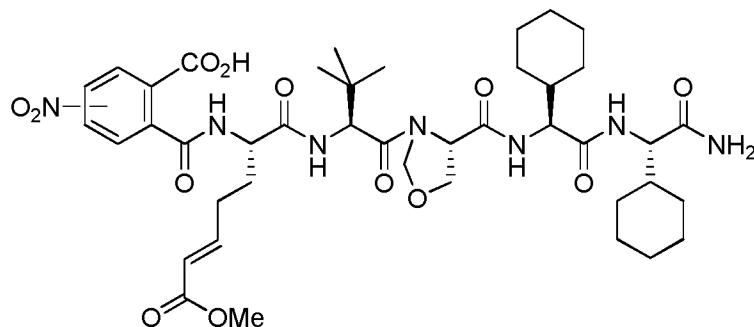
Exact Mass: 883,43

Molecular Weight: 883,98

15 The synthesis of example 1-25 was performed according to example 1-1, using the corresponding amino acids.

Yield: 39 mg, 53 %, ratio of regioisomers: approximately 1:1

ESI-MS: 884.6 $[M+H]^+$

Example 1-26. Preparation of compounds 26a/b:

2-((S,E)-1-((S)-1-((S)-4-((S)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)oxazolidin-3-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{42}H_{59}N_7O_{13}$

Exact Mass: 869,42

Molecular Weight: 869,96

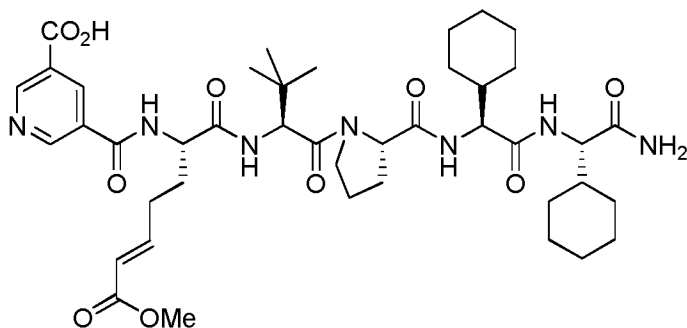
5

The synthesis of example 1-26 was performed according to example 1-1, using the corresponding amino acids.

Yield: 56 mg, 59 %, ratio of regioisomers: approximately 1:1

ESI-MS: 870.5 $[M+H]^+$

10

Example 1-27. Preparation of compound 27:

5-((S,E)-1-((S)-1-((S)-2-((S)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)pyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)nicotinic acid

Chemical Formula: $C_{42}H_{61}N_7O_{10}$

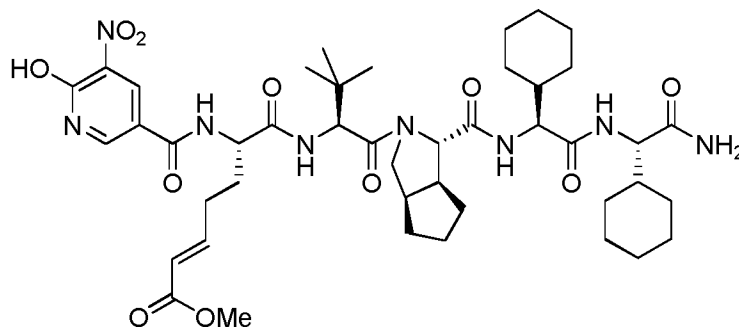
Exact Mass: 823,45

Molecular Weight: 823,97

15 The synthesis of example 1-27 was performed according to example 1-1, using the corresponding carboxylic acid and amino acids.

Yield: 79 mg, 52 %

ESI-MS: 824.6 $[M+H]^+$

Example 1-28. Preparation of compound 28:

(*S,E*)-methyl 7-(((1*S*,3*aR*,6*aS*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)hexahydrocyclopenta[*c*]pyrrol-2(1*H*)-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-6-(6-hydroxy-5-nitronicotinamido)-7-oxohept-2-enoate

Chemical Formula: C₄₄H₆₄N₈O₁₁

Exact Mass: 880,47

Molecular Weight: 881,03

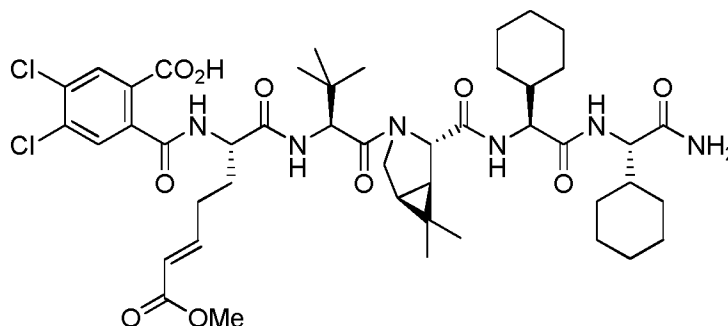
5

The synthesis of example 1-28 was performed according to example 1-1, using the corresponding carboxylic acid and amino acids.

Yield: 26 mg, 32 %

ESI-MS: 881.6 [M+H]⁺

10

Example 1-29. Preparation of compound 29:

2-(((*S,E*)-1-((*S*)-1-((1*R*,2*S*,5*S*)-2-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-6,6-dimethyl-3-azabicyclo[3.1.0]hexan-3-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4,5-dichlorobenzoic acid

Chemical Formula: C₄₆H₆₄Cl₂N₆O₁₀

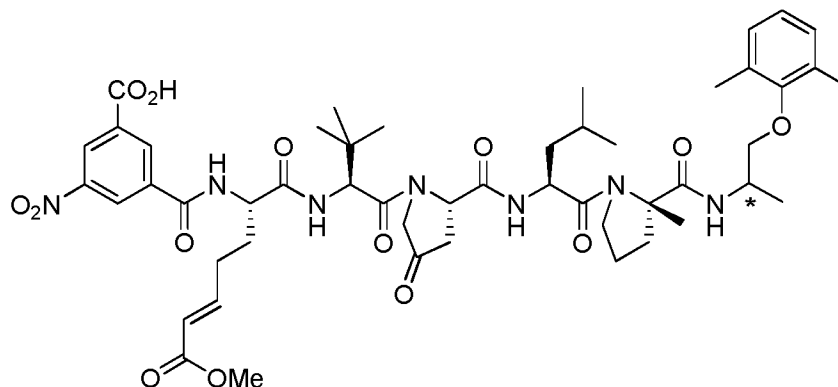
Exact Mass: 930,41

Molecular Weight: 931,94

15 The synthesis of example 1-29 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 15 mg, 27 %

ESI-MS: 931.6 [M+H]⁺

Example 1-30. Preparation of compound 30:

3-((2*S*,*E*)-1-((2*S*)-1-((2*S*)-2-((2*S*)-1-((2*S*)-2-(1-(2,6-dimethylphenoxy)propan-2-ylcarbamoyl)-2-methylpyrrolidin-1-yl)-4-methyl-1-oxopentan-2-ylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-5-nitrobenzoic acid

Chemical Formula: $C_{50}H_{67}N_7O_{14}$

Exact Mass: 989,47

Molecular Weight: 990,11

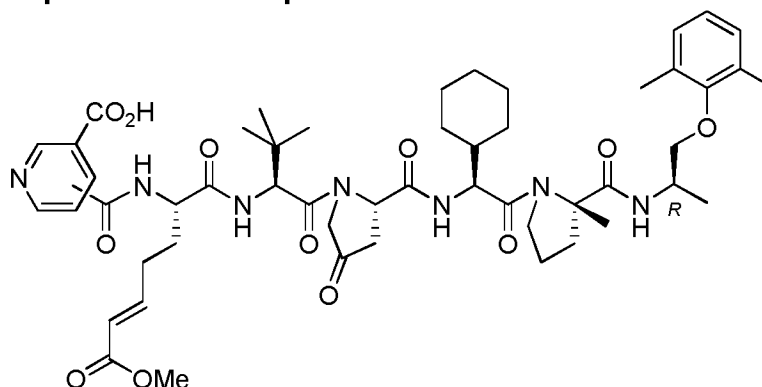
5

The synthesis of example 1-30 was performed according to scheme 4, using the corresponding carboxylic acid, amine (H-E) and amino acids.

Yield: 36 mg, 52 %

ESI-MS: 990.7 $[M+H]^+$

10

Example 1-31. Preparation of compounds 31a/b:

3/4-((*S*,*E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-cyclohexyl-2-((*S*)-2-((*R*)-1-(2,6-dimethylphenoxy)propan-2-ylcarbamoyl)-2-methylpyrrolidin-1-yl)-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: $C_{51}H_{69}N_7O_{12}$

Exact Mass: 971,50

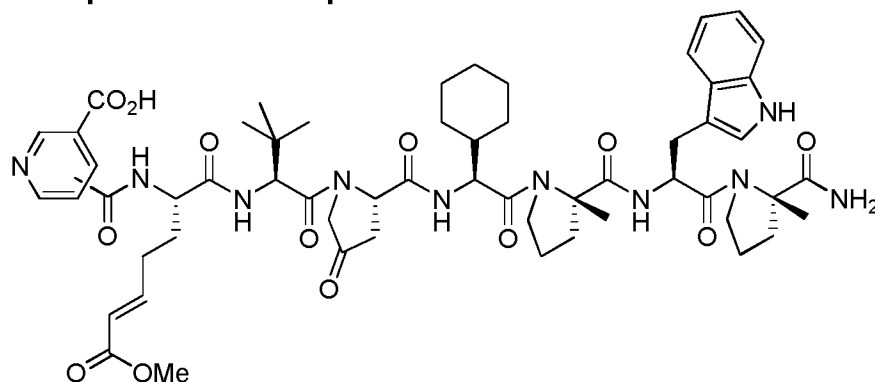
Molecular Weight: 972,13

15

The synthesis of example 1-31 was performed according to scheme 4, using the corresponding anhydride, amine (H-E) and amino acids.

Yield: 26 mg, 48 %, ratio of regioisomers: approximately 1:1

ESI-MS: 972.7 $[M+H]^+$

Example 1-32. Preparation of compounds 32a/b:

3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-((*S*)-2-((*S*)-1-((*S*)-2-carbamoyl-2-methylpyrrolidin-1-yl)-3-(1*H*-indol-3-yl)-1-oxopropan-2-ylcarbamoyl)-2-methylpyrrolidin-1-yl)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: $C_{57}H_{74}N_{10}O_{13}$

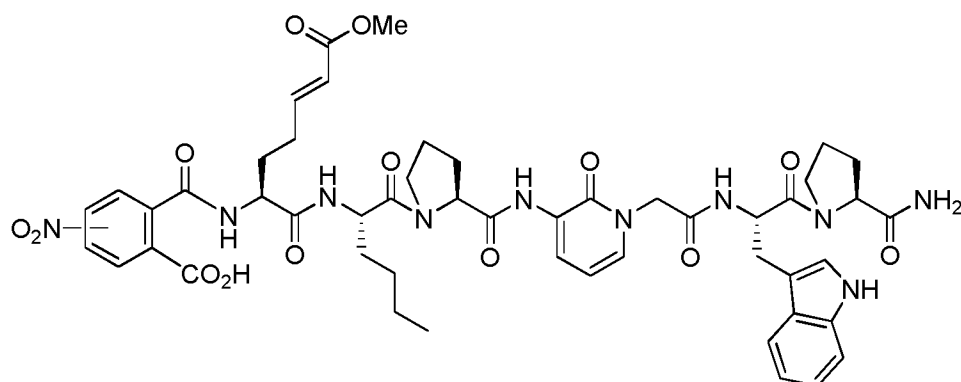
Exact Mass: 1106,54

Molecular Weight: 1107,26

The synthesis of example 1-32 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 56 mg, 53 %, ratio of regioisomers: approximately 1:1

ESI-MS: 1107.8 $[M+H]^+$

Example 1-33. Preparation of compounds 33a/b:

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((1-(2-((*S*)-1-((*S*)-2-carbamoylpyrrolidin-1-yl)-3-(1*H*-indol-3-yl)-1-oxopropan-2-ylamino)-2-oxoethyl)-2-oxo-1,2-dihydropyridin-3-ylcarbamoyl)pyrrolidin-1-yl)-1-oxohexan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{50}H_{58}N_{10}O_{14}$

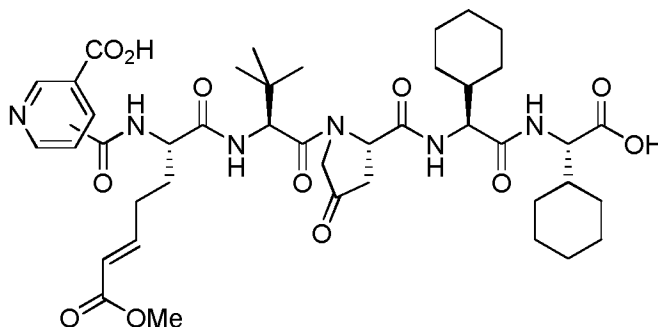
Exact Mass: 1022,41

Molecular Weight: 1023,05

The synthesis of example 1-33 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 32 mg, 65 %, ratio of regioisomers: approximately 1:1

ESI-MS: 1145.5 $[M+Na]^+$

Example 1-34. Preparation of compounds 34a/b:

3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-carboxy(cyclohexyl)methylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: $C_{42}H_{58}N_6O_{12}$

Exact Mass: 838,41

Molecular Weight: 838,94

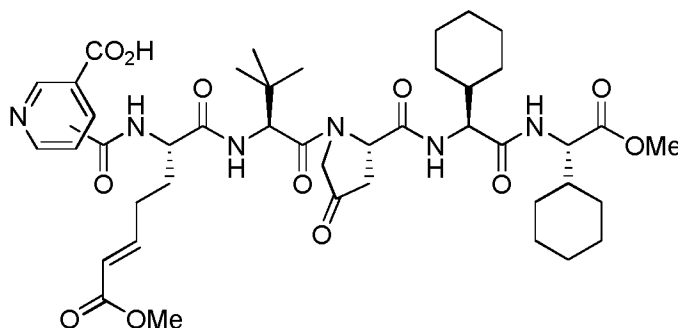
5

The synthesis of example 1-34 was performed according to example 1-1, using the corresponding anhydride, amino acids and Wang resin.

Yield: 15 mg, 24 %, ratio of regioisomers: approximately 1:1

ESI-MS: 839.4 $[M+H]^+$

10

Example 1-35. Preparation of compounds 35a/b:

3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-cyclohexyl-2-((*S*)-1-cyclohexyl-2-methoxy-2-oxoethylamino)-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: $C_{43}H_{60}N_6O_{12}$

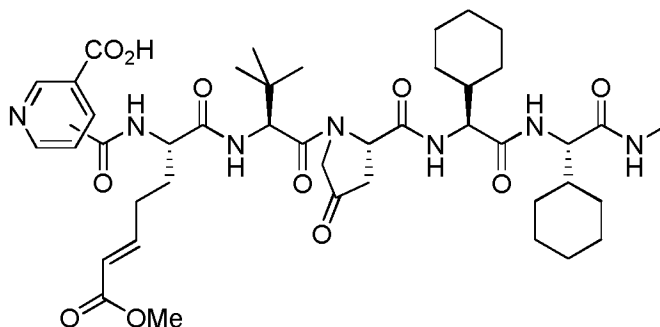
Exact Mass: 852,43

Molecular Weight: 852,97

15 The synthesis of example 1-35 was performed according to scheme 4, using the corresponding anhydride and amino acids.

Yield: 24 mg, 41 %, ratio of regioisomers: approximately 1:1

ESI-MS: 853.6 $[M+H]^+$

Example 1-36. Preparation of compounds 36a/b:

3/4-((S,E)-1-((S)-1-((S)-2-((S)-1-cyclohexyl-2-((S)-1-cyclohexyl-2-(methylamino)-2-oxoethylamino)-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)iso/nicotinic acid

Chemical Formula: C₄₃H₆₁N₇O₁₁

Exact Mass: 851,44

Molecular Weight: 851,98

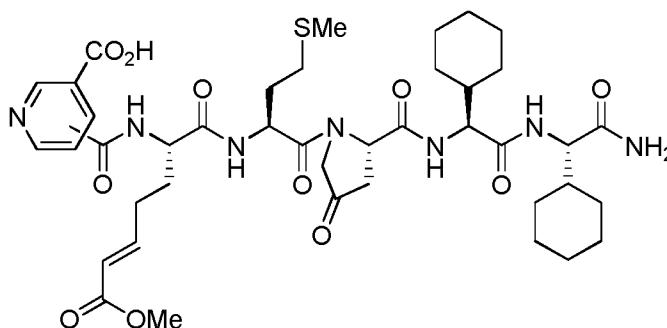
5

The synthesis of example 1-36 was performed according to example 1-1, using the corresponding anhydride, amino acids and Methyl Indole AM resin.

Yield: 36 mg, 32 %, ratio of regioisomers: approximately 1:1

ESI-MS: 852.6 [M+H]⁺

10

Example 1-37. Preparation of compounds 37a/b:

4-((S,E)-1-((S)-1-((S)-2-((S)-2-((S)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-4-(methylthio)-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)nicotinic acid

Chemical Formula: C₄₁H₅₇N₇O₁₁S

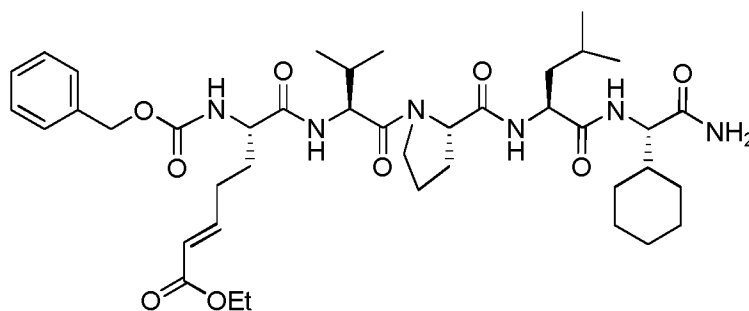
Exact Mass: 855,38

Molecular Weight: 856,00

15 The synthesis of example 1-37 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 31 mg, 42 %, ratio of regioisomers: approximately 1:1

ESI-MS: 856.5 [M+H]⁺

Example 1-38:**1.1 Preparation of compound Ref. 08:**

(*S,E*)-ethyl 7-((*S*)-1-((*S*)-2-((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-ylamino)-6-(benzyloxycarbonylamino)-7-oxohept-2-enoate

Chemical Formula: C₄₁H₆₂N₆O₉

Exact Mass: 782,46

Molecular Weight: 782,97

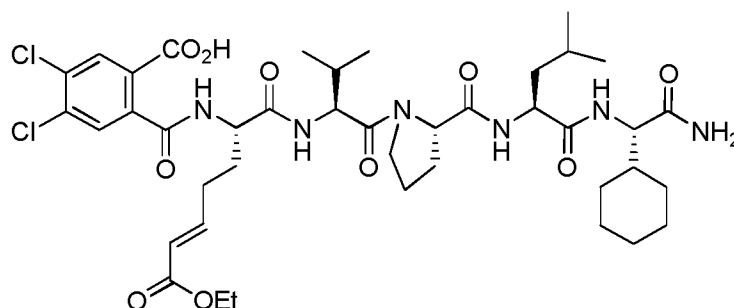
5

The backbone tetrapeptide H-Val-Pro-Leu-Chg-NH₂ was built by standard Fmoc solid-phase peptide chemistry according to compound **ZED3478**, using the corresponding amino acids. The Michael acceptor (ethyl acrylate) was directly coupled according to compound **ZED3481**, using **compound Ic**. Finally, compound **Ref.08** was synthesized according to **Example 1-1**, using Cbz-Cl.

10

Yield: 86 mg, 61 %

ESI-MS: 783.6 [M+H]⁺

1.2 Preparation of compound 38:

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-ylamino)-7-ethoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4,5-dichlorobenzoic acid

Chemical Formula: C₄₁H₅₈Cl₂N₆O₁₀

Exact Mass: 864,36

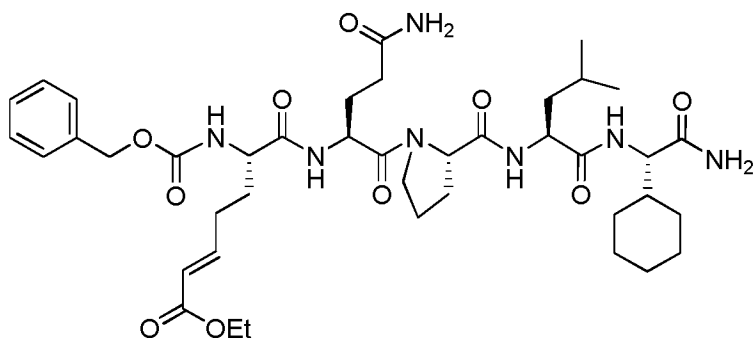
Molecular Weight: 865,84

15

The synthesis of compound **38** was performed according to compound **Ref.06**, using 4,5-dichlorophthalic anhydride instead of Cbz-Cl in the final step.

Yield: 36 mg, 51 %

ESI-MS: 865.5 [M+H]⁺

Example 1-39:**1. Preparation of compound Ref. 09:**

(*S,E*)-ethyl 7-((*S*)-5-amino-1-((*S*)-2-((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-1,5-dioxopentan-2-ylamino)-6-(benzyloxycarbonylamino)-7-oxohept-2-enoate

Chemical Formula: $C_{41}H_{61}N_7O_{10}$

Exact Mass: 811,45

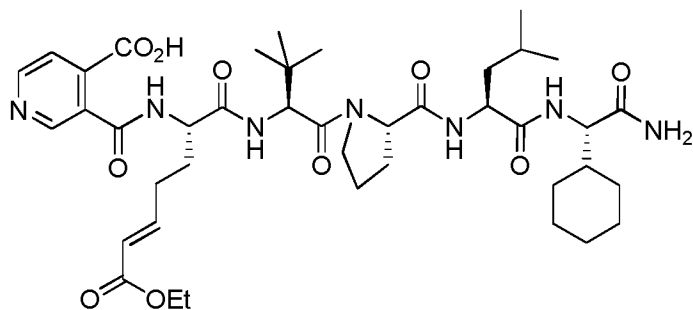
Molecular Weight: 811,96

5

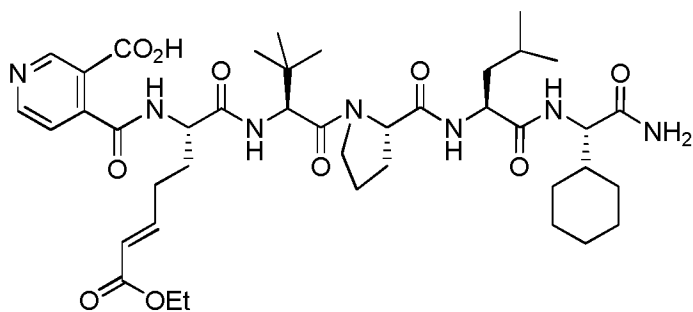
The synthesis of compound **Ref.09** was performed according to compound **Ref.08**, using the corresponding amino acids for the synthesis of the backbone tetrapeptide by standard Fmoc solid-phase peptide chemistry.

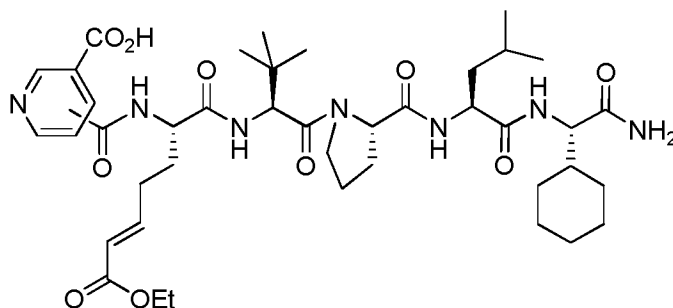
10 Yield: 93 mg, 57 %

ESI-MS: 812.6 $[M+H]^+$

2. Preparation of compound 39a/39b (regioisomers):**39a**

15

**39b**



3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-ethoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)nicotinic acid

Chemical Formula: $C_{41}H_{61}N_7O_{10}$

Exact Mass: 811,45

Molecular Weight: 811,96

39

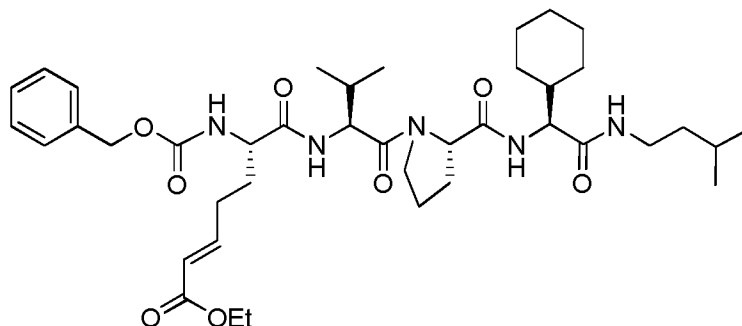
The synthesis of compound **39 (39a/39b)** was performed according to compound **Ref.09**, using the corresponding amino acids for the buildup of the backbone tetrapeptide and 3,4-pyridinedicarboxylic anhydride instead of Cbz-Cl in the final step.

5 Yield: 41 mg, 36 %, ratio of regioisomers: approximately 1:1

ESI-MS: 812.6 $[M+H]^+$

Example 1-40:

1. Preparation of compound Ref. 10:



(*S,E*)-ethyl 6-(benzyloxycarbonylamino)-7-((*S*)-1-((*S*)-2-((*S*)-1-cyclohexyl-2-(isopentylamino)-2-oxoethylcarbamoyl)pyrrolidin-1-yl)-3-methyl-1-oxobutan-2-ylamino)-7-oxohept-2-enoate

Chemical Formula: $C_{40}H_{61}N_5O_8$

Exact Mass: 739,45

Molecular Weight: 739,94

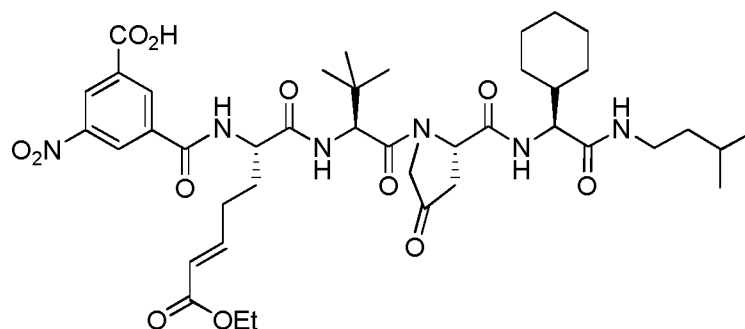
10

The backbone tripeptide Fmoc-Val-Pro-Chg-OH was built by standard Fmoc solid-phase peptide chemistry according to compound **ZED3478**, using 2-chlorotrityl resin and the corresponding amino acids. After cleavage from the resin (using 95% TFA / 2.5 % water / 2.5 % triisopropylsilane), C-terminal coupling of isopentylamine was performed according to compound **ZED3480** with HATU/DIPEA. Subsequently the Fmoc protecting group was removed with piperidine in DMF and the Michael acceptor (ethyl acrylate) was coupled according to compound **ZED3481**, using **compound Ic**. Finally, compound **Ref.10** was synthesized according to **Example 1-1**, using Cbz-Cl.

Yield: 72 mg, 45 %

20 ESI-MS: 740.6 $[M+H]^+$

2. Preparation of compound 40:



3-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-cyclohexyl-2-(isopentylamino)-2-oxoethylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-ethoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-5-nitrobenzoic acid

Chemical Formula: $C_{41}H_{58}N_6O_{12}$

Exact Mass: 826,41

Molecular Weight: 826,93

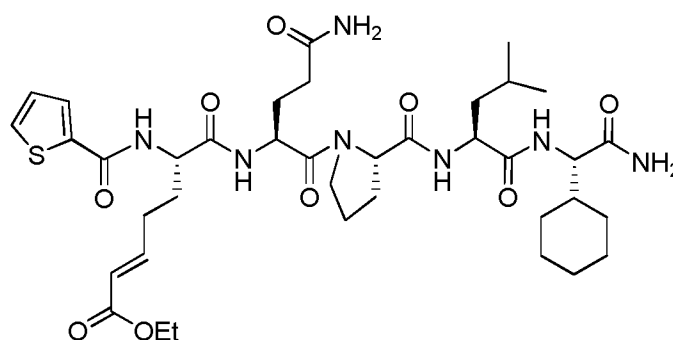
The synthesis of compound **40** was performed according to compound **Ref.10**, using the corresponding amino acids for the buildup of the backbone tripeptide but 5-nitroisophthalic acid (coupling according to compound **ZED3480** with HATU/DIPEA) instead of Cbz-Cl in the final step.

Yield: 56 mg, 62 %

ESI-MS: 827.7 $[M+H]^+$

Example 1-41:

1. Preparation of compound Ref. 11:



(*S,E*)-ethyl 7-((*S*)-5-amino-1-((*S*)-2-((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-1,5-dioxopentan-2-ylamino)-7-oxo-6-(thiophene-2-carboxamido)hept-2-enoate

Chemical Formula: $C_{38}H_{57}N_7O_9S$

Exact Mass: 787,39

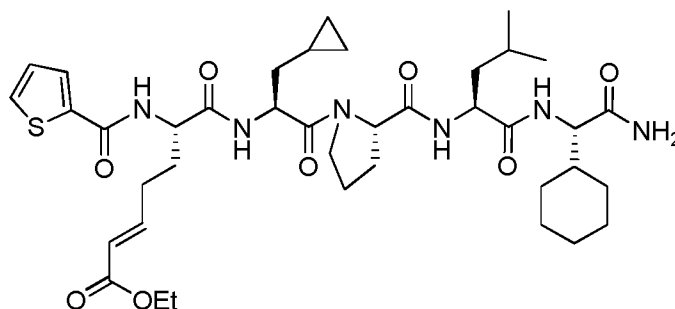
Molecular Weight: 787,97

The synthesis of compound **Ref.11** was performed according to compound **Ref.08**, using the corresponding amino acids for the synthesis of the backbone tetrapeptide and 2-Thiophenecarboxylic acid (coupling according to compound **ZED3480** with HATU/DIPEA) instead of Cbz-Cl in the final step.

Yield: 69 mg, 56 %

ESI-MS: 788.5 $[M+H]^+$

2. Preparation of compound 41:



(*S,E*)-ethyl 7-(((*S*)-1-(((*S*)-2-(((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-3-cyclopropyl-1-oxopropan-2-ylamino)-7-oxo-6-(thiophene-2-carboxamido)hept-2-enoate

Chemical Formula: $C_{39}H_{58}N_6O_8S$

Exact Mass: 770,40

Molecular Weight: 770,98

- 5 The synthesis of compound **41** was performed according to compound **Ref.11**, using the corresponding amino acids for the buildup of the backbone tetrapeptide.

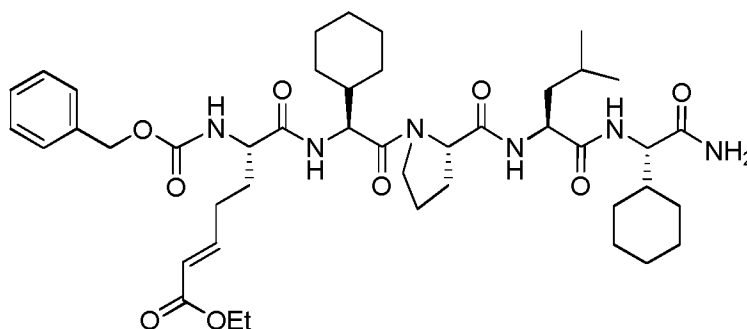
Yield: 45 mg, 61 %

ESI-MS: 771.7 $[M+H]^+$

10

Example 1-42:

1. Preparation of compound Ref.12:



(*S,E*)-ethyl 7-(((*S*)-2-(((*S*)-2-(((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-1-cyclohexyl-2-oxoethylamino)-6-(benzyloxycarbonylamino)-7-oxohept-2-enoate

Chemical Formula: $C_{44}H_{66}N_6O_9$

Exact Mass: 822,49

Molecular Weight: 823,03

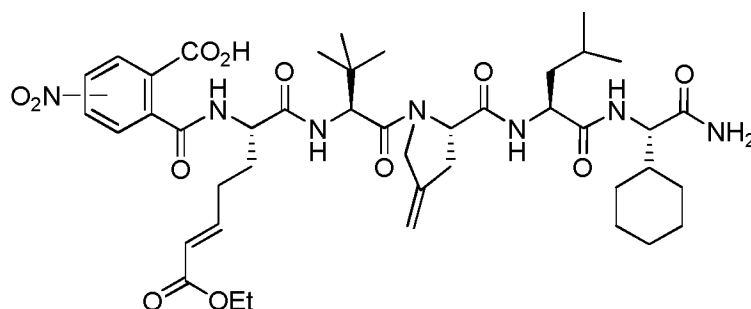
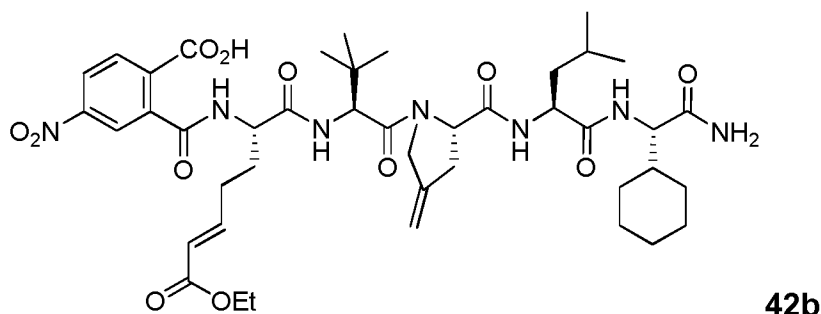
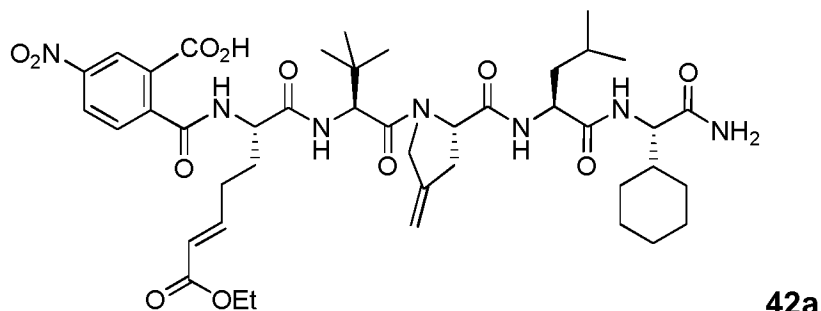
- 15 The synthesis of compound **Ref.12** was performed according to compound **Ref.08**, using the corresponding amino acids for the solid phase chemistry yielding the backbone tetrapeptide.

Yield: 78 mg, 52 %

ESI-MS: 823.8 $[M+H]^+$

20

2. Preparation of compound 42a/42b (regioisomers):



2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)-4-methylenepyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-ethoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₃H₆₁N₇O₁₂

Exact Mass: 867,44

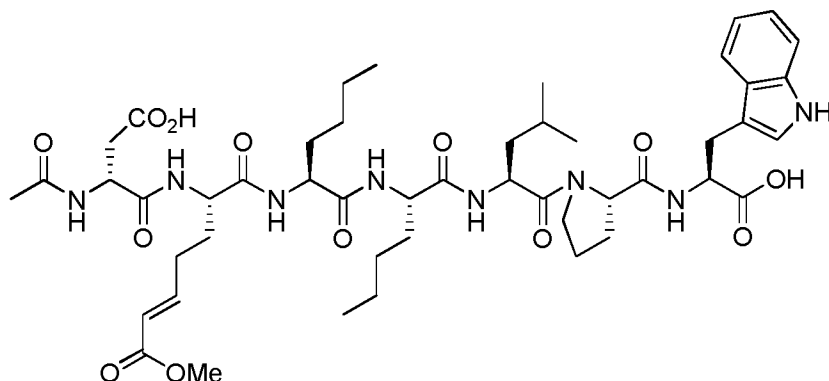
Molecular Weight: 867,98

42

- 10 The synthesis of compound **42a/42b** was performed according to compound **Ref.12**, using the corresponding amino acids for the buildup of the backbone tetrapeptide and 4-nitrophthalic anhydride instead of Cbz-Cl in the final step.

Yield: 32 mg, 37 %, ratio of regioisomers: approximately 1:1

ESI-MS: 868.7 [M+H]⁺

Example 1-43:**1. Preparation of compound Ref. 13:**

(S)-2-(((S)-1-((4R,7S,10S,13S,16S)-4-(carboxymethyl)-10,13-dibutyl-7-((E)-5-methoxy-5-oxopent-3-enyl)-18-methyl-2,5,8,11,14-pentaoxo-3,6,9,12,15-pentaazonadecanecarbonyl)pyrrolidine-2-carboxamido)-3-(1H-indol-3-yl)propanoic acid

Chemical Formula: C₄₈H₇₀N₈O₁₃

Exact Mass: 966,51

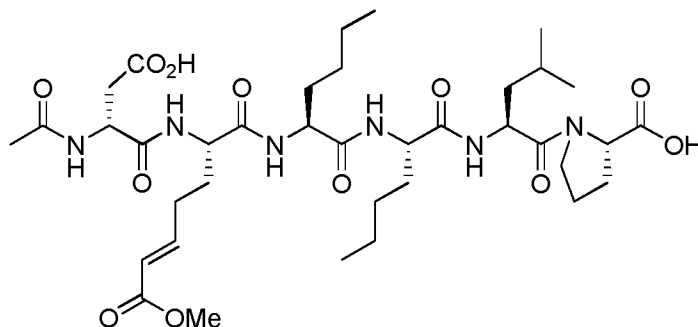
Molecular Weight: 967,12

- 5 The backbone pentapeptide H-Nle-Nle-Leu-Pro-Trp-OH was built by standard Fmoc solid-phase peptide chemistry according to compound **ZED3478**, using 2-chlorotrityl resin and the corresponding amino acids. The Michael acceptor (methyl acrylate) was directly coupled according to compound **ZED3481**, using **compound Ib**. Finally, compound **Ref.13** was synthesized according to compound **ZED3480** by coupling Ac-(D)-Asp(OtBu)-OH with HATU/DIPEA followed by cleavage of the *tert*-butyl ester with TFA in DCM.

Yield: 142 mg, 65 %

ESI-MS: 967.8 [M+H]⁺

15 **2. Preparation of compound Ref.14:**



(S)-1-(((4R,7S,10S,13S,16S)-10,13-dibutyl-4-(carboxymethyl)-7-((E)-5-methoxy-5-oxopent-3-enyl)-18-methyl-2,5,8,11,14-pentaoxo-3,6,9,12,15-pentaazonadecanecarbonyl)pyrrolidine-2-carboxylic acid

Chemical Formula: C₃₇H₆₀N₆O₁₂

Exact Mass: 780,43

Molecular Weight: 780,91

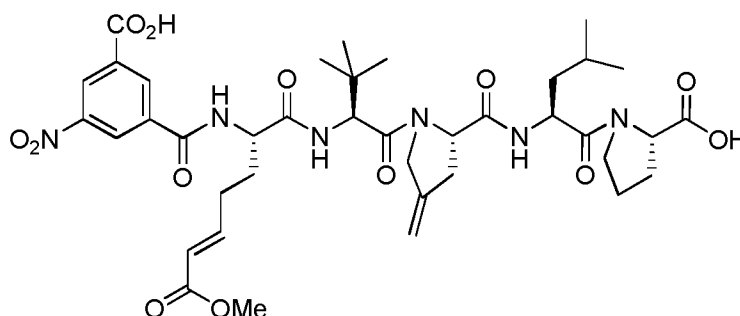
The synthesis of compound **Ref.14** was performed according to **Ref.13**, using the corresponding amino acids for the buildup of the backbone tetrapeptide.

Yield: 107 mg, 59 %

ESI-MS: 781.7 [M+H]⁺

5

3. Preparation of compound 43:



(S)-1-((S)-2-((S)-1-((S)-2-((S,E)-2-(3-carboxy-5-nitrobenzamido)-7-methoxy-7-oxohept-5-enamido)-3,3-dimethylbutanoyl)-4-methylenepyrrolidine-2-carboxamido)-4-methylpentanoyl)pyrrolidine-2-carboxylic acid

Chemical Formula: C₃₉H₅₂N₆O₁₃

Exact Mass: 812,36

Molecular Weight: 812,86

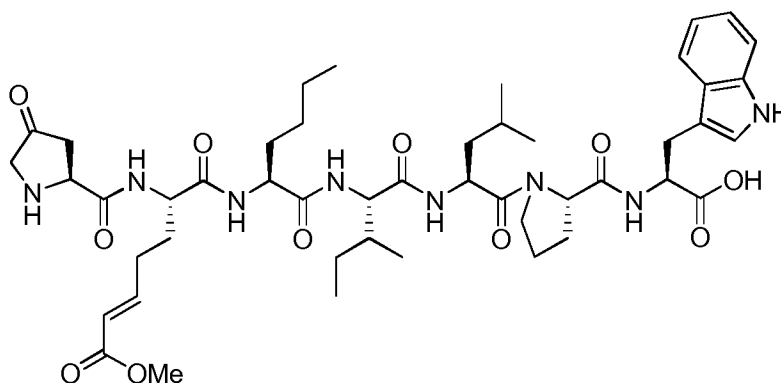
The synthesis of compound **43** was performed according to **Ref.14** using the corresponding amino acids for the synthesis of the backbone tetrapeptide. N-terminal capping was obtained by 5-nitroisophthalic acid (coupling according to compound **ZED3480** with HATU/DIPEA) instead of Ac-D-Asp(OtBu)-OH in the final step.

Yield: 65 mg, 57 %

ESI-MS: 813.6 [M+H]⁺

15 Example 1-44:

1. Preparation of compound Ref.15:



(S)-2-((S)-1-((8S,11S,14S,17S,E)-14-sec-butyl-11-butyl-17-isobutyl-3,9,12,15-tetraoxo-8-((S)-4-oxopyrrolidine-2-carboxamido)-2-oxa-10,13,16-triazaoctadec-4-ene)pyrrolidine-2-carboxamido)-3-(1H-indol-3-yl)propanoic acid

Chemical Formula: C₄₇H₆₈N₈O₁₁

Exact Mass: 920,50

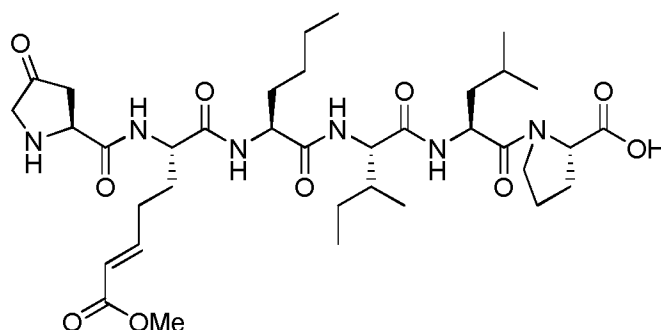
Molecular Weight: 921,09

The synthesis of compound **Ref.15** was performed according to **Ref.13**, using the corresponding amino acids for the buildup of the backbone pentapeptide and (S)-N-Boc-4-oxopyrrolidine-2-carboxylic acid (coupling according to compound **ZED3480** with HATU/DIPEA) instead of Ac-D-Asp(OtBu)-OH in the final step. The Boc protecting group is cleaved with TFA in DCM accordingly.

Yield: 127 mg, 57 %

ESI-MS: 921.8 [M+H]⁺

2. Preparation of compound Ref.16:



(S)-1-(((8S,11S,14S,17S,E)-14-sec-butyl-11-butyl-17-isobutyl-3,9,12,15-tetraoxo-8-((S)-4-oxopyrrolidine-2-carboxamido)-2-oxa-10,13,16-triazaoctadec-4-ene)pyrrolidine-2-carboxylic acid

Chemical Formula: C₃₆H₅₈N₆O₁₀

Exact Mass: 734,42

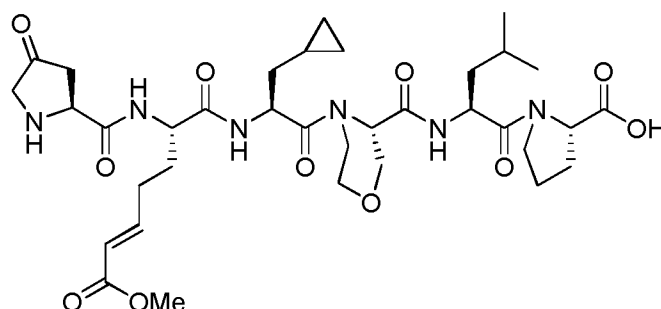
Molecular Weight: 734,88

The synthesis of compound **Ref.16** was performed according to **Ref.15**, using the corresponding amino acids for the buildup of the backbone tetrapeptide.

Yield: 93 mg, 47 %

ESI-MS: 735.6 [M+H]⁺

3. Preparation of compound 44:



(S)-1-(((S)-2-((R)-4-((S)-3-cyclopropyl-2-((S,E)-7-methoxy-7-oxo-2-((S)-4-oxopyrrolidine-2-carboxamido)hept-5-enamido)propanoyl)morpholine-3-carboxamido)-4-methylpentanoyl)pyrrolidine-2-carboxylic acid

Chemical Formula: C₃₅H₅₂N₆O₁₁

Exact Mass: 732,37

Molecular Weight: 732,82

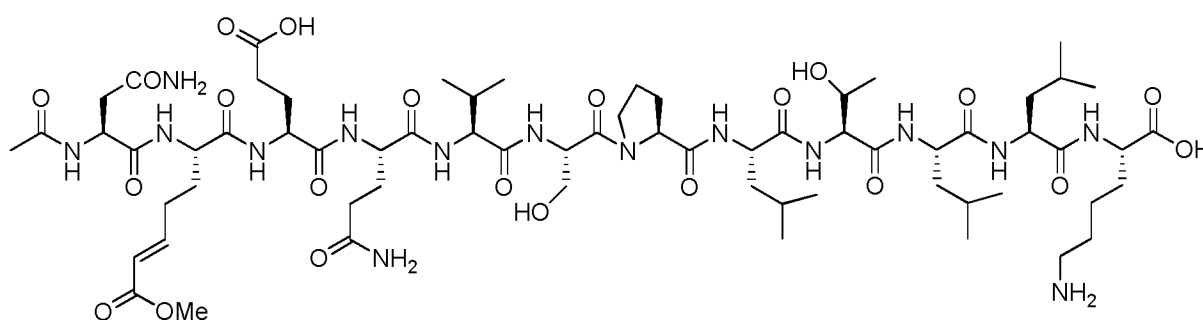
The synthesis of compound **44** was performed according to **Ref.14** using the corresponding amino acids for the buildup of the backbone tetrapeptide.

Yield: 78 mg, 59 %

ESI-MS: 733.6 [M+H]⁺

Example 1-45:

1. Preparation of compound Ref.17 (ZED1265):



(3S,6S,9S,12S,15S)-1-((S)-1-((2S,5S,8S,11S,14S,17S)-17-(2-amino-2-oxoethyl)-8-(3-amino-3-oxopropyl)-11-(2-carboxyethyl)-2-(hydroxymethyl)-5-isopropyl-14-((E)-5-methoxy-5-oxopent-3-enyl)-4,7,10,13,16,19-hexaoxo-3,6,9,12,15,18-hexaazaicosane)pyrrolidin-2-yl)-15-(4-aminobutyl)-6-((R)-1-hydroxyethyl)-3,9,12-triisobutyl-1,4,7,10,13-pentaoxo-2,5,8,11,14-pentaazahexadecan-16-oic acid

Chemical Formula: C₆₅H₁₀₉N₁₅O₂₂

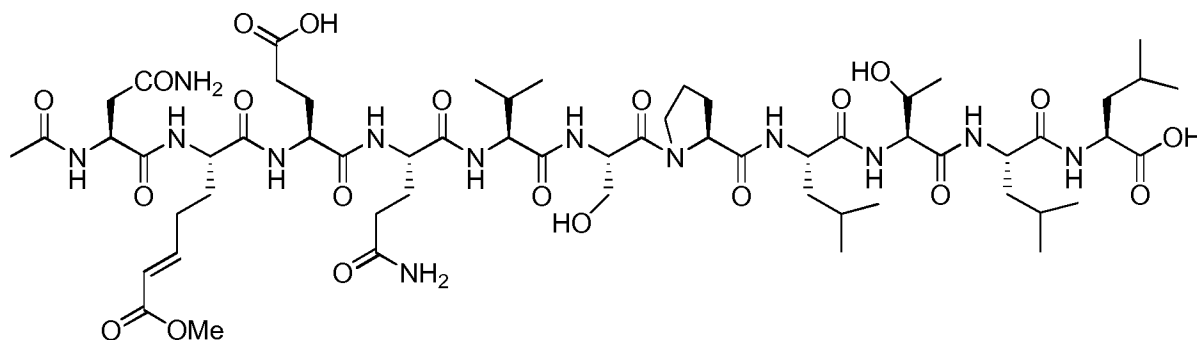
Exact Mass: 1451,79

Molecular Weight: 1452,65

The backbone decapeptide H-Glu-Gln-Val-Ser-Pro-Leu-Thr-Leu-Lys(Alloc)-OH was built by standard Fmoc solid-phase peptide chemistry according to compound **ZED3478**, using 2-chlorotrityl resin and the corresponding (side chain protected) amino acids. The Michael acceptor (methyl acrylate) was directly coupled according to compound **ZED3481**, using **compound Ib**. Finally, compound **ZED1265** was synthesized according to compound **ZED3480** by coupling Ac-Asn-OH with HATU/DIPEA followed by cleavage of the alloc protecting group with Tetrakis(triphenylphosphine)palladium(0) in DCM.

Yield: 177 mg, 36 %

ESI-MS: 1453.2 [M+H]⁺

2. Preparation of compound Ref.18 (ZED1246):

(3*S*,6*S*,9*S*,12*S*)-1-((*S*)-1-((2*S*,5*S*,8*S*,11*S*,14*S*,17*S*)-17-(2-amino-2-oxoethyl)-8-(3-amino-3-oxopropyl)-11-(2-carboxyethyl)-2-(hydroxymethyl)-5-isopropyl-14-((*E*)-5-methoxy-5-oxopent-3-enyl)-4,7,10,13,16,19-hexaoxo-3,6,9,12,15,18-hexaazaicosane)pyrrolidin-2-yl)-6-((*R*)-1-hydroxyethyl)-3,9,12-trisobutyl-1,4,7,10-tetraoxo-2,5,8,11-tetraazatridecan-13-oic acid

Chemical Formula: C₅₉H₉₇N₁₃O₂₁

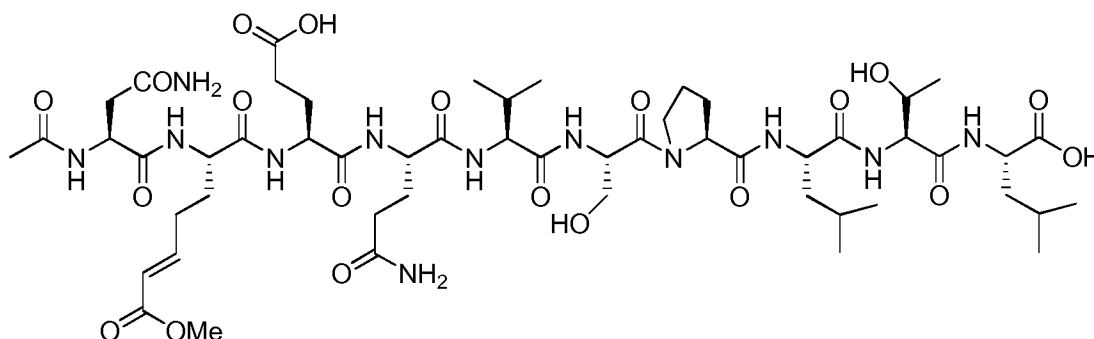
Exact Mass: 1323,69

Molecular Weight: 1324,48

The synthesis of compound **ZED1246** was performed according to **ZED1265**, using the corresponding amino acids for the buildup of the backbone nonapeptide.

Yield: 158 mg, 39 %

ESI-MS: 1325.1 [M+H]⁺

3. Preparation of compound Ref.19 (ZED1274):

(*S*)-4-((*S*,*E*)-2-((*S*)-2-acetamido-4-amino-4-oxobutanamido)-7-methoxy-7-oxohept-5-enamido)-5-((*S*)-5-amino-1-((*S*)-1-((*S*)-1-((*S*)-2-((*S*)-1-((2*S*,3*R*)-1-((*S*)-1-carboxy-3-methylbutylamino)-3-hydroxy-1-oxobutan-2-ylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-3-hydroxy-1-oxopropan-2-ylamino)-3-methyl-1-oxobutan-2-ylamino)-1,5-dioxopentan-2-ylamino)-5-oxopentanoic acid

Chemical Formula: C₅₃H₈₆N₁₂O₂₀

Exact Mass: 1210,61

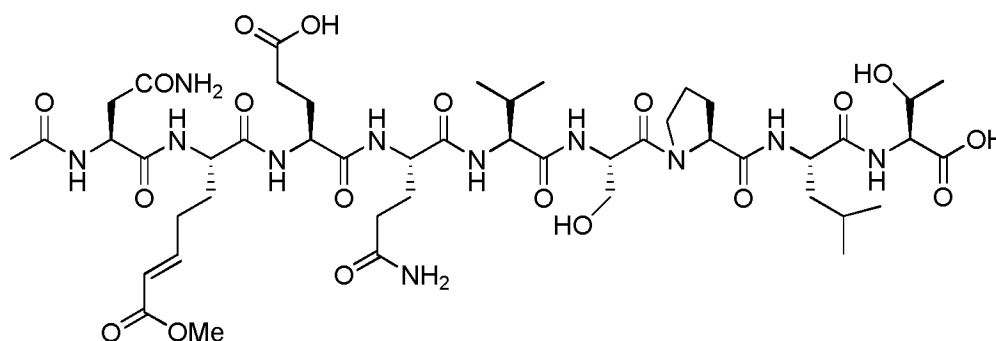
Molecular Weight: 1211,32

The synthesis of compound **ZED1274** was performed according to **ZED1265**, using the corresponding amino acids for the buildup of the backbone octapeptide.

Yield: 132 mg, 45 %

ESI-MS: 1212.0 [M+H]⁺

4. Preparation of compound Ref.20 (ZED1282):



(S)-4-((S,E)-2-((S)-2-acetamido-4-amino-4-oxobutanamido)-7-methoxy-7-oxohept-5-enamido)-5-((S)-5-amino-1-((S)-1-((S)-1-((S)-2-((S)-1-((1S,2R)-1-carboxy-2-hydroxypropylamino)-4-methyl-1-oxopentan-2-ylcarbamoyl)pyrrolidin-1-yl)-3-hydroxy-1-oxopropan-2-ylamino)-3-methyl-1-oxobutan-2-ylamino)-1,5-dioxopentan-2-ylamino)-5-oxopentanoic acid

Chemical Formula: $C_{47}H_{75}N_{11}O_{19}$

Exact Mass: 1097,52

Molecular Weight: 1098,16

5

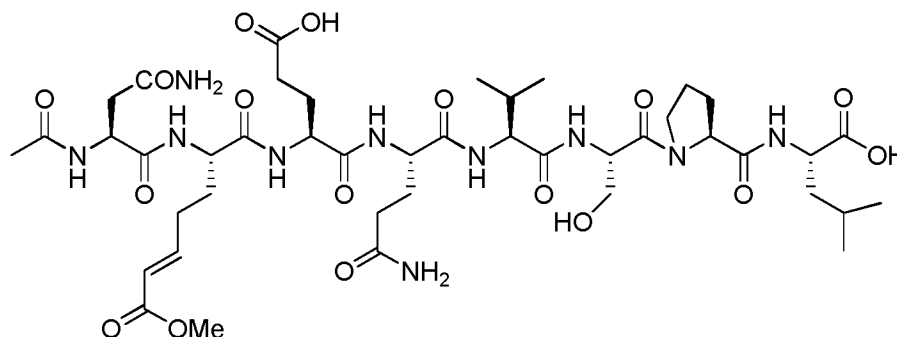
The synthesis of compound **ZED1282** was performed according to **ZED1265**, using the corresponding amino acids for the buildup of the backbone heptapeptide.

Yield: 165 mg, 61 %

ESI-MS: 1098.8 $[M+H]^+$

10

5. Preparation of compound Ref.21 (ZED1283):



(S)-4-((S,E)-2-((S)-2-acetamido-4-amino-4-oxobutanamido)-7-methoxy-7-oxohept-5-enamido)-5-((S)-5-amino-1-((S)-1-((S)-1-((S)-2-((S)-1-carboxy-3-methylbutylcarbamoyl)pyrrolidin-1-yl)-3-hydroxy-1-oxopropan-2-ylamino)-3-methyl-1-oxobutan-2-ylamino)-1,5-dioxopentan-2-ylamino)-5-oxopentanoic acid

Chemical Formula: $C_{43}H_{68}N_{10}O_{17}$

Exact Mass: 996,48

Molecular Weight: 997,06

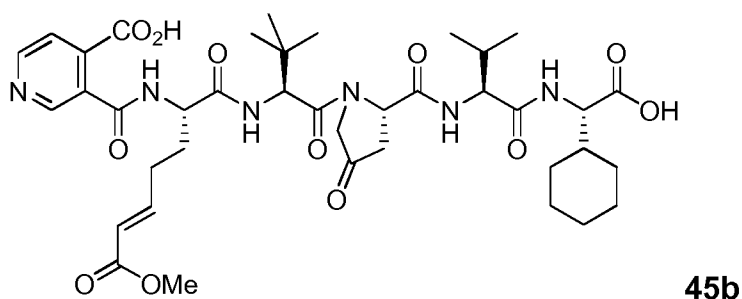
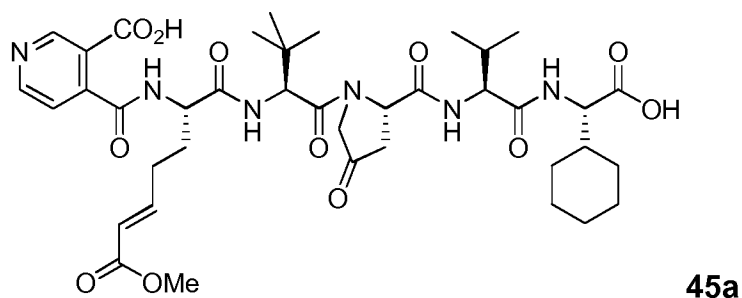
15 The synthesis of compound **ZED1283** was performed according to **ZED1265**, using the corresponding amino acids for the buildup of the backbone hexapeptide.

Yield: 127 mg, 47 %

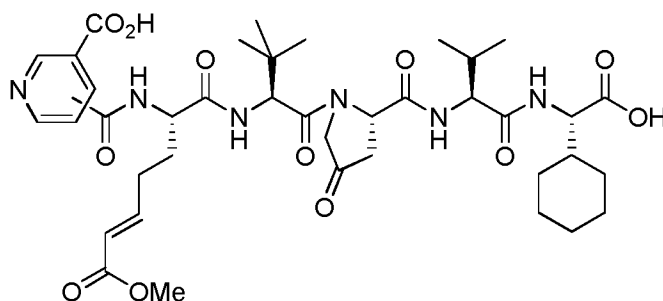
ESI-MS: 997.8 $[M+H]^+$

Example 1-46: Preparation of compound 45a/45b (regioisomers):

5



10



3/4-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-1-((*S*)-carboxy(cyclohexyl)methylamino)-3-methyl-1-oxobutan-2-ylcarbamoyl)-4-oxopyrrolidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)isonicotinic acid

Chemical Formula: $C_{39}H_{54}N_6O_{12}$

Exact Mass: 798,38

Molecular Weight: 798,88

45

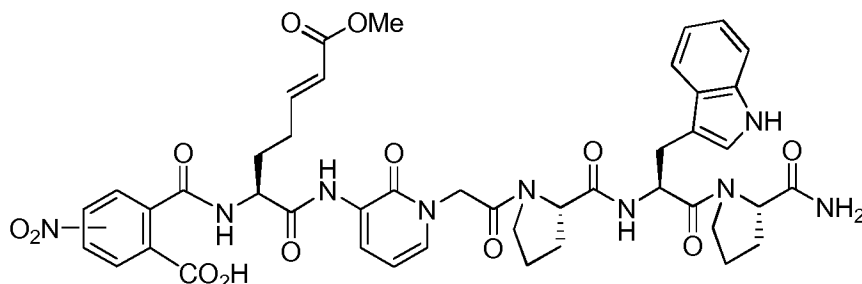
- 15 The synthesis of compound **45a/45b** was performed according to **Ref.11** using the corresponding amino acids for the buildup of the backbone tetrapeptide and capping by 3,4-pyridinedicarboxylic anhydride instead of Ac-(*D*)-Asp(OtBu)-OH in the final step.

Yield: 77 mg, 32 %, ratio of regioisomers: approximately 1:1

ESI-MS: 799.6 $[M+H]^+$

Example 1-47:**Reference example 1 (Ref.1):**

5



2-((*S,E*)-1-(1-(2-((*S*)-2-((*S*)-1-((*S*)-2-carbamoylpyrrolidin-1-yl)-3-(1*H*-indol-3-yl)-1-oxopropan-2-ylcarbamoyl)pyrrolidin-1-yl)-2-oxoethyl)-2-oxo-1,2-dihydropyridin-3-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{44}H_{47}N_9O_{13}$

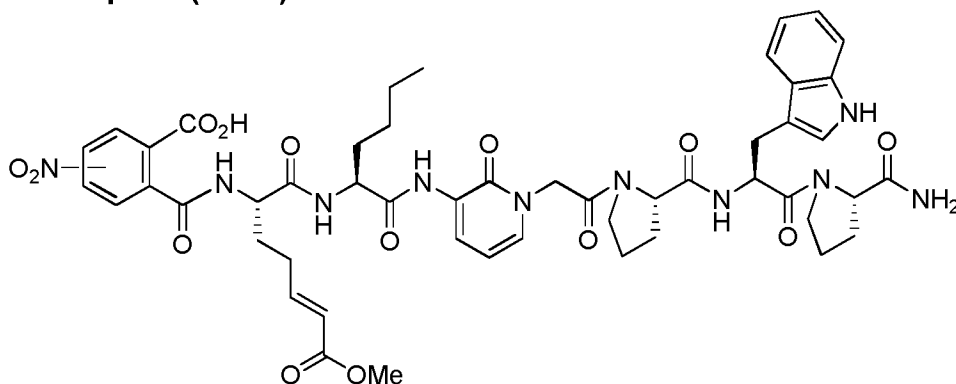
Exact Mass: 909,33

Molecular Weight: 909,90

The synthesis of Ref.1 was performed according to example 1-1, using the corresponding anhydride and amino acids.

10 Yield: 12 mg, 26 %, ratio of regioisomers: approximately 1:1

ESI-MS: 910.5 $[M+H]^+$

Reference example 2 (Ref.2):

2-((*S,E*)-1-((*S*)-1-(1-(2-((*S*)-2-((*S*)-1-((*S*)-2-carbamoylpyrrolidin-1-yl)-3-(1*H*-indol-3-yl)-1-oxopropan-2-ylcarbamoyl)pyrrolidin-1-yl)-2-oxoethyl)-2-oxo-1,2-dihydropyridin-3-ylamino)-1-oxohexan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{50}H_{58}N_{10}O_{14}$

Exact Mass: 1022,41

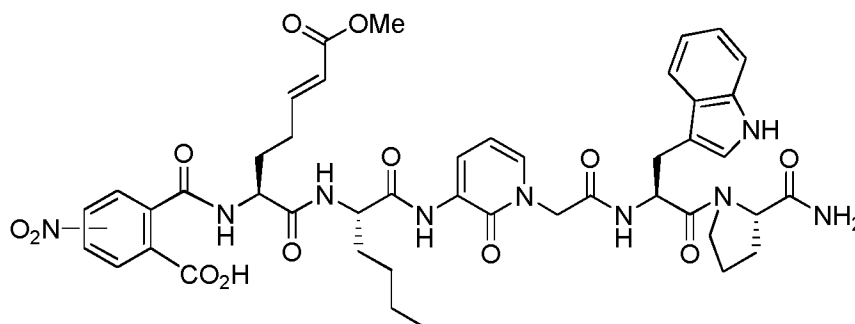
Molecular Weight: 1023,05

15

The synthesis of Ref.2 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 16 mg, 23 %, ratio of regioisomers: approximately 1:1

20 ESI-MS: 1023.5 $[M+H]^+$

Reference example 3 (Ref.3):

2-((*S,E*)-1-((*S*)-1-(1-(2-((*S*)-1-((*S*)-2-carbamoylpyrrolidin-1-yl)-3-(1*H*-indol-3-yl)-1-oxopropan-2-ylamino)-2-oxoethyl)-2-oxo-1,2-dihydropyridin-3-ylamino)-1-oxohexan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₅H₅₁N₉O₁₃

Exact Mass: 925,36

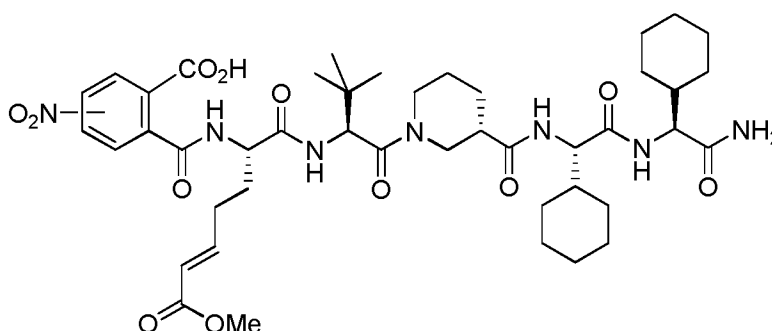
Molecular Weight: 925,94

5

The synthesis of Ref.3 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 11 mg, 19 %, ratio of regioisomers: approximately 1:1

10 ESI-MS: 926.5 [M+H]⁺

Reference example 4 (Ref.4):

2-((*S,E*)-1-((*S*)-1-((*S*)-3-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)piperidin-1-yl)-3,3-dimethyl-1-oxobutan-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: C₄₄H₆₃N₇O₁₂

Exact Mass: 881,45

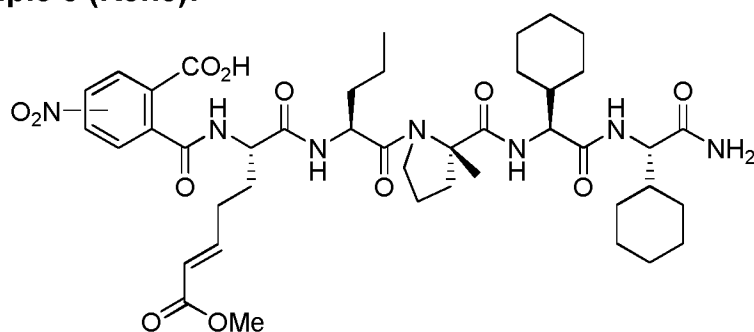
Molecular Weight: 882,01

15

The synthesis of Ref.4 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 79 mg, 58 %, ratio of regioisomers: approximately 1:1

20 ESI-MS: 882.6 [M+H]⁺

Reference example 5 (Ref.5):

2-((*S,E*)-1-((*S*)-1-((*S*)-2-((*S*)-2-amino-1-cyclohexyl-2-oxoethylamino)-1-cyclohexyl-2-oxoethylcarbamoyl)-2-methylpyrrolidin-1-yl)-1-oxopentane-2-ylamino)-7-methoxy-1,7-dioxohept-5-en-2-ylcarbamoyl)-4/5-nitrobenzoic acid

Chemical Formula: $C_{43}H_{61}N_7O_{12}$

Exact Mass: 867,44

Molecular Weight: 867,98

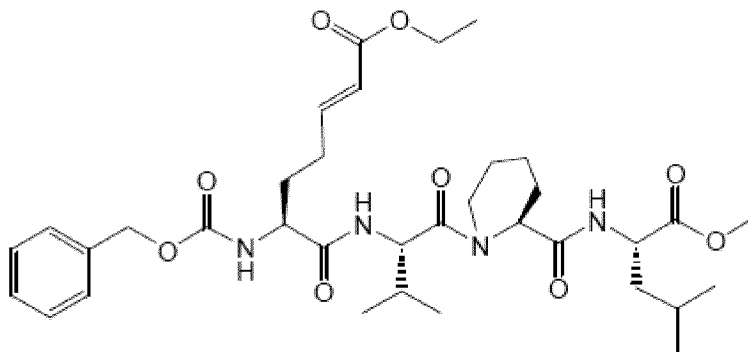
- 5 The synthesis of Ref.5 was performed according to example 1-1, using the corresponding anhydride and amino acids.

Yield: 41 mg, 56 %, ratio of regioisomers: approximately 1:1

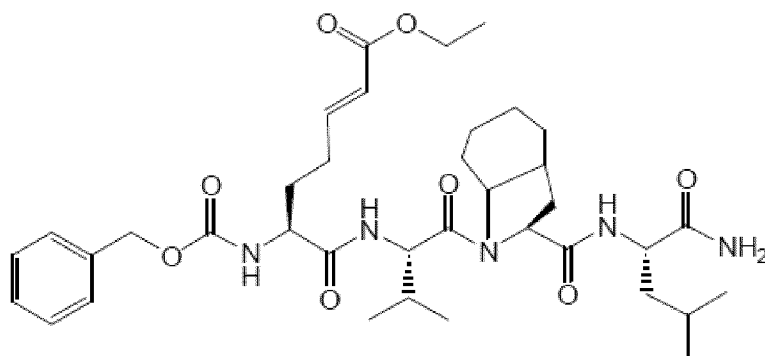
ESI-MS: 868.6 $[M+H]^+$

10

Reference compound 6 (Ref.6) disclosed in WO 2008055488 A1 as compound 38.

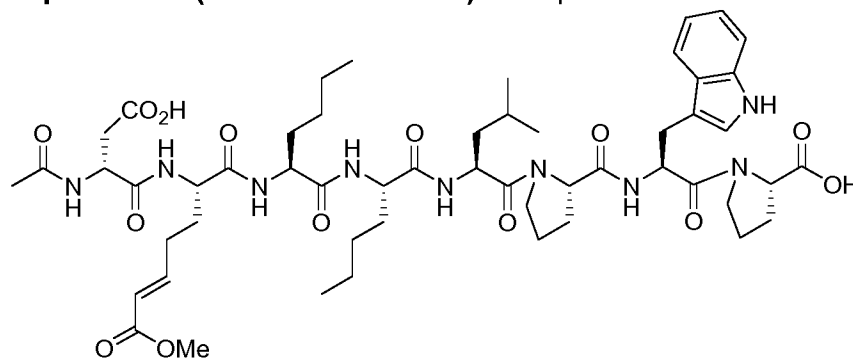


Reference compound 7 (Ref.7) disclosed in WO 2008055488 A1 as compound 4.1.

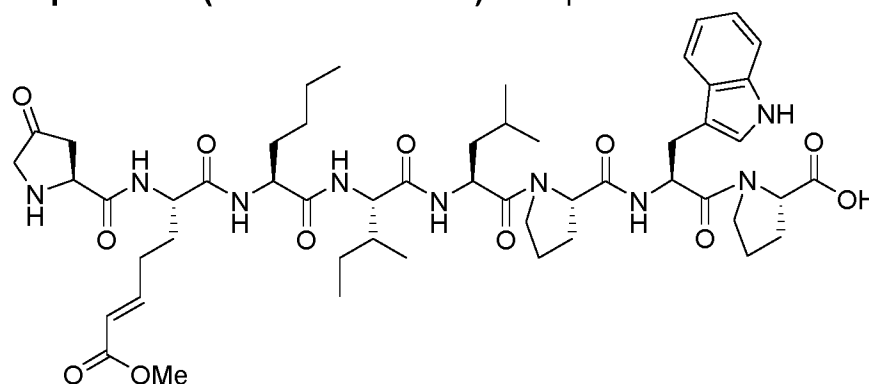


15

Reference compound 22 (Ref.22 - ZED1301): compound 4 of WO2014/090835

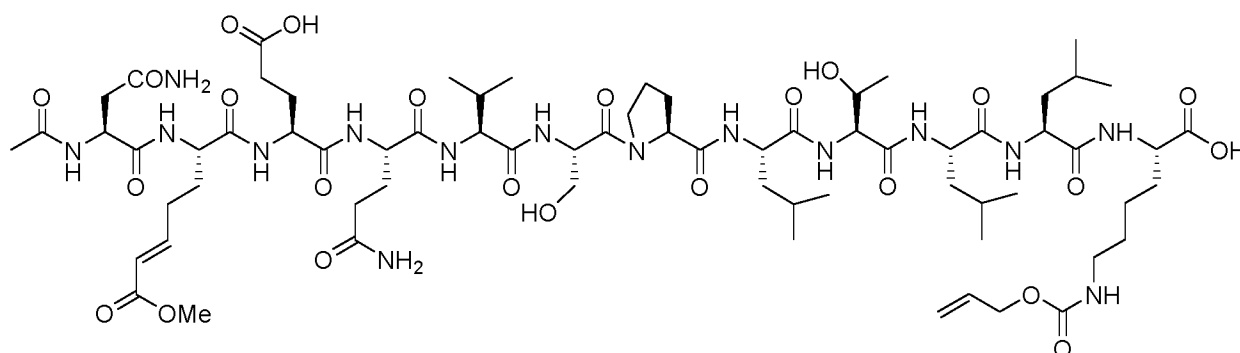


5 **Reference compound 23 (Ref.23 - ZED1390):** compound 7 of WO2014/090835

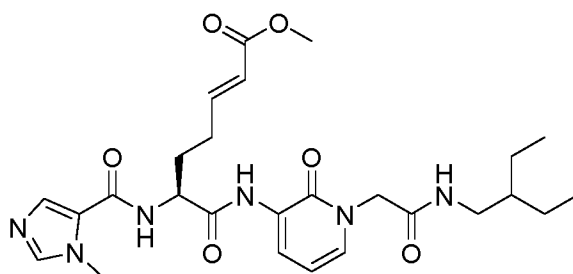


Reference compound 24 (Ref.24 - ZED1251) disclosed in *Thrombosis Research*, **2013**, 131, e214-e222.

10



Reference compound 25 (Ref.25 - ZED1227) disclosed in *Amino Acids*, **2017**, 49, 585-595.



15

Biological Examples

Example 2-1: FXIII activity assays

5 A: Isopeptidase assay for estimating inhibitor potency

FXIIIa activity has been determined using substrate A101 (Zedira GmbH, Darmstadt, Germany), which is based on the N-terminal dodecapeptide of α_2 -antiplasmin. FXIIIa catalyzes by its isopeptidase activity the release of dark quencher dinitrophenyl at the original substrate glutamine position resulting in fluorescence increase (based on the
10 N-terminal 2-aminobenzoyl fluorescent dye) (Oertel K, Hunfeld A, Specker E, Reiff C, Seitz R, Pasternack R, Dodt J. A highly sensitive fluorometric assay for determination of human coagulation factor XIII in plasma. *Anal Biochem* 2007; **367**: 152–8.)

Briefly, 12 μ L recombinant cFXIII-A2 (T027, Zedira GmbH, Darmstadt, Germany) or
15 FXIII-A₂B₂ derived from human plasma (T007) (25 μ g/mL) and 3 μ L human α -thrombin (0.5 U/mL, T056, Zedira) were mixed with 270 μ L assay buffer (50 mM Tris–HCl, 10 mM CaCl₂, 150 mM NaCl, 5.56 mM glycine methyl ester, 5 mM DTT, pH 7.5) containing 55 μ M A101 substrate. The mixture was incubated for 20 min at room temperature to activate FXIII. 15 μ L of inhibitor solution (serial dilution from 1.25 μ M to 1.25 nM)
20 dissolved in DMSO/assay buffer were added, mixed and the kinetic measurement started after 3 min. Fluorescence emission was monitored at 418 nm (λ_{ex} = 313 nm) and 37 °C for 30 min using a CLARIOstar fluorescence micro plate reader (BMG Labtech, Ortenberg, Germany). For measurements without inhibitor, 15 μ L of assay buffer / 2% (v/v) DMSO were added. All measurements were performed in triplicate.
25 The respective IC₅₀ values were calculated by non-linear regression using the MARS software package (BMG Labtech).

The inhibition of FXIIIa from animal species was performed accordingly using 36 μ g/mL mouse FXIII-A₂ (T061, Zedira), 27 μ g/mL rat FXIII-A₂ (T065), 11 μ g/mL pig FXIII-A₂ (T066), 32 μ g/mL dog FXIII-A₂ (T062), and 22 μ g/mL cynomolgus cFXIII-A₂ (T161), all
30 produced recombinantly.

B: Transamidation assay for determining inhibitor selectivity

The most relevant off-targets are the transglutaminase isoenzymes especially tissue transglutaminase (TG2) because the enzyme is ubiquitously expressed throughout the
35 human body. To determine selectivity, the fluorescence increase upon transglutaminase-catalyzed incorporation of dansylcadaverine into the universal transglutaminase substrate N,N-dimethylcasein was used (Lorand L, Lockridge OM, Campbell LK, Myhrman R, Bruner-Lorand J. Transamidating enzymes. *Anal Biochem* 1971; **44**: 221–31.).

Briefly, 15 μ L of recombinant transglutaminase enzyme[5] [15 μ g/mL hTG1 (T035, Zedira), 69 μ g/mL hTG2 (T022), 29 μ g/mL hTG6 (T021), 18 μ g/mL hTG7 (T011)] were mixed with 270 μ L assay buffer containing dansylcadaverine and N,N-dimethyl casein. In the case of FXIII, 12 μ L cFXIII (25 μ g/mL) and 3 μ L human α -thrombin (0.5 U/mL, T056, Zedira) were mixed with 270 μ L assay buffer. The mixture was incubated for 20 min at room temperature to activate FXIII. In the case of TG3 78 μ g hTG3 (T024) were activated using 14 μ g dispase II (Roche, Mannheim, Germany) in the presence of 1.4 mM CaCl_2 and incubated for 30 min at 25°C. The activated hTG3 was subsequently assayed as described above. 15 μ L of inhibitor solution dissolved in DMSO/assay buffer were added, mixed and the kinetic measurement started after 3 min. Fluorescence emission was continuously monitored for 30 min at 500 nm (λ_{ex} = 330 nm) and 37 °C using the CLARIOstar fluorescence plate reader. All measurements were performed in triplicate. The respective IC_{50} values were calculated by non-linear regression using the MARS software package (BMG Labtech, Ortenberg, Germany).

The following tables summarize the inhibition data of compound 5 (=5a/b) against human plasma derived FXIII-A₂B₂ and the recombinant cellular form (FXIII-A₂). In addition, the inhibition of cFXIII from mouse, rat, rabbit, dog, pig and cynomolgus is shown using different assays.

Table 1

Transglutaminase		Isopeptidase Assay	Transamidation Assay
	Species	IC_{50} [nM]	IC_{50} [nM]
pFXIII	human	10 $\pm$ 0.1	4 $\pm$ 0.4
cFXIII	human	16 $\pm$ 0.6	24 $\pm$ 1.5
cFXIII	mouse	19 $\pm$ 0.6	15 $\pm$ 1.2
cFXIII	rat	8 $\pm$ 0.1	17 $\pm$ 0.6
cFXIII	rabbit	20 $\pm$ 1.0	7 $\pm$ 1.7
cFXIII	dog	28 $\pm$ 0.6	24 $\pm$ 0.6
cFXIII	pig	365 $\pm$ 8.0	16 $\pm$ 1.5
cFXIII	cynomolgus	15 $\pm$ 0.1	19 $\pm$ 0.6

Table 2. The selectivity against human transglutaminases iso-enzymes.

Transglutaminase		Transamidation Assay	Selectivity
		IC_{50} [nM]	

cFXIII	24 ± 1.5	1
TG1	11035 ± 1003	463
TG2	445 ± 20	19
TG3	66511 ± 4544	2791
TG6	17 ± 0.6	0.7
TG7	1330 ± 102	56

Table 3 inhibitory activity of the inventive compounds against FXIII and TG2 selectivity for selected compounds (isopeptidase assay)

Compound	IC ₅₀ [nM]	IC ₅₀ [nM]	selectivity
	FXIII	TG2	
1a/b	11	75	6.8
2a/b	16	69	4.3
3	20	16	0.8
4	13	14	1.1
5a/b	16	67	4.2
6	17	12	0.7
7a/b	21	610	29.0
8a/b	21	417	19.9
9a/b	139	501	3.6
10a/b	42	38	0.9
11a/b	70	178	2.5
12a/b	51	257	5.0
13a/b	96	221	2.3
14a/b	26	59	2.3
15a/b	69	483	7.0
16a/b	106	204	1.9
17a/b	41	295	7.2
18a/b	510	239	0.5
19a/b	141	298	2.1
20a/b	156	218	1.4
21a/b	59	100	1.7
22a/b	42	56	1.3
23a/b	91	160	1.8
24a/b	18	63	3.5
25a/b	20	35	1.8
26a/b	43	98	2.3
27	27	64	2.4
28	36	41	1.1

29	24	32	1.3
30	15	16	1.1
31a/b	10	27	2.7
32a/b	12	72	6.0
33a/b	2138	7980	3.7
34a/b	123	356	2.7
35a/b	86	198	2.3
36a/b	41	168	4.1
37a/b	69	324	4.7
Ref. 1	>10000	7040	-
Ref. 2	>10000	>10000	-
Ref. 3	>10000	>10000	-
Ref. 4	>10000	7039	-
Ref. 5	9762	3462	0.4
Ref. 6	>10000	48	-
Ref. 7	>10000	32	-

*Compounds a/b means 1 to 1 mixutere of two regiomers

Table 4 inhibitory activity of the inventive compounds against FXIII and TG2 selectivity of prior art compounds

Compound	FXIII IC ₅₀ [nM]	TG2 IC ₅₀ [nM]	Selectivity
Ref.08	3648	36	0.01
38	47	760	16.17
Ref.09	5690	26	0.00
39a/b	39	698	17.90
Ref.10	8183	176	0.02
40	81	848	10.47
Ref.11	5361	253	0.05
42a/b	127	1207	9.50
Ref.12	6771	345	0.05
42a/b	56	679	12.13
Ref.13	465	2800	6.02
Ref.14	>10.000	2150	-
43	158	856	5.42
Ref.15	226	117	0.52
Ref.16	>10.000	196	-
44	141	798	5.66
Ref.17	420	227	0.54

Ref.18	995	341	0.34
Ref.19	4975	370	0.07
Ref.20	8475	381	0.04
Ref.21	>10.000	421	-
45a/b	35	705	20.14
Ref.22	110	2919	26.54
Ref.23	56	102	1.82
Ref.24	306	169	0.55
Ref.25	>10.000	45	-

Example 2-2: Inhibition of fibrin cross-linking and size exclusion chromatography of fibrin degradation products

For the *in vitro* preparation of fibrin clots, HSA-free human fibrinogen (2.5 mg/mL, FIB3, Enzyme Research Laboratories, South Bend, IN, USA), diluted in 20 mM Tris-HCl, 300 mM NaCl, pH 7.4, was mixed with cFXIII (10 µg/mL, T027, Zedira), and 5 mM CaCl₂. Prior to the addition of 50 U human thrombin (T053, Zedira), either DMSO (2.4% v/v) or the inventive compound as inhibitor (10 µM final concentration dissolved in DMSO) were added to the mixture. To allow completion of fibrin cross-linking, incubation was performed at 37°C for 16 h. Subsequently, recombinant human plasmin (0.2 mg/mL, P012, Zedira) was added to the mixture and incubated at 37°C for 1 h to solubilize the fibrin clots. Separation of cross-linked and non-cross-linked fibrin degradation products (x FDPs / FDPs, respectively) was performed using a Sephacryl S-200 column (CV = 120 mL, GE Healthcare, Uppsala, Sweden) equilibrated in 20 mM Tris-HCl, 500 mM NaCl, pH 7.4.

Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) was performed according to Laemmli (Laemmli UK. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. *Nature* 1970; **227**: 680–5.). Briefly, samples were mixed with non-reducing 5 × SDS-PAGE loading buffer (128 mM Tris-HCl at pH 6.8, 30% glycerol, 10% SDS, and 0.05% bromophenol blue), and loaded on a 10% polyacrylamide gel. Separation was performed at 200 V for 40 min. Gels were stained with Coomassie Brilliant Blue R-250. Electro-blotting was performed in a Trans-Blot SD semi-dry transfer cell (Bio-Rad, Hercules, CA, U.S.A.) at 20 V for 80 min. After blotting, the nitrocellulose membranes were pre-soaked in 48 mM Tris, 39 mM glycine, 1.3 mM SDS, and 20% (v/v) methanol. Residual binding sites were blocked in 5% skimmed milk powder in TBS-T [10 mM Tris, 150 mM NaCl, and 0.05% (v/v) Tween 20 at pH 8.0] for 60 min. The membrane was washed in TBS-T wash buffer and incubated for 1 h. with primary antibody (diluted 10,000-fold in TBS-T). After washing for 3 × 5 min in TBS-T, anti-mouse IgG (Sigma-Aldrich, Schnellendorf, Germany) conjugated to alkaline phosphatase and diluted 10,000-fold in TBS-T buffer was added to the

membranes followed by 1 h incubation. The membranes were placed in detection reagent (100-fold dilution of AP color reagent in color development buffer, Bio-Rad, Hercules, CA, U.S.A.). Excess detection reagent was drained off, and the staining reaction was stopped with 20 mM Tris-HCl and 5 mM EDTA at pH 8.0. All steps were performed at room temperature on a shaker (Figure 1).

Example 2-3: Thromboelastometry (TEM)

Thromboelastometry is a visco-elastic method for the assessment of blood coagulation (Lang T, von Depka M. Possibilities and limitations of thrombelastometry/-graphy. *Hamostaseologie* 2006; **26**: S20–9.). Clotting time (CT), clot formation time (CFT), maximum clot firmness (MCF) and lysis index at 60 min (LI60) were obtained using fresh whole blood in the ROTEM[®] delta device according to the manufacturer's instructions.

The potency of the inventive compounds as inhibitors (serial dilution covering 20.0 μ M to 0.08 μ M final concentration) in the presence of 0.02 μ g/mL tissue plasminogen activator (t-PA; P016, Zedira) was investigated. Briefly, 20 μ L star-TEM[®] (0.2 mol/L CaCl₂), 20 μ L r ex-TEM[®] (recombinant tissue factor, phospholipids, heparin inhibitor), 10 μ L inhibitor stock solution (720 μ M – 2.88 μ M), combined with 10 μ L t-PA stock solution (0.72 μ g/mL) to yield concentrations of 360 μ M - 1.44 μ M in 7.2% DMSO/PBS with 0.36 μ g/mL t-PA and 300 μ L fresh citrated whole blood (from healthy consenting donors) were mixed in a disposable cuvette. As a control the inhibitor stock solution was replaced by 3.6 % DMSO / 0.36 μ g/mL t-PA in PBS.

The figure 2 shows the thromboelastogram of whole human blood spiked with compound 5 at serial dilution 20 μ M – 0.63 μ M compared to control in the presence of 0.02% t-PA

In Figure 3, two graphs (A) and (B) show the reduction of maximum clot firmness compared to inhibitor-free control (MCFc) and the increase in clot lysis at 60 minutes compared to control (LI60c).

The inhibitor has no influence on the clotting time (CT) indicating that the compound does not interfere with other coagulation factors leaving the coagulation cascade, the fibrin formation, and the platelet activation untapped.

The potency of several published FXIII inhibitors (e.g. **Ref.22**, **Ref.23**, **Ref.24** as well as reference molecules **Ref.13**, **Ref.14**, **Ref.15**, and **Ref.16**) was evaluated using thromboelastometry. The detailed dose-dependent influence on key coagulation parameters of compound 5, as novel preferred compound, is shown in figures 2, 3A and 3B. Compound 5 reduced the maximum clot firmness (MCFc, figure 3A) and increased the clot lysis at 60 minutes (LI60c, figure 3B) compared to control lacking the FXIII inhibitor. As detailed in the graphs 3A/3B, at a concentration of 2.5 μ M, compound

5 lowers the clot firmness (MCFc) by 20% while increasing the lysis by 35% compared to control.

The potency of **Ref.22**, **Ref.23**, **Ref.24** as well as reference molecules **Ref.13**, **Ref.14**, **Ref.15**, and **Ref.16** were determined at fixed concentration of 2.5 μ M in the same experimental setting. Spiked into whole human blood the compounds did not influence the clot parameters MCFc and LI60c. Therefore, the molecules were considered being not preferred, while missing the novel structural features claimed herein. In contrast, novel compounds **43**, **44**, and **45a/b** (also spiked at 2.5 μ M) showed efficacy in reducing clot firmness MCFc by 8%, 7%, and 17% (compare to figure 3A) while facilitating clot lysis to 14%, 11%, and 27% (LI60c, compare to figure 3B). Compounds **43**, **44**, and **45a/b** are novel displaying the structural features claimed herein to design potent drug-like FXIII inhibitors.

Further, the stability of compounds in plasma was determined as prerequisite for drug-likeness. Briefly, after spiking the chemical entities, the plasma was incubated at 37°C. At certain time points (e.g. at 15 and 120 minutes), 3 vol. cold MeOH were added to extract the compounds. After centrifugation, the supernatant was analyzed by HPLC. The half life was calculated based on the respective calibration curve. Compounds **Ref.22**, **Ref.23**, **Ref.24** as well as reference molecules **Ref.13**, **Ref.14**, **Ref.15**, **Ref.16**, **Ref.17**, and **Ref.18** were unstable in plasma as indicated by plasma half life below 15 minutes. Therefore, they were considered being not suitable FXIII inhibitors due to the short half life in blood. These compounds are missing the novel structural features disclosed herein. In contrast, compounds **1a/b**, **2a/b**, **3**, **4**, **5a/b**, **6**, **7a/b**, **8a/b**, **9a/b**, **10a/b**, **11a/b**, **12a/b**, **13a/b**, **14a/b**, **15a/b**, **16a/b**, **17a/b**, **18a/b**, **19a/b**, **20a/b**, **21a/b**, **22a/b**, **23a/b**, **24a/b**, **25a/b**, **26a/b**, **27**, **28**, **29**, **30**, **31a/b**, **32a/b**, **33a/b**, **34a/b**, **35a/b**, **36a/b**, **37a/b**, **38**, **39a/b**, **40**, **41**, **42a**, **42b**, **43**, **44**, and **45a/b** were found to be stable in plasma over a period of 2 hours (>75% recovery each determined by HPLC).

In contrast to the reference compounds exceeding a length of 7 amino acids, each inventive compound showed a plasma half-life exceeding 2 h so that the FXIII inhibitors disclosed herein are sufficiently drug-like in contrast to the reference compounds having a half-life in blood of less than 15 minutes.

Example 2-4: anti-coagulation in a rabbit model of venous stasis and reperfusion

Purpose bred animals were identified upon arrival in the test facility according to the respective guidelines. Male New Zealand White rabbits (2-3 kg) were anesthetized for the duration of the procedure. The rabbit's right jugular vein was exposed and any collateral veins to the venous stasis segment were ligated. In order to prevent

embolization, approximately 4 cm of a 10 cm long polyester suture thread was inserted from upstream into the lumen of the designated stasis segment prior to the ligations to allow thrombus formation around the thread. An ultrasound probe was placed perivascularly on the right jugular vein downstream to the venous stasis segment, and blood flow was recorded continuously (3 mm probe, Transonic Systems Inc, Ithaca, USA). Blood samples were taken from the right femoral artery (1 mL in 150 mM sodium citrate) as shown below. Test compound 5 (n=7) or negative control (n=6) were administered at the selected concentration and flow rate through an i.v. bolus or infusion via the right femoral vein as visualized below. The negative control animals received 2 x PBS / 5% glucose containing in mM: NaCl 273.8, NaH₂PO₄ x 2 H₂O 14.2, KCl 5.4 and KH₂PO₄ 2.9, pH 7.4 ± 0.05 / 5% (w/v) glucose. This solution was administered at the same volume, via the same route and at the same flow rate as the test compound 5 (identical formulation). Fifteen min (counting from the end of the injection) after the slow bolus injection (approx. 60 s injection time) of test article or vehicle, the right jugular vein was clamped, starting with the downstream clamp, followed 10 s later by the upstream one. 150 µL of blood were collected from the femoral artery and supplemented with 45 µL of 0.25 M calcium chloride. Next, 25 µL of human α-thrombin (2.5 U/mL, Sigma-Aldrich) was added to the blood mixture to induce coagulation. Immediately after mixing the blood, the clotting blood was administered in the isolated part of the right jugular vein. After a venous stasis period of 15 min, the vessel clamps were removed to restore blood flow from the jugular vein. The test article was infused during this venous stasis period. Blood flow was recorded with the transonic flow probe for a period of two h while the test article was infused at the selected concentration (see **Table 4**). 2 h after reperfusion, the venous stasis segment was removed, opened longitudinally and emptied into a petri dish containing 5% sodium citrate solution. Any existing thrombi were removed and blotted on a filter paper. The thrombi were measured, weighed and the appearance was judged.

A bleeding time was performed 30 min after beginning of reperfusion using an ITC SurgicuttTM Bleeding Time Device (International Technidyne SU50I via Fisher Scientific, Ottawa, Canada). Bleeding time was assessed with a filter paper by carefully collecting blood from the wound rim until no red staining of the filter paper could be observed. For each measure, a different non-stained part of the filter paper was used. The maximum bleeding time was defined as 300 s.

For each blood sample time point, plasma samples were generated using 150 mM sodium citrate as anticoagulant. Samples were stored at -20°C until further analysis: determination of compound 5 concentration by HPLC and determination of residual FXIII activity after thrombin activation using the isopeptidase assay described above. In

addition, one blood sample was taken at 60 min after the test article administration for thromboelastography (TEG). The TEG 5000 traces were recorded on the fresh whole blood sample for a period of 60 min according to the manufacturer. The read-outs are similar to the thromboelastometry and key parameters were combined to give the coagulation index (CI). Subsequent to the observation period of about 150 min after reperfusion, the animals were euthanized following an intracardiac blood draw by administering an overdose of pentobarbital.

Statistical Analysis

Unpaired Student's t-tests were performed on all experimental conditions, comparing the values obtained from rabbits injected with the test article to the values obtained from the negative control rabbits. Statistical significance is indicated if $p \leq 0.05$ compared to negative control animals. For each group, data is expressed as the mean $\pm$ S.E.M.

Experimental schedule of the rabbit model of venous stasis and reperfusion is briefly presented in **Figure 4A**.

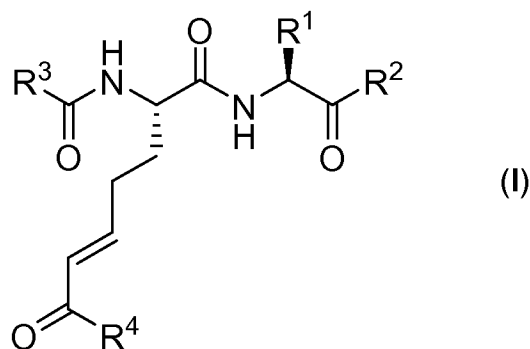
Table 4. Intravenous Injection Parameters

Injection	Injection Time (min)	Compound 5 (= 5a/b) Concentration (mg/mL)	Volume (mL)	Flow Rate (mL/min)	Total Dose (mg)
Bolus	1	4	8	8	32
Infusion	15	4	2	0.13	8
Infusion	135 (15 stasis +120 post stasis)	4	18	0.13	72

The in vivo experiment proves significantly higher flow rates after compound 5 infusion compared to PBS control animals (**Figure 4B**). The area under the curve of flow rate is in accordance to the vein flow rate. In the compound 5 group the mean areas under the curve (AUC) of the jugular flow rate normalized to baseline between time points 35 and 135 minutes are significantly higher (**Figure 4C**). The Thrombus wet weight is significantly reduced in the compound 5 group. Thrombus wet weight was determined after 135 min of infusion (**Figure 4D**). Most importantly the template skin bleeding time is not influenced. Template skin bleeding time was determined after 60 min of infusion. No difference between PBS and compound 5 was observed. Maximal observation time was pre-defined at 300 seconds (**Figure 4E**).

Claims

1. A compound of the general formula (I):

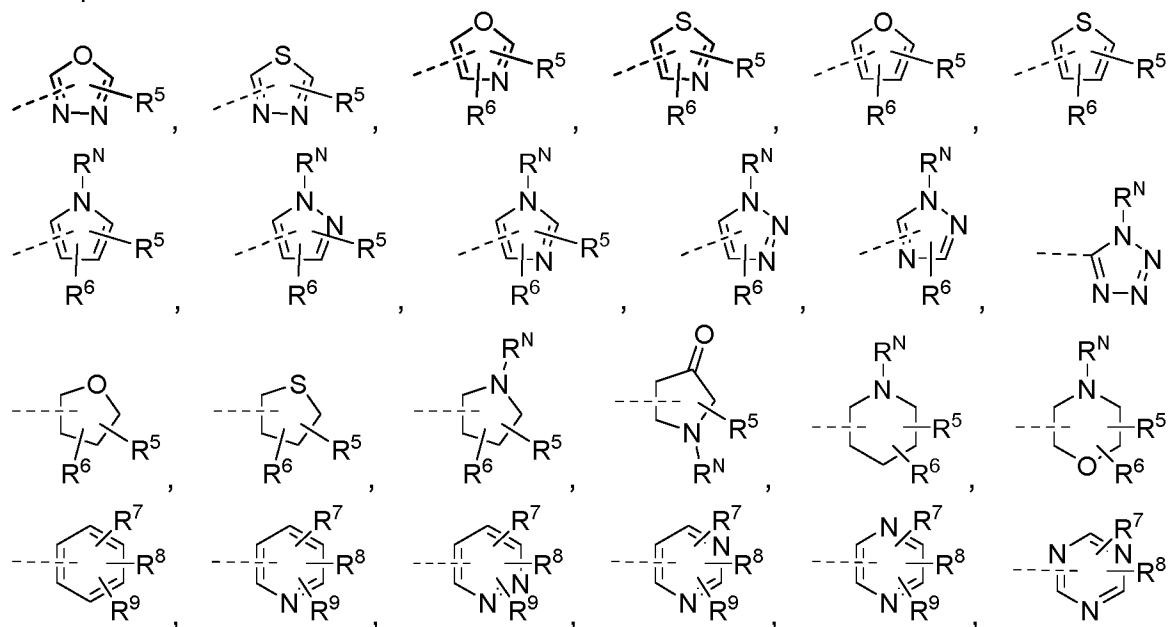


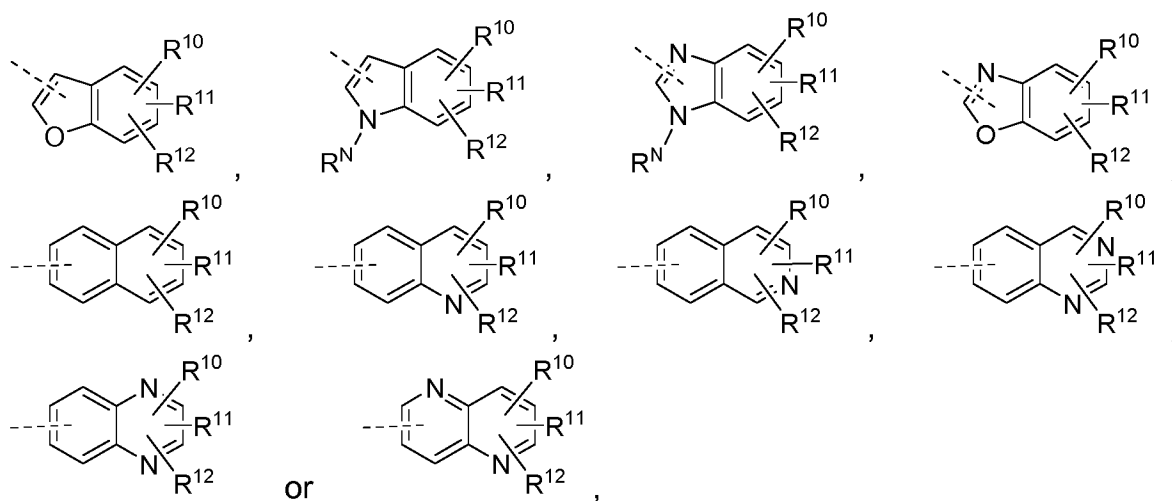
wherein

R¹ represents -H, -CH₃, -C(CH₃)₃, -cyclo-C₃H₅, -cyclo-C₄H₇, -cyclo-C₅H₉, -cyclo-C₆H₁₁, -CH₂-CH(CH₃)₂, -CH₂CH₃, -CH₂CH₂CH₃, -CH₂CH₂CH₂CH₃, -CH₂CH₂CH₂CH₂CH₃, -CH₂CH₂CH₂CH₂CH₂CH₃, -CH(CH₃)₂, -CH₂-C(CH₃)₃, -CH₂CH₂SCH₃, -CH₂-cyclo-C₃H₅, -CH₂-cyclo-C₄H₇, -CH₂-cyclo-C₅H₉ or -CH₂-cyclo-C₆H₁₁;

R² represents -A¹-A²-A³-E, -A¹-A²-A³-A⁴-E or -A¹-A²-A³-A⁴-A⁵-E;

R³ represents

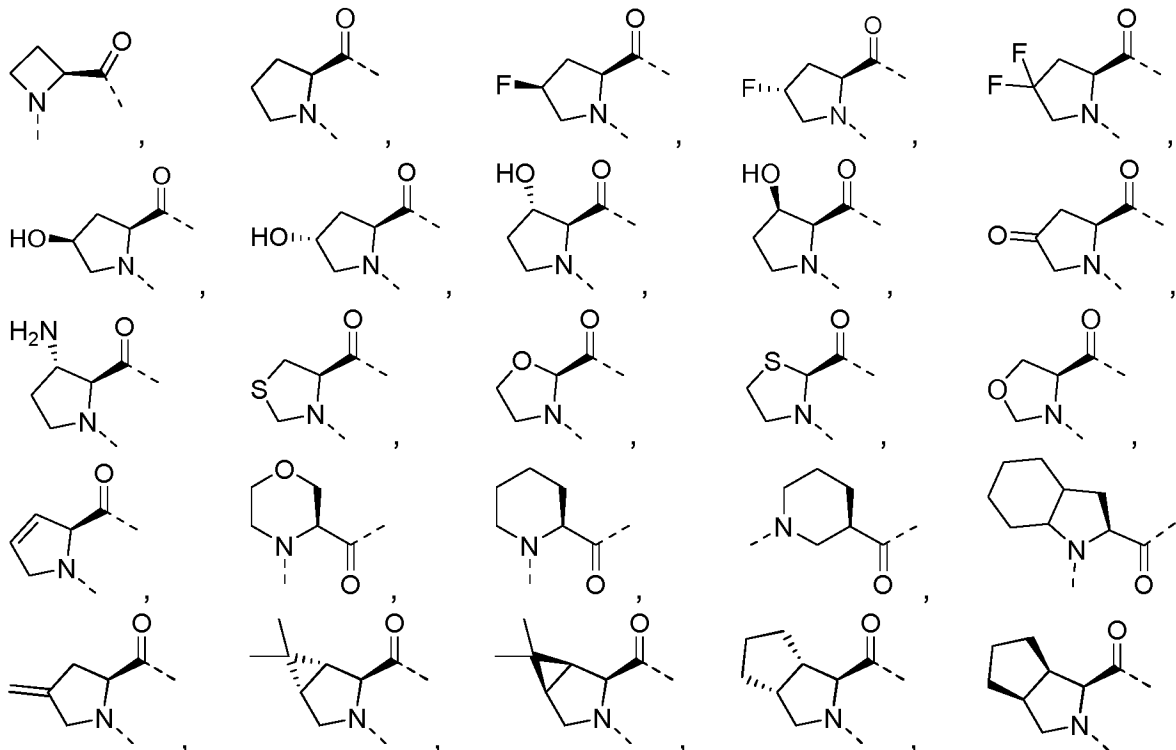


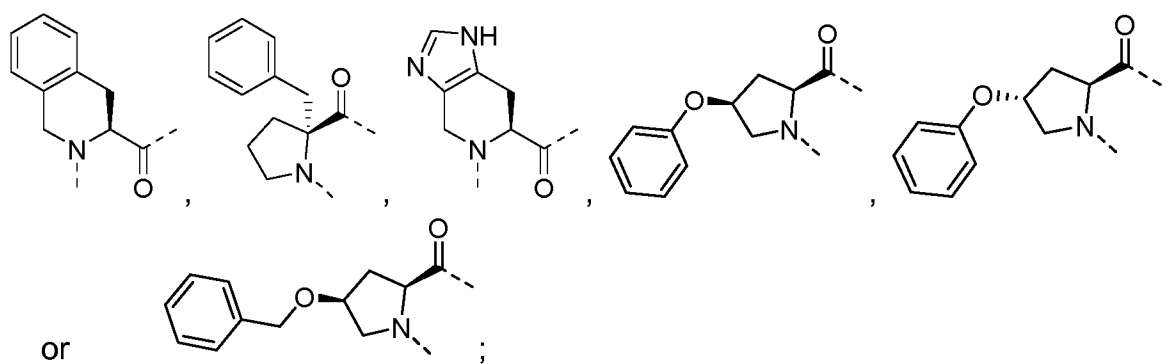


5 R^4 represents $-OR^*$, $-NH_2$, $-NHR^\#$ or $-NR^*R^\#$;

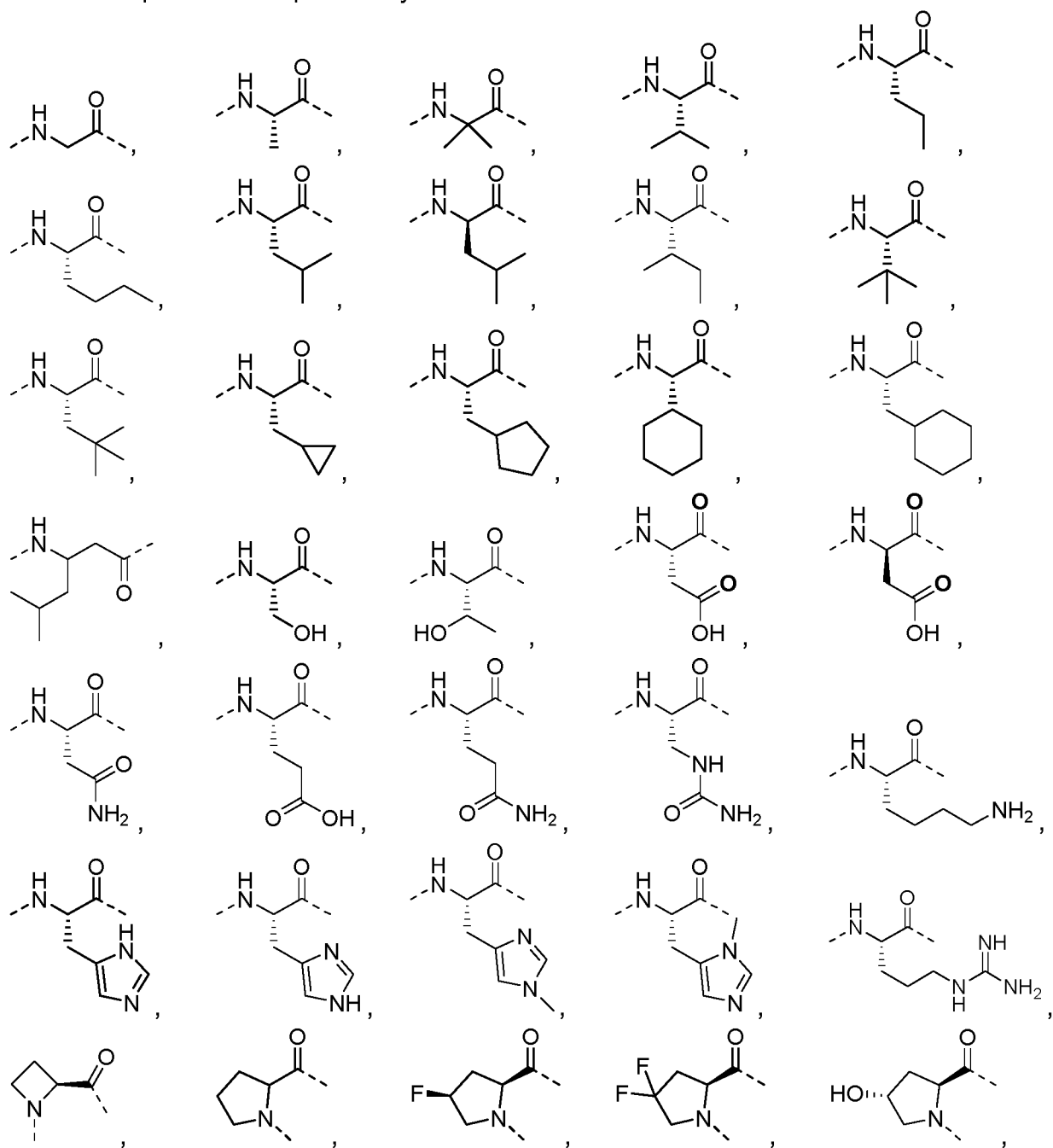
R^* and $R^\#$ represent independently of each other $-CH_3$, $-CH_2CH_3$,
 $-CH(CH_3)_2$, $-CH_2CH_2CH_3$, $-CH_2CH(CH_3)_2$, $-C(CH_3)_3$, $-cyclo-C_3H_5$,
 $-cyclo-C_4H_7$, $-cyclo-C_5H_9$, $-cyclo-C_6H_{11}$, $-CH_2-cyclo-C_3H_5$, $-CH_2-cyclo-C_4H_7$,
 10 $-CH_2-cyclo-C_5H_9$, $-CH_2-cyclo-C_6H_{11}$, $-CH_2-Ph$, $-CH_2OCH_3$, $-CH_2OCH_2CH_3$,
 $-CH_2CH_2OCH_3$, or $-CH_2CH_2SCH_3$;

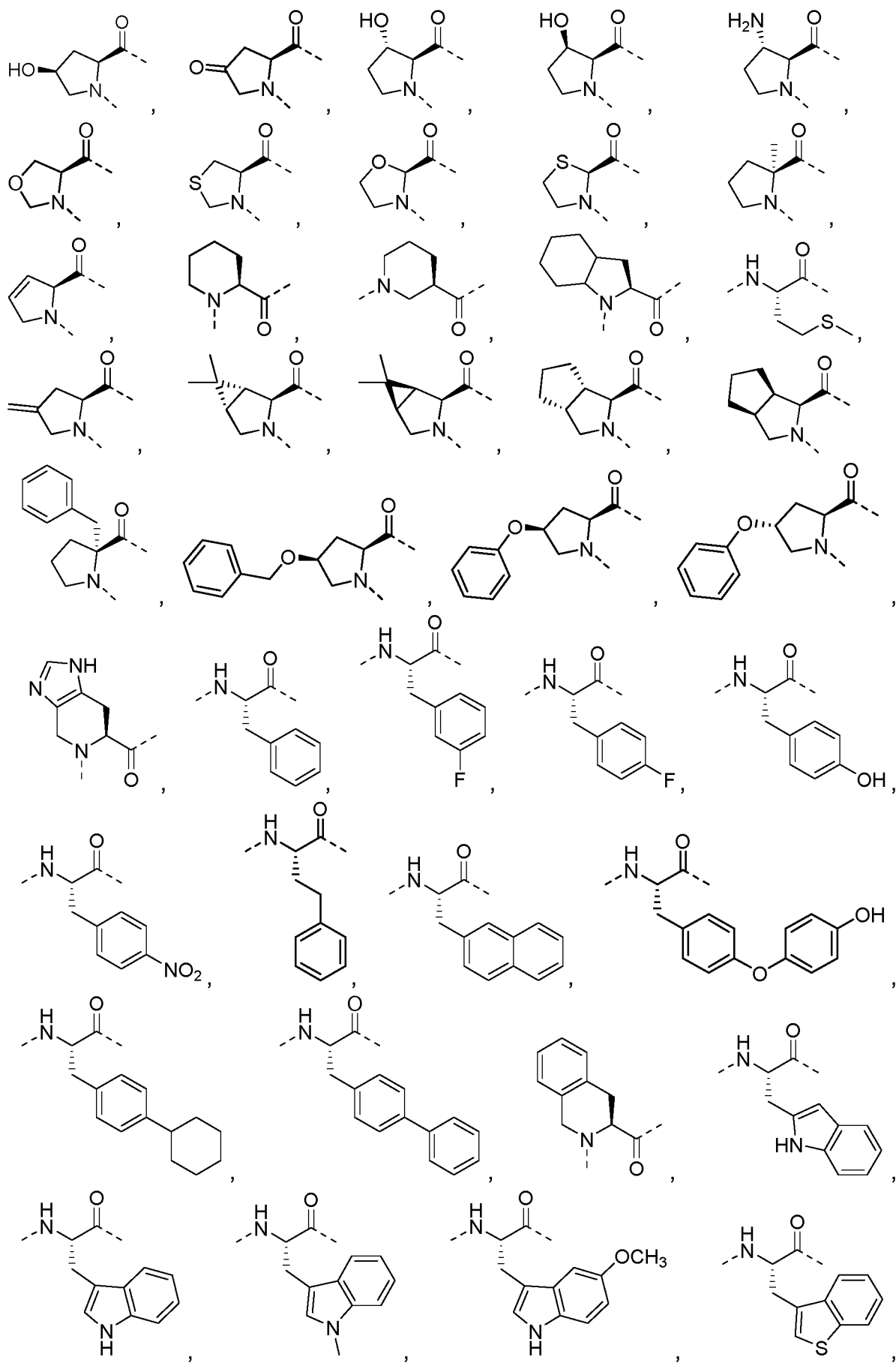
A^1 represents

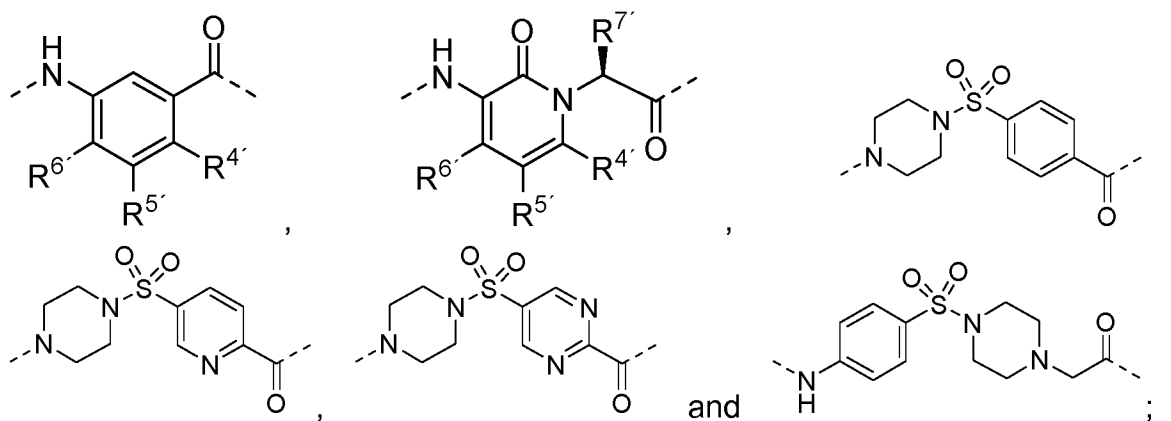




$A^2 - A^5$ represent independently of each other

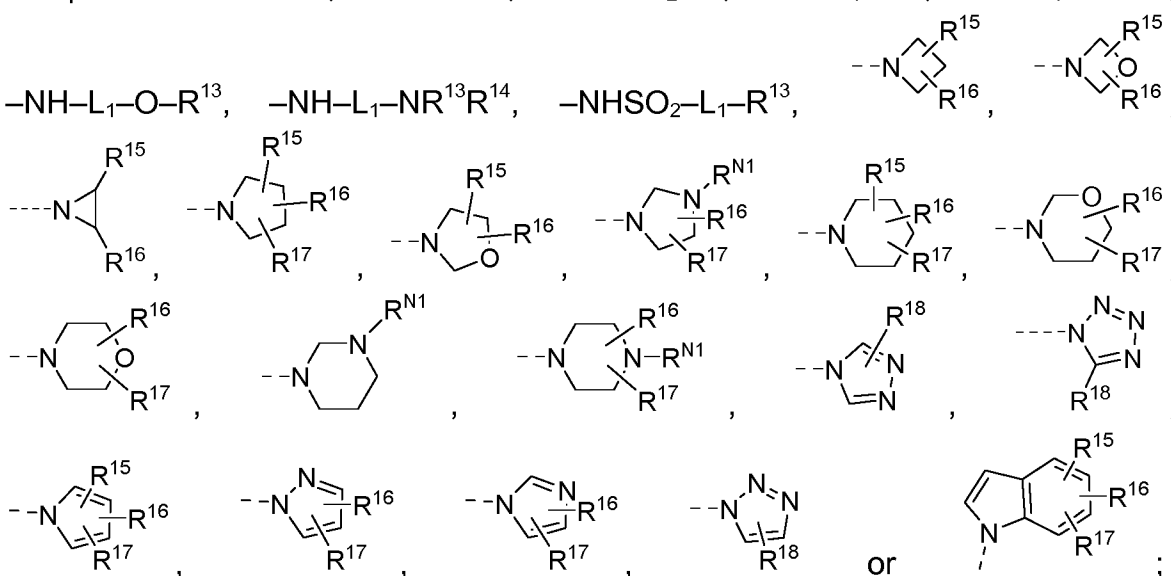




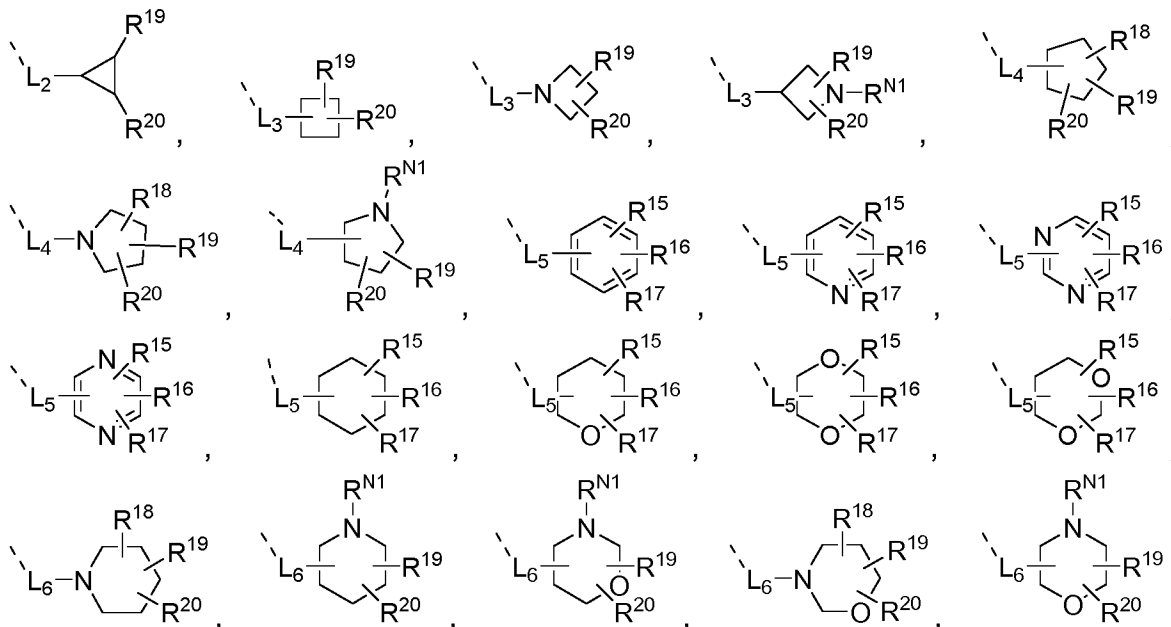


E represents: $-\text{OR}^{13}$, $-\text{NR}^{13}\text{R}^{14}$, $-\text{NHSO}_2\text{R}^{13}$, $-\text{O}-\text{L}_1-\text{R}^{13}$, $-\text{O}-\text{L}_1-\text{O}-\text{R}^{13}$,

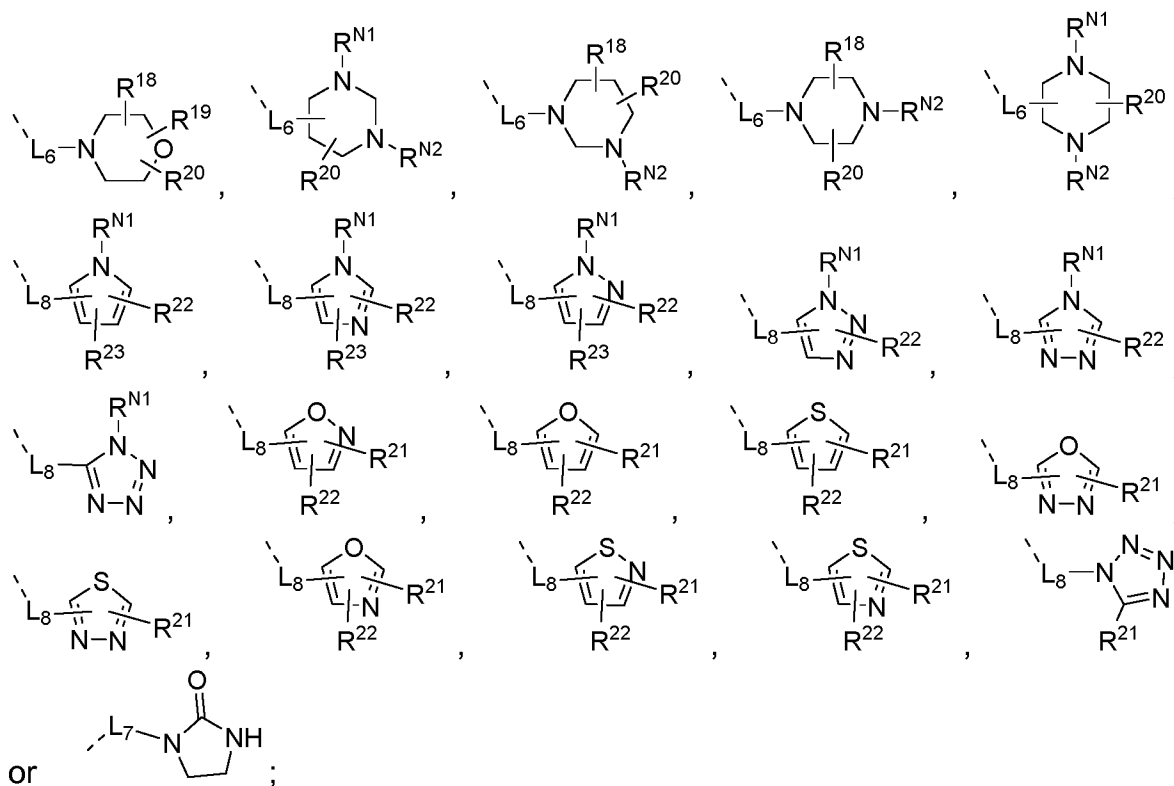
5 $-\text{NH}-\text{L}_1-\text{O}-\text{R}^{13}$, $-\text{NH}-\text{L}_1-\text{NR}^{13}\text{R}^{14}$, $-\text{NHSO}_2-\text{L}_1-\text{R}^{13}$,



10 R^{13} and R^{14} represent independently of each other: $-\text{H}$, $-\text{CH}_3$, $-\text{CH}_2\text{CH}_3$, $-\text{C}(\text{CH}_3)_3$, $-\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}(\text{CH}_3)_2$, $-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$, $-\text{CH}_2\text{CH}(\text{CH}_3)_2$, $-\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$,

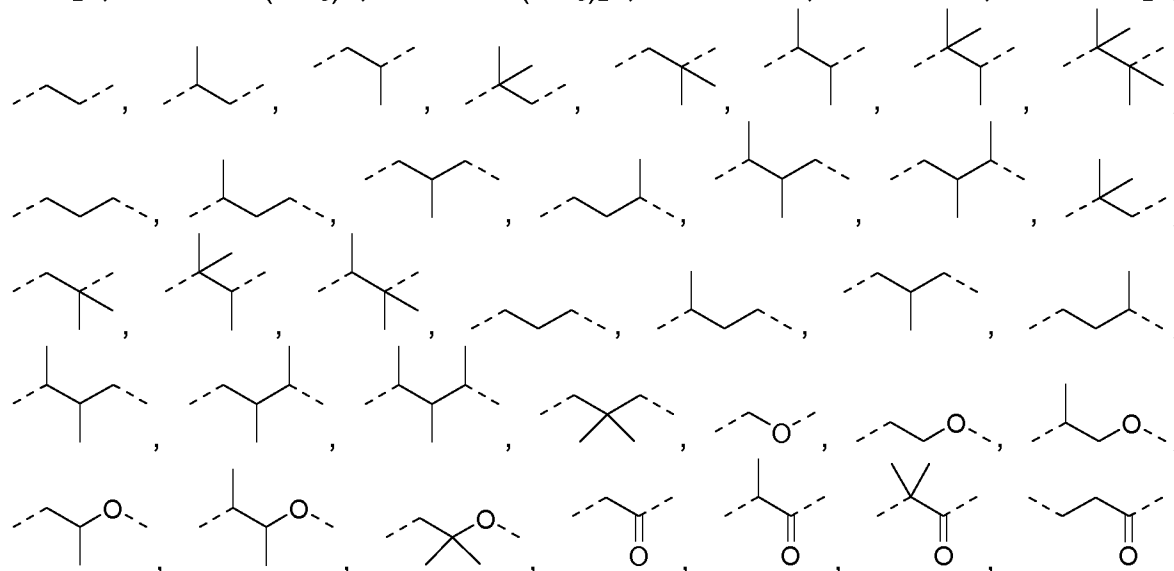


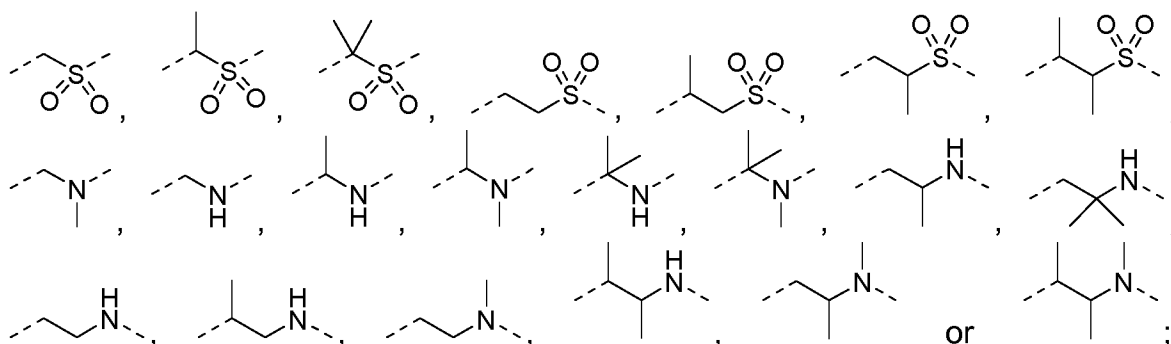
15 $-\text{L}_2$, $-\text{L}_3$, $-\text{L}_4$, $-\text{L}_5$, $-\text{L}_6$,



R^N , R^{N1} and R^{N2} represents independently of each other $-H$, $-CH_3$, $-C_2H_5$, $-C_3H_7$, $-CH(CH_3)_2$, $-C_4H_9$, $-CH_2-CH(CH_3)_2$, $-CH(CH_3)-C_2H_5$, $-C(CH_3)_3$, $-cyclo-C_3H_5$, $-CH_2-cyclo-C_3H_5$, $-CH_2F$, $-CHF_2$, $-CF_3$, $-CH_2Cl$, $-CH_2Br$, $-CH_2I$, $-CH_2-CH_2F$, $-CH_2-CHF_2$, $-CH_2-CF_3$, $-CH_2-CH_2Cl$, $-CH_2-CH_2Br$, $-CH_2-CH_2I$, $-CH_2-CH=CH_2$, $-CH_2-C\equiv CH$, $-CHO$, $-COCH_3$, $-COC_2H_5$, $-COC_3H_7$, $-COCH(CH_3)_2$, $-COC(CH_3)_3$, $-COOCH_3$, $-COOC_2H_5$, $-COOC_3H_7$, $-COOCH(CH_3)_2$, or $-COOC(CH_3)_3$;

$L^1 - L^8$ represents independently of each other a covalent bond, $-CH_2-$, $-CH(CH_3)-$, $-CH(CH_3)_2-$, $-CO-$, $-SO-$, $-SO_2-$,

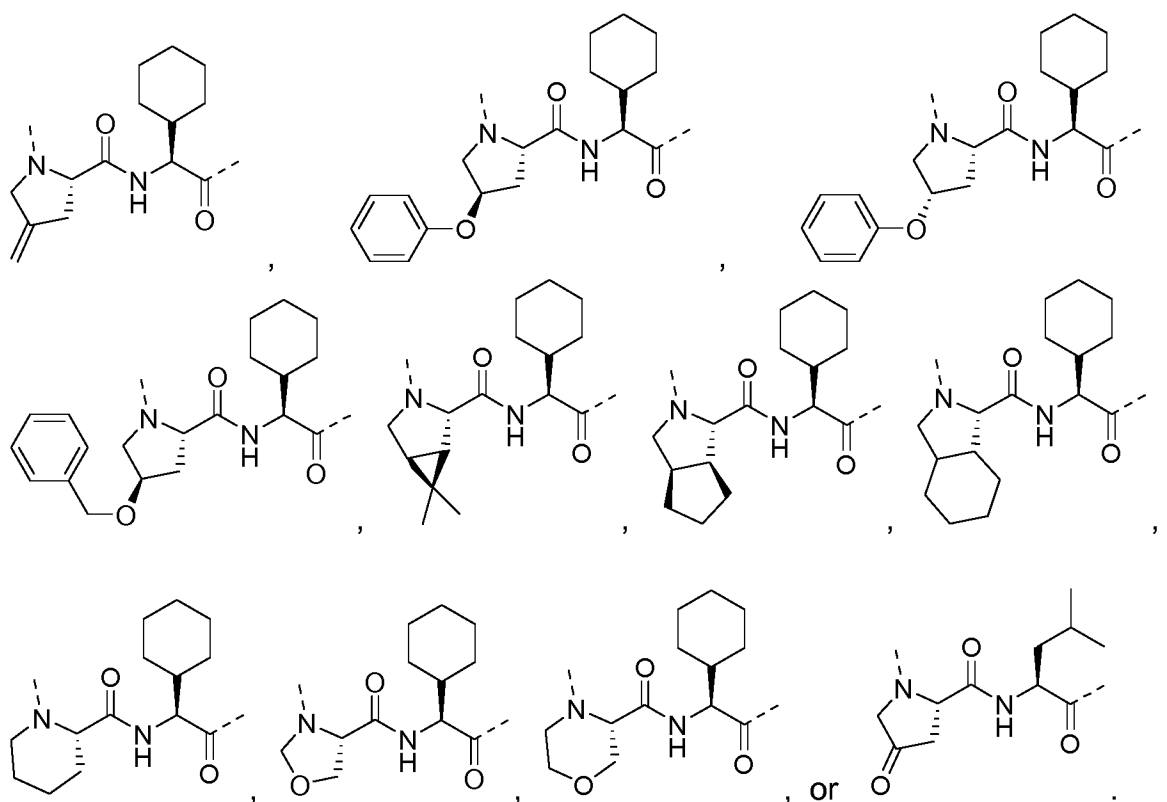




- 5 $R^5 - R^{12}$, $R^{4'} - R^{7'}$, and $R^{15} - R^{23}$ represents independently of each other
 -H, -F, -Cl, -Br, -I, -OH, -CN, -NO₂, -CH₃, -C₂H₅, -C₃H₇,
 -CH(CH₃)₂, -C₄H₉, -CH₂-CH(CH₃)₂, -CH(CH₃)-C₂H₅, -C(CH₃)₃,
 -cyclo-C₃H₅, -CH₂-cyclo-C₃H₅, -CH₂F, -CHF₂, -CF₃, -CH₂Cl, -CH₂Br,
 -CH₂I, -CH₂-CH₂F, -CH₂-CHF₂, -CH₂-CF₃, -CH₂-CH₂Cl, -CH₂-CH₂Br,
 10 -CH₂-CH₂I, -OCH₃, -OC₂H₅, -OC₃H₇, -OCH(CH₃)₂, -OC(CH₃)₃,
 -OC₄H₉, -OCHF₂, -OCF₃, -OCH₂CF₃, -OC₂F₅, -OCH₂OCH₃,
 -O-cyclo-C₃H₅, -OCH₂-cyclo-C₃H₅, -O-C₂H₄-cyclo-C₃H₅, -CHO, -COCH₃,
 -COCF₃, -COC₂H₅, -COC₃H₇, -COCH(CH₃)₂, -COC(CH₃)₃,
 -COOH, -COOCH₃, -COOC₂H₅, -COOC₃H₇, -COOCH(CH₃)₂, -COOC(CH₃)₃,
 15 -OOC-CH₃, -OOC-CF₃, -OOC-C₂H₅, -OOC-C₃H₇, -OOC-CH(CH₃)₂,
 -OOC-C(CH₃)₃, -NH₂, -NHCH₃, -NHC₂H₅, -NHC₃H₇, -NHCH(CH₃)₂,
 -NHC(CH₃)₃, -N(CH₃)₂, -N(C₂H₅)₂, -N(C₃H₇)₂, -N[CH(CH₃)₂]₂, -N[C(CH₃)₃]₂,
 -NHCOCH₃, -NHCOCF₃, -NHCOC₂H₅, -NHCOC₃H₇, -NHCOCH(CH₃)₂,
 -NHCOC(CH₃)₃, -CONH₂, -CONHCH₃, -CONHC₂H₅, -CONHC₃H₇,
 20 -CONHCH(CH₃)₂, -CONH-cyclo-C₃H₅, -CONHC(CH₃)₃, -CON(CH₃)₂,
 -CON(C₂H₅)₂, -CON(C₃H₇)₂, -CON[CH(CH₃)₂]₂, -CON[C(CH₃)₃]₂, -SO₂NH₂,
 -SO₂NHCH₃, -SO₂NHC₂H₅, -SO₂NHC₃H₇, -SO₂NHCH(CH₃)₂,
 -SO₂NH-cyclo-C₃H₅, -SO₂NHC(CH₃)₃, -SO₂N(CH₃)₂, -SO₂N(C₂H₅)₂,
 -SO₂N(C₃H₇)₂, -SO₂N[CH(CH₃)₂]₂, -SO₂N[C(CH₃)₃]₂, -NHSO₂CH₃,
 25 -NHSO₂CF₃, -NHSO₂C₂H₅, -NHSO₂C₃H₇, -NHSO₂CH(CH₃)₂,
 -NHSO₂C(CH₃)₃, -CH=CH₂, -CH₂-CH=CH₂, -C(CH₃)=CH₂, -CH=CH-CH₃,
 -C≡CH, -C≡C-CH₃, -CH₂-C≡CH, -Ph, -O-Ph, or -O-CH₂-Ph,
-

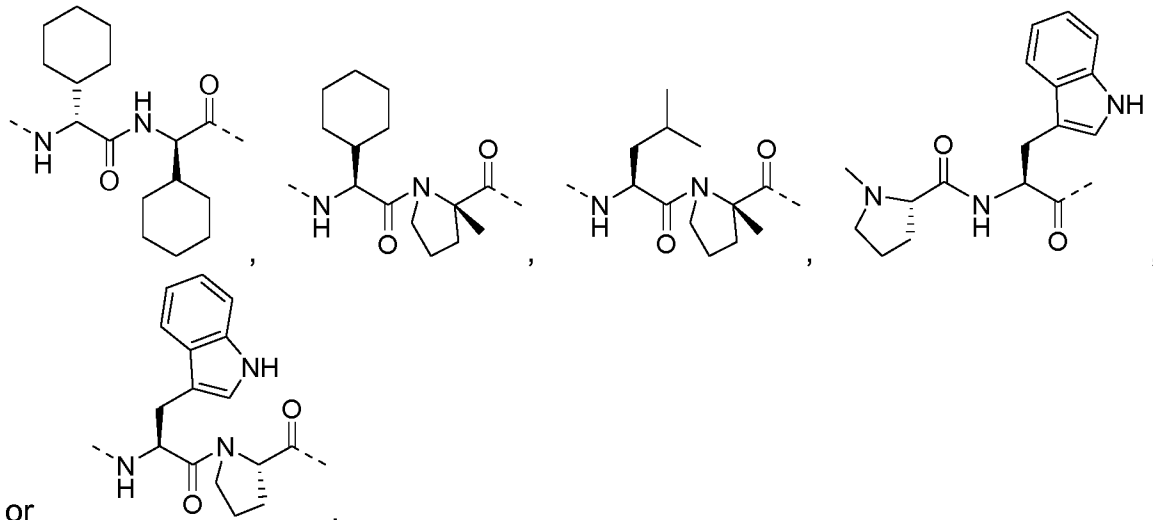
30

or R^7 and R^8 or R^8 and R^9 form together one of the following ring moieties;



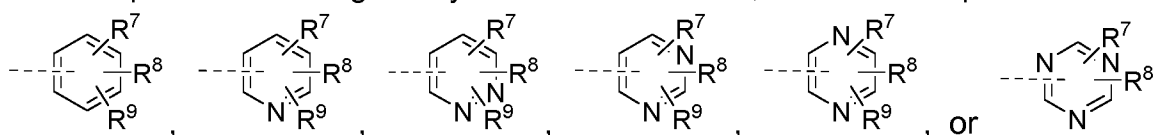
5

5. The compound according to any one of Claims 1 – 4, wherein $-A^2-A^3-$ represents



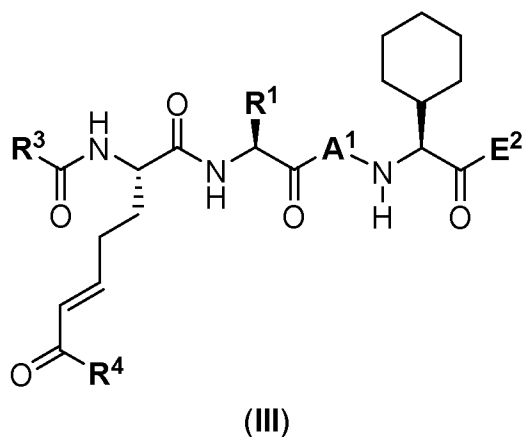
10

6. The compound according to any one of Claims 1 – 5, wherein R^3 represents



and R^7 , R^8 and R^9 have the meanings as defined in Claim 1.

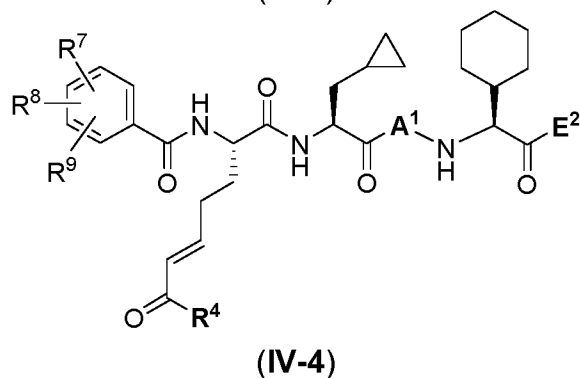
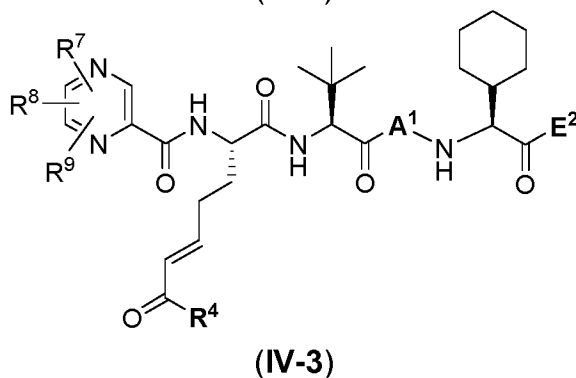
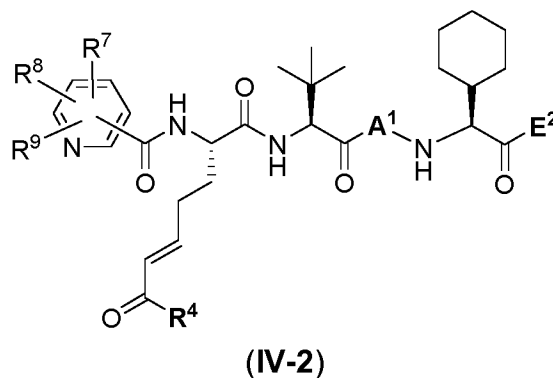
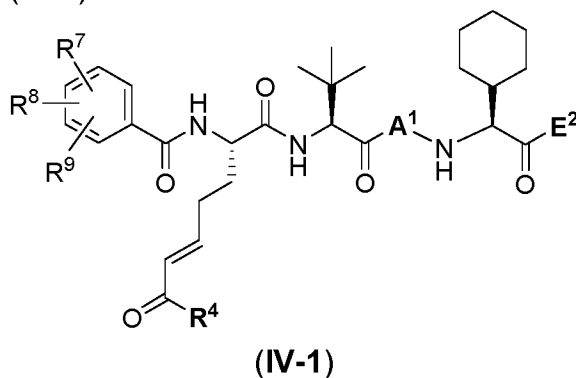
- 15 7. The compound according to Claim 1 of the general formula (III):



wherein

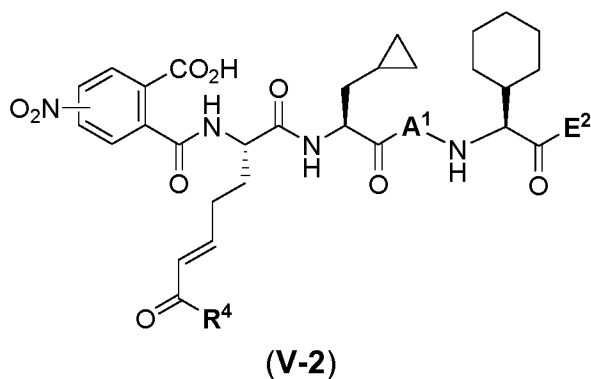
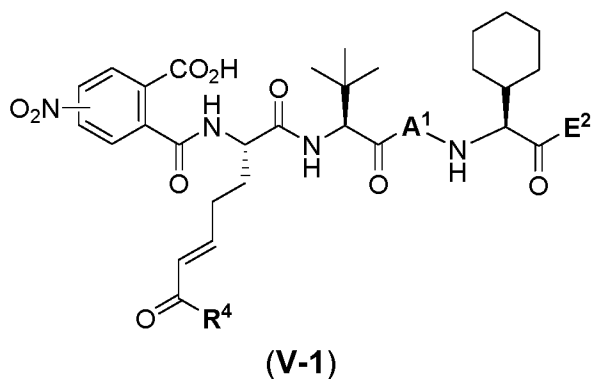
- 5 E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$, or $-A^3-A^4-A^5-E$; and
 A^1 , A^3 , A^4 , A^5 , R^1 , R^3 , R^4 , and E have the meanings as defined in Claim 1.

8. The compound according to Claim 1 or 7 having any one of the formulae (IV-1) to (IV-4):



- 10 wherein
 E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$ or $-A^3-A^4-A^5-E$;
 R^4 represents $-OCH_3$ or $-OCH_2CH_3$;
 R^7 , R^8 and R^9 are independently of each other selected from $-H$, $-Cl$, $-OH$,
 $-NO_2$ or $-COOH$; and
15 A^1 , A^3 , A^4 , A^5 and E have the meanings as defined in Claim 1.

9. The compound according to any one of Claims 1 – 8, wherein the compound has any one of the formulae (V-1) and (V-2):

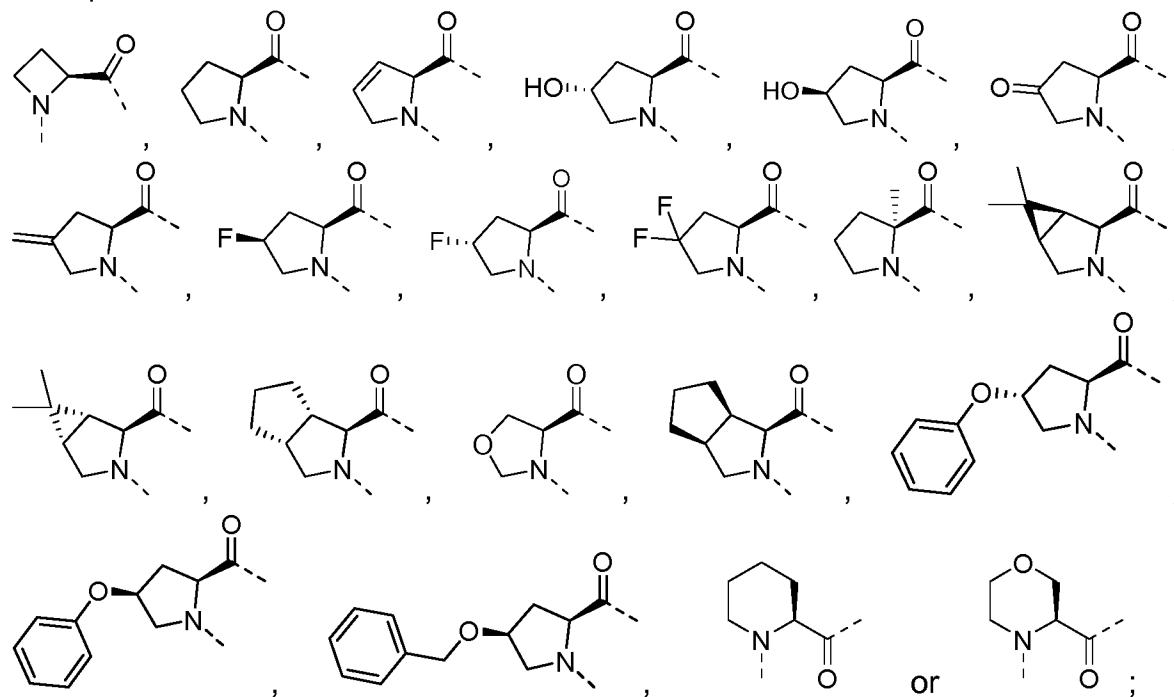


wherein

5 E^2 represents $-E$, $-A^3-E$, $-A^3-A^4-E$ or $-A^3-A^4-A^5-E$;

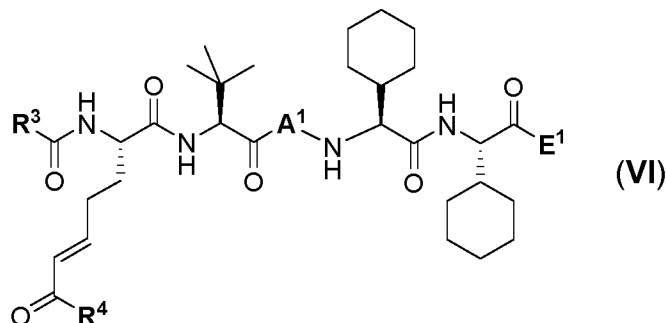
R^4 represents $-OCH_3$ or $-OCH_2CH_3$;

A^1 represents



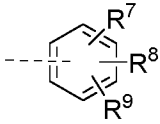
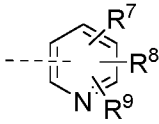
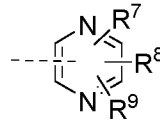
10 and A^3 , A^4 , A^5 and E have the meanings as defined in Claim 1.

- 15 10. The compound according to any one of Claims 1 – 7 having the formula (VI):



wherein

E^1 represents $-E$, $-A^4-E$ or $-A^4-A^5-E$;

R^3 represents ,  or ; and

A^1 , A^4 , A^5 , R^4 , R^7 , R^8 , R^9 and E have the meanings as defined in Claim 7.

11. The compound according to claim 1 selected from a group consisting of:
 compounds **1a**, **1b**, **2a**, **2b**, **3**, **4**, **5a**, **5b**, **6**, **7a**, **7b**, **8a**, **8b**, **9a**, **9b**, **10a**, **10b**, **11a**, **11b**, **12a**, **12b**, **13a**, **13b**, **14a**, **14b**, **15a**, **15b**, **16a**, **16b**, **17a**, **17b**, **18a**, **18b**, **19a**, **19b**, **20a**, **20b**, **21a**, **21b**, **22a**, **22b**, **23a**, **23b**, **24a**, **24b**, **25a**, **25b**, **26a**, **26b**, **27**, **28**, **29**, **30**, **31a**, **31b**, **32a**, **32b**, **33a**, **33b**, **34a**, **34b**, **35a**, **35b**, **36a**, **36b**, **37a**, **37b**, **38**, **39a**, **39b**, **40**, **41**, **42a**, **42b**, **43**, **44**, **45a**, and **45b**.

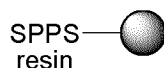
12. The compound according to any one of claims 1 – 11 for use as a medicament, especially for use as a medicament in anticoagulation and FXIIIa inhibition.

13. A pharmaceutical composition comprising at least one compound according to any one of claims 1 – 11 as an active ingredient together with at least one pharmaceutically acceptable carrier, excipient and/or diluent.

14. The compound according to any one of claims 1 – 11 or the pharmaceutical composition according to claim 13 for use in the treatment or prophylaxis of coeliac disease, Duhring-Brocq-disease, gluten ataxia, tissue fibrosis, cystic fibrosis, kidney fibrosis and diabetic nephropathy, liver fibrosis, cataract, ichthyosis, acne, psoriasis, skin aging, candidosis, neurodegenerative disorders including Huntington's disease, Parkinson's disease and Alzheimer's disease as well as atherosclerosis, thrombosis, thrombocytopenia and thrombopreventive indications and for use as anticoagulant in the treatment of sepsis, stroke, recurrent occlusion and acute care setting including acute kidney injury, acute lung injury and acute coronary syndrome.

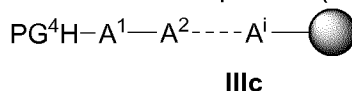
15. A Method for producing compound according to claim 1 comprising:

Step (0B): providing a resin, suitable for solid-phase peptide synthesis (SPPS).

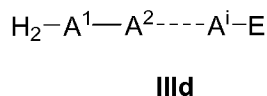


Step (1B) (a): performing coupling reaction of the corresponding C-terminal amino acid buliding block PG^4NH-A^i-OH .

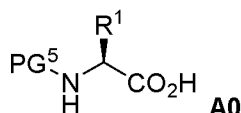
(d) deprotecting the protecting group PG^4 of a resulting compound after Step (a);
 (e) repeating the steps (a) and (b) i times, wherein i is 1-5,
 to obtain a resin bound intermediate compound (**IIIc**).



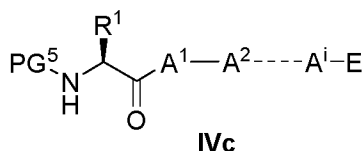
Step (2B): cleavage from resin and deprotecting the protecting group PG^4 to obtain an intermediate compound (**IIId**).



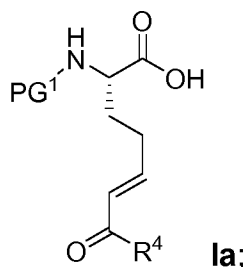
Step (3B): performing coupling reaction of the intermediate compound **IIId** with an amino acid building block **A0**



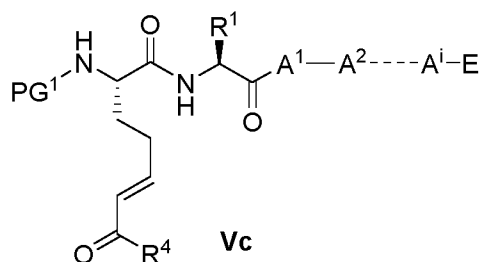
to obtain a compound **IVc**.



Step (4B): deprotecting the protecting group PG^5 and subsequent coupling reaction with protected amino acid **la**



to obtain compound **Vc**



Step (5B): deprotecting the protecting group PG^1 and subsequent coupling reaction with a N-terminal building block $R^3\text{-CO}_2\text{H}$ to produce the compound of the formula (I);

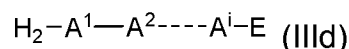
or

Step (0C): providing a N-deprotected C-terminal building block H-E or H-Aⁱ-E.

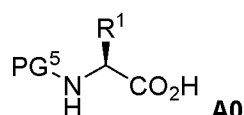
Step (1C): (a) performing coupling reaction of the corresponding C-terminal amino acid building block PG⁴NH-Aⁱ-OH or PG⁴NH-Aⁱ⁻¹-OH.

(d) deprotecting the protecting group PG⁴ of a resulting compound after Step (a);

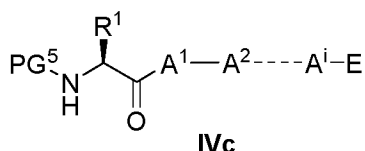
(e) repeating the steps (a) and (b) *i* times, wherein *i* is 1-5 or 1-4, to obtain intermediate compound (IIIId).



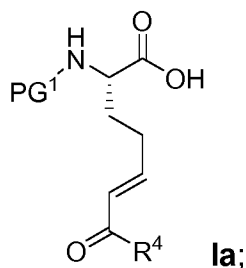
Step (3B): performing coupling reaction of the intermediate compound IIIId with an amino acid building block A0



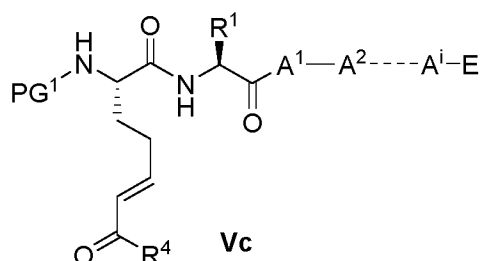
to obtain a compound IVc.



Step (4B): deprotecting the protecting group PG⁵ and subsequent coupling reaction with protected amino acid Ia



to obtain compound Vc



Step (5B): deprotecting the protecting group PG¹ and subsequent coupling reaction with a N-terminal building block R³-CO₂H to produce the compound of the formula (I).

Figures

Figure 1

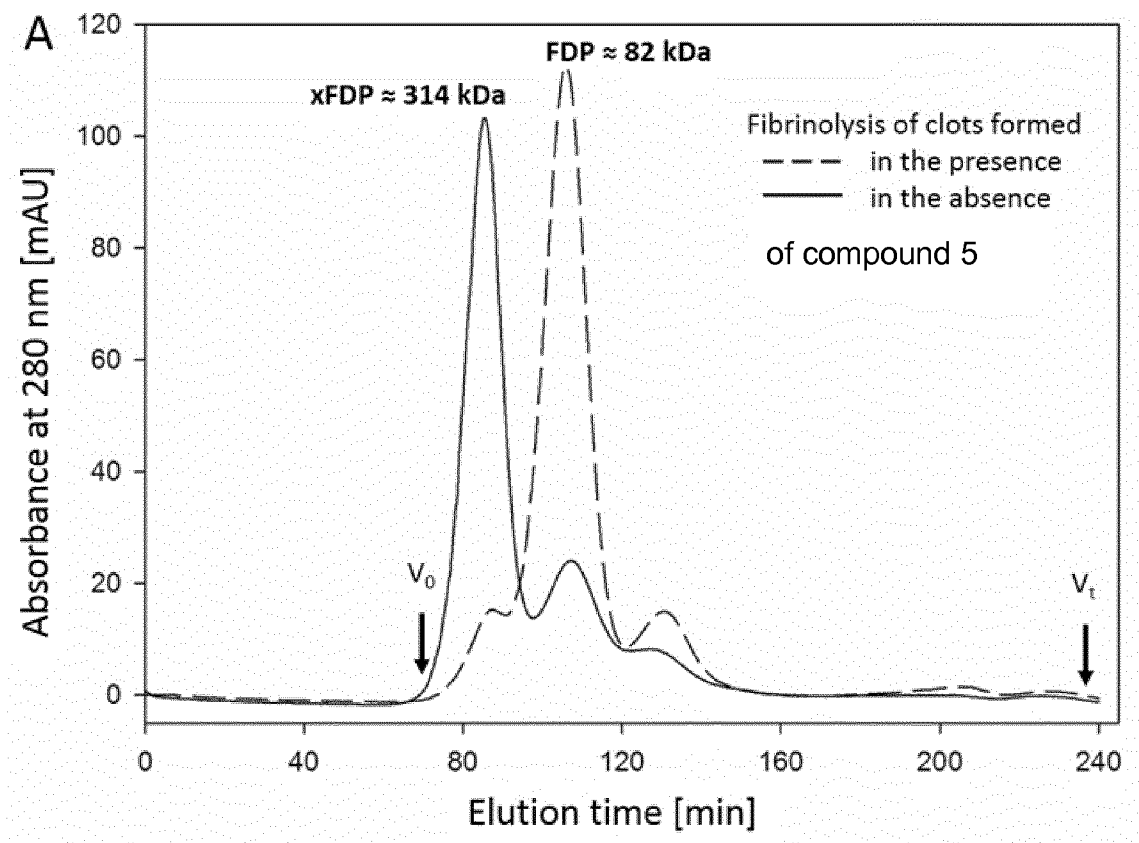


Figure 1 continued

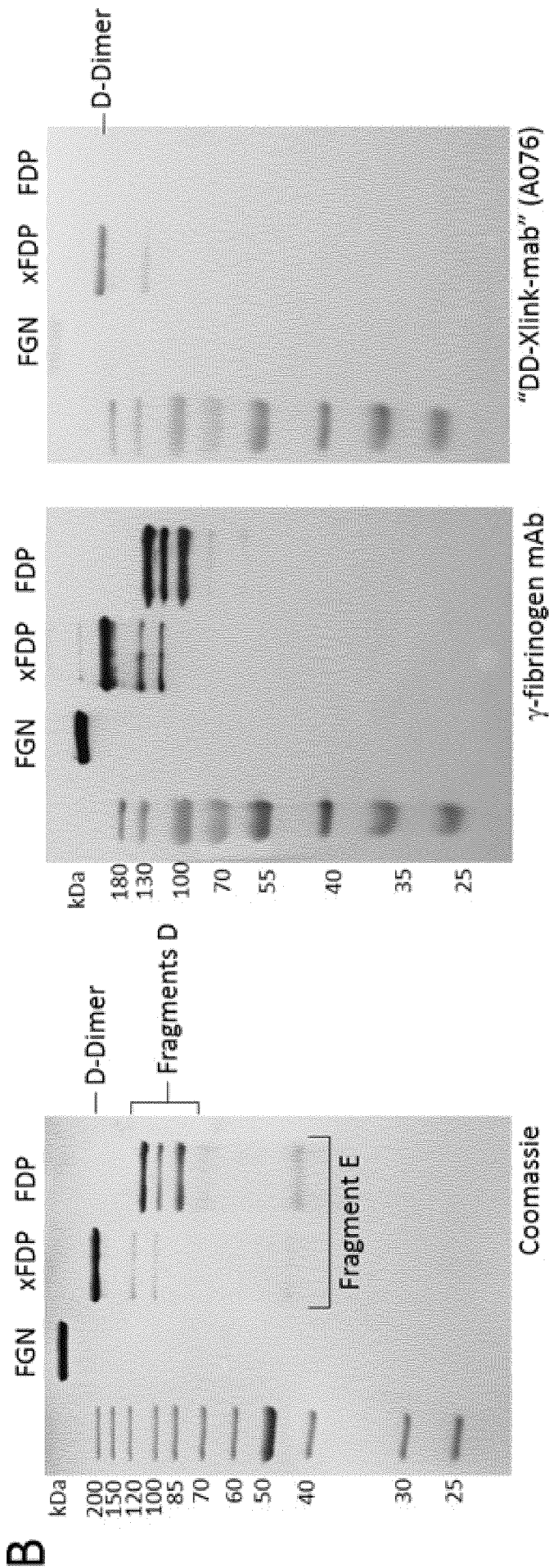


Figure 2

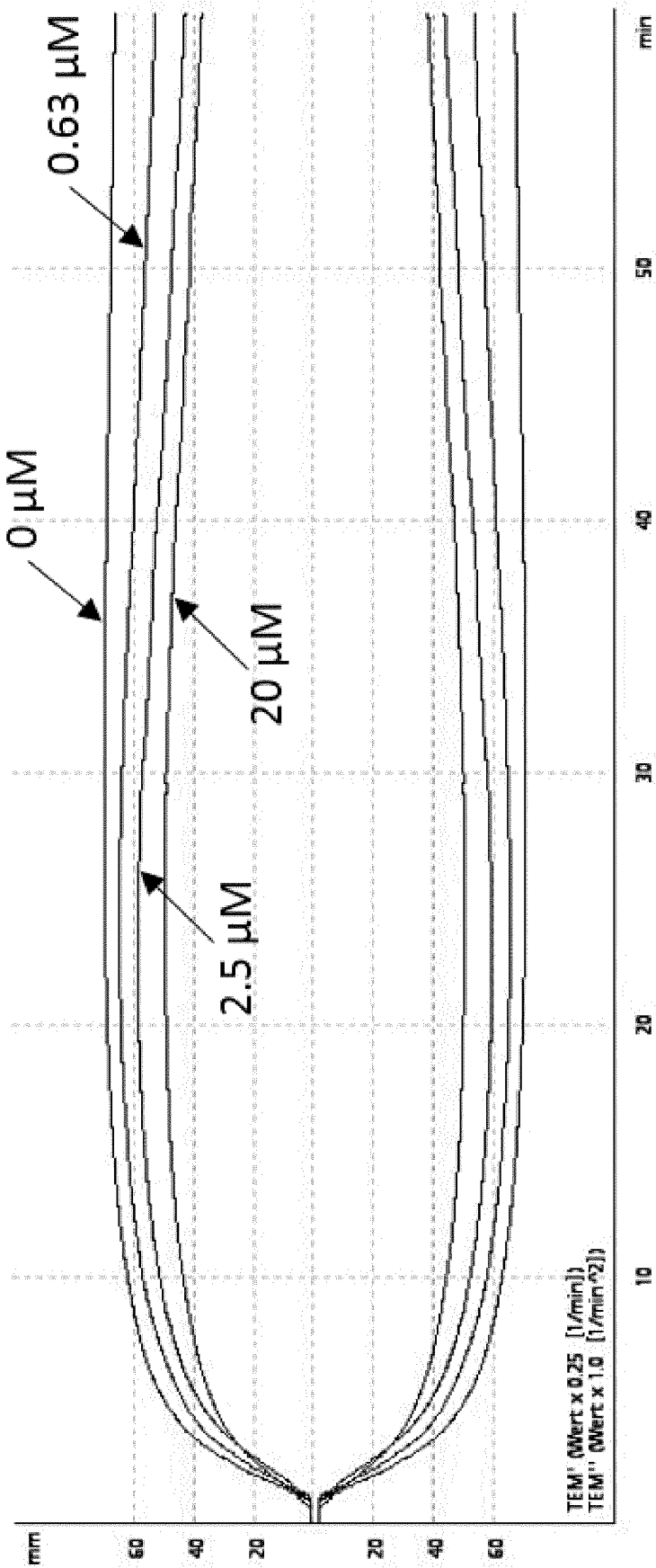
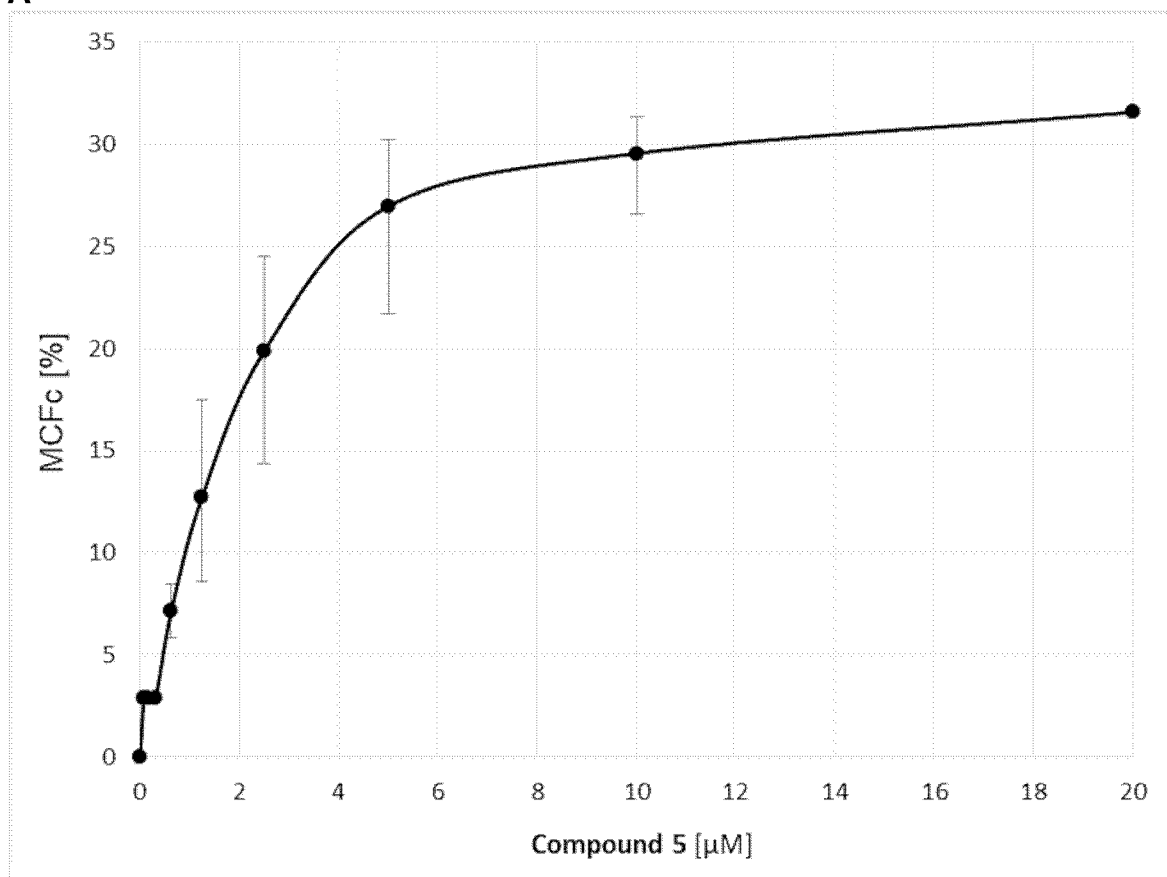


Figure 3

A



B

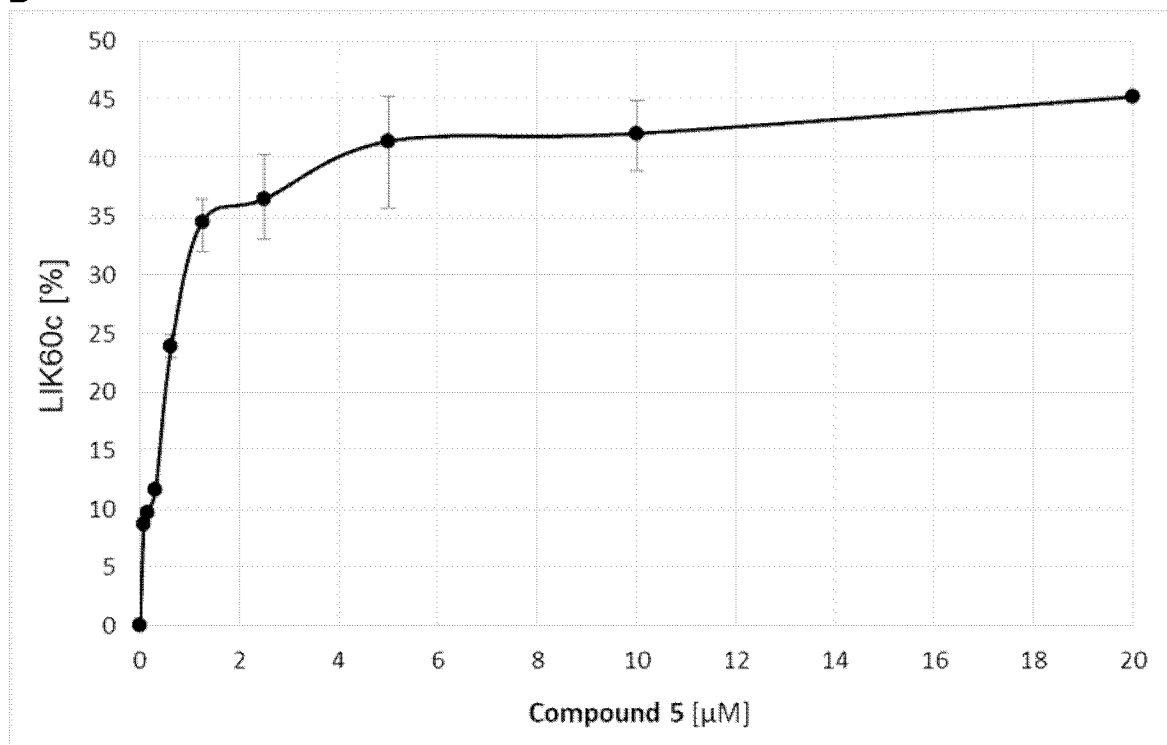


Figure 4

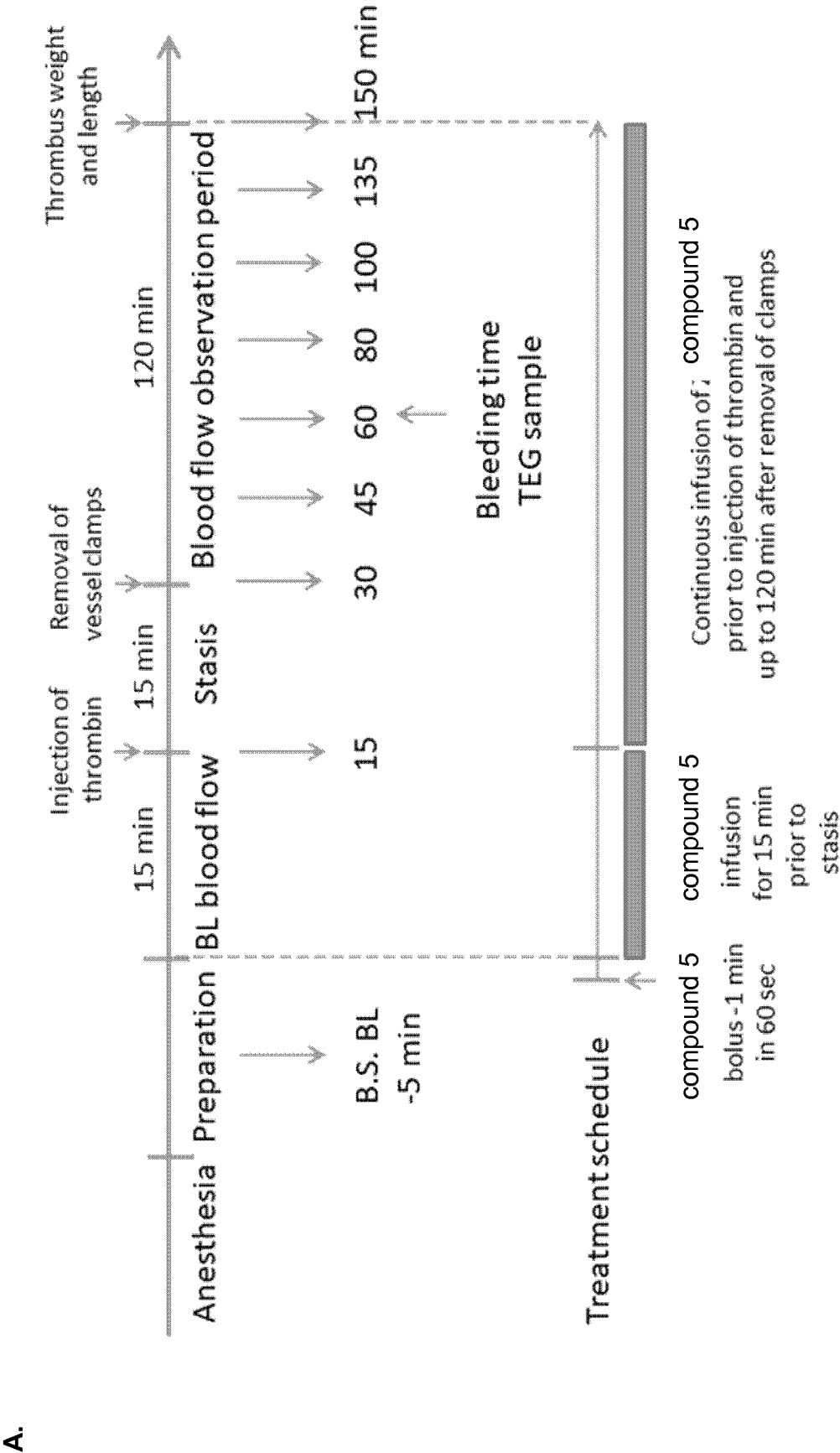
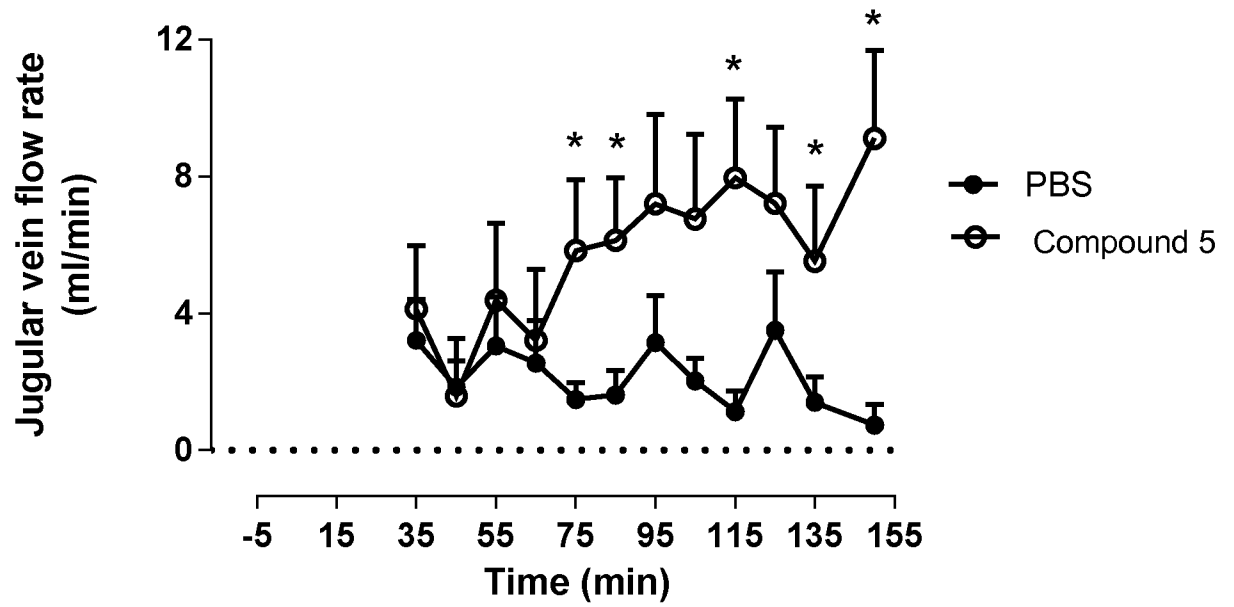


Figure 4 continued

B.



C.

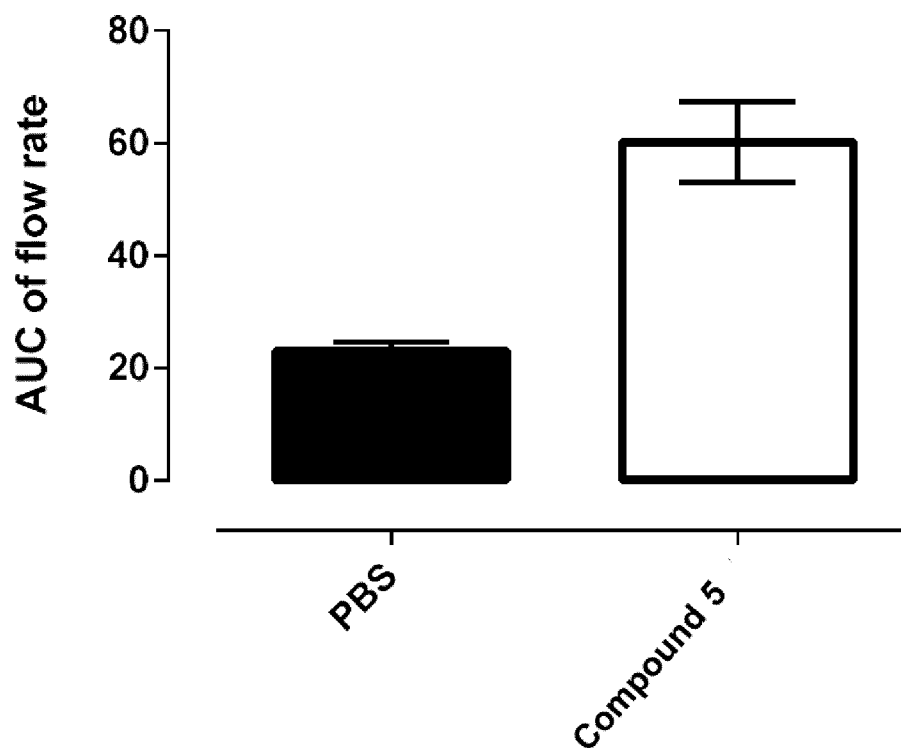
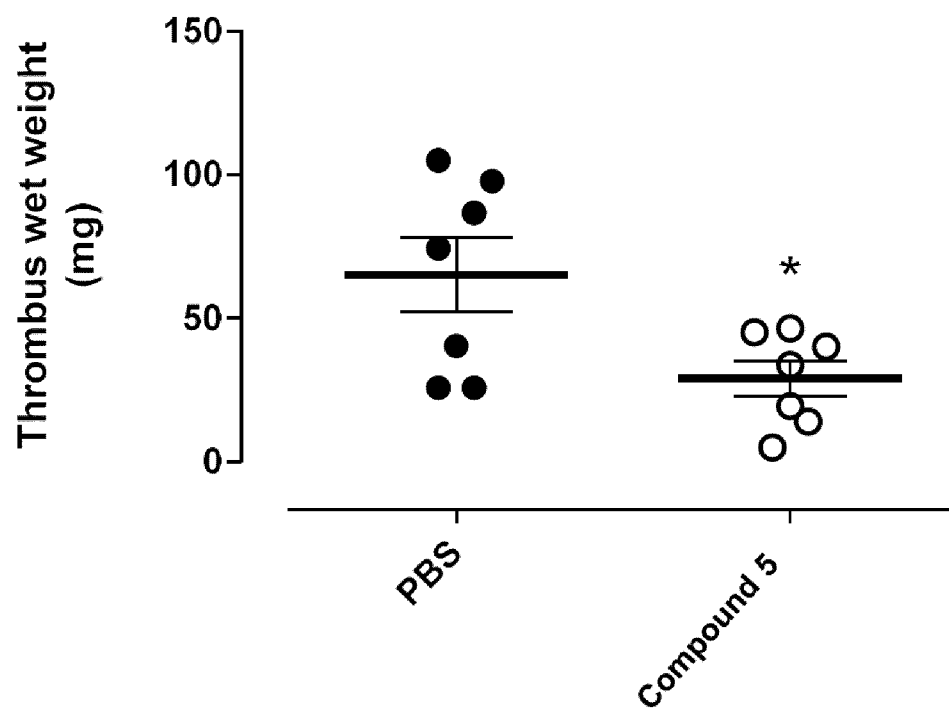
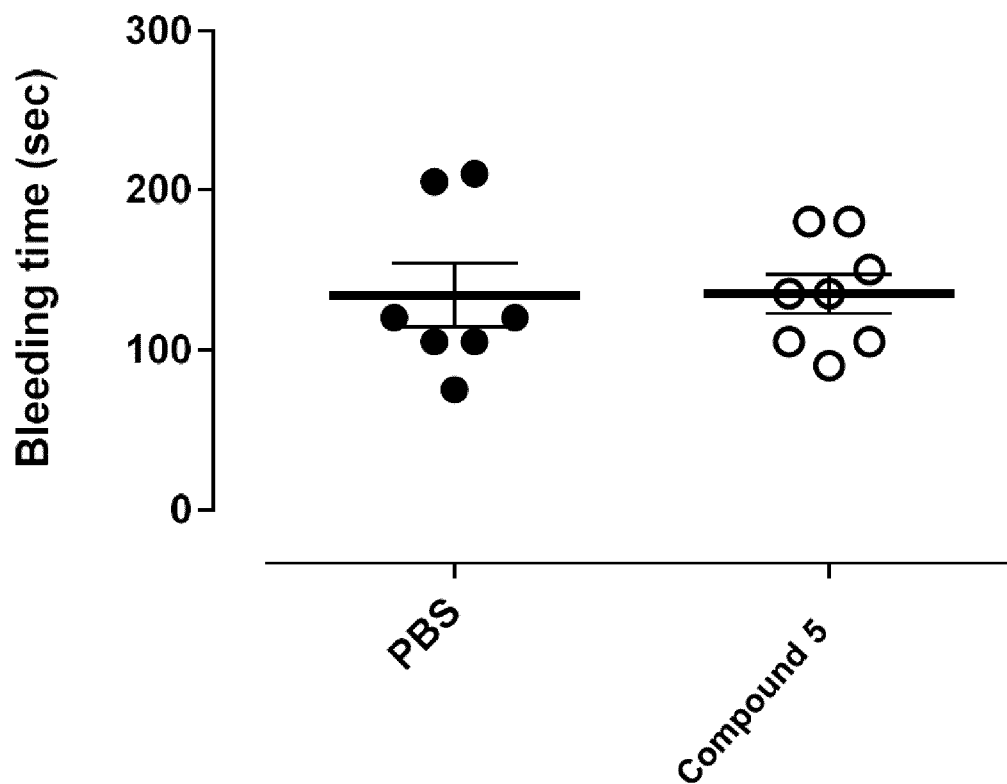


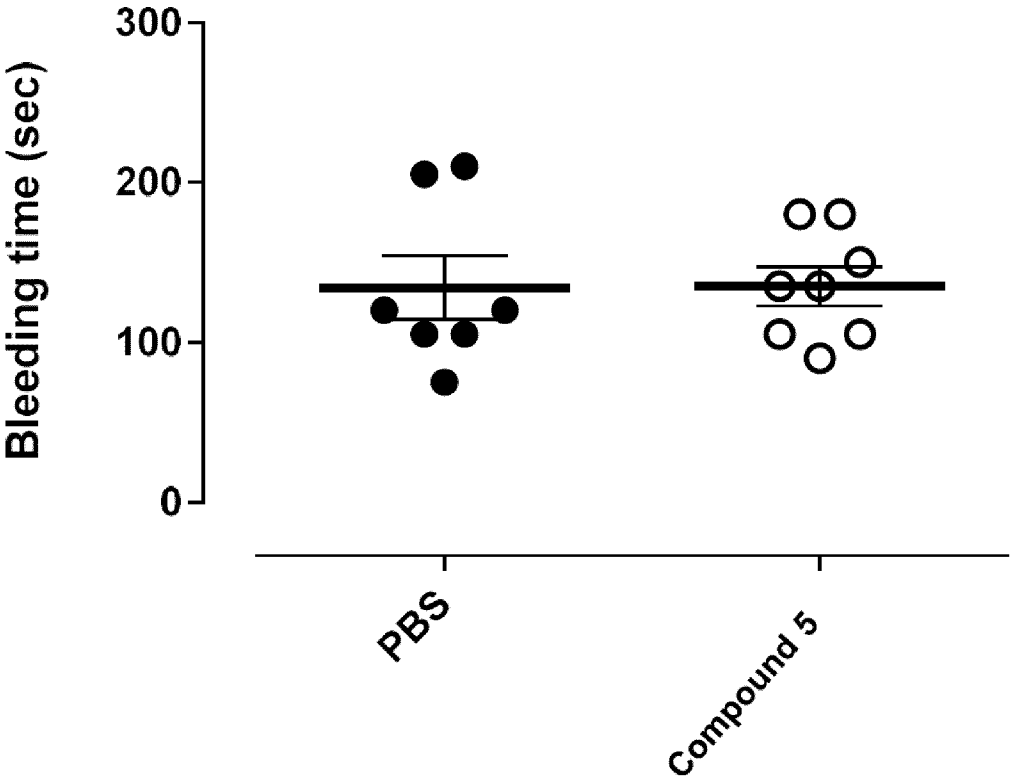
Figure 4 continued

D.



E.





INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/060030

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61K47/64 A61P7/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, BIOSIS, EMBASE, CHEM ABS Data, DISSERTATION ABS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/060030

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	----- WO 2014/090835 A1 (ZEDIRA GMBH [DE]) 19 June 2014 (2014-06-19) examples	1-15
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Information on patent family members

International application No

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