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(54) Titre : COMPOSITIONS ET PROCEDES POUR PRODUIRE DES PROTEINES DE FUSION BIOACTIVES

(54) Title: COMPOSITIONS AND METHODS FOR PRODUCING BIOACTIVE FUSION PROTEINS

(57) **Abrégé/Abstract:**

Disclosed is a composition of matter involving a recombinant fusion protein comprising a pharmacologically active protein partner, and a small pharmacologically inactive protein domain partner of human origin, such as but not limited to a 10th fibronectin III domain, a SH3 domain, a SH2 domain, a CH2 domain of IgG 1, a PDZ domain, a thrombospondin repeat domain, an ubiquitin domain, a leucine-rich repeat domain, a villin headpiece HP35 domain, a villin headpiece HP76 domain, or a fragment or modification of any of these. Also disclosed are nucleic acids (e.g., DNA constructs) encoding the fusion protein, expression vectors and recombinant host cells for expression of the fusion protein, and pharmaceutical compositions containing the recombinant fusion protein and a pharmaceutically acceptable carrier, and method of producing a pharmacologically active recombinant fusion protein.



ABSTRACT OF THE DISCLOSURE

Disclosed is a composition of matter involving a recombinant fusion protein comprising a pharmacologically active protein partner, and a small pharmacologically inactive protein domain partner of human origin, such as but not limited to a 10th fibronectin III domain, a SH3 domain, a SH2 domain, a CH2 domain of IgG1, a PDZ domain, a thrombospondin repeat domain, an ubiquitin domain, a leucine-rich repeat domain, a villin headpiece HP35 domain, a villin headpiece HP76 domain, or a fragment or modification of any of these. Also disclosed are nucleic acids (e.g., DNA constructs) encoding the fusion protein, expression vectors and recombinant host cells for expression of the fusion protein, and pharmaceutical compositions containing the recombinant fusion protein and a pharmaceutically acceptable carrier, and method of producing a pharmacologically active recombinant fusion protein.

COMPOSITIONS AND METHODS FOR PRODUCING BIOACTIVE FUSION PROTEINS

BACKGROUND OF THE INVENTION

[0003] 1. Field of Art.

[0004] The present invention relates to the biochemical arts, particularly to recombinant expression of polypeptides.

[0005] 2. Discussion of Related Art.

[0006] Bioactive or therapeutic peptides can be potent drugs which specifically target and modulate unique signaling and metabolic pathways. Their relatively small size and simple composition makes these peptides amenable to molecular engineering to refine and enhance desirable activities. Subtle changes to the peptide sequence can discriminate between linked activities or help prevent degradation *in vivo*. Similarly, well placed linker sites can permit conjugation of large molecules, such as poly(ethylene glycol) PEG, to enhance circulating half-lives. However, these same properties also present special challenges to peptide production and delivery.

[0007] Artificial synthetic techniques are not cost-effective for producing many peptides, particularly the larger peptides (15-40 amino acid residues or more). As an alternative, the use of recombinant host cells is well known for recombinant production of bioactive peptides or proteins. Commonly used recombinant host cells include bacteria (such as E. coli sp.), yeast (such as Saccharomyces sp.) and other fungi, insect cells, plant cells, and mammalian cells in culture. However, recombinant expression is often difficult. One reason for the low expression of recombinant peptides or proteins is likely due to their poor refolding potential, owing to marginally stable secondary and tertiary structures in solution.

[0008] To overcome this, many peptides have been expressed as chimeric fusions with proteins such as immunoglobulin Fc domains, ubiquitin, an albumin (e.g., human serum albumin

(HSA)), a transthyretin (TTR), or a thyroxine-binding globulin (TBG). (See, e.g., Sullivan et al., Toxin Peptide therapeutic agents, WO 2006/116156 A2; Gegg et al., Modified Fc molecules, WO 2006/036834 A2; Gegg et al., Modified Fc molecules, PCT/US2006/031609; Feige et al., Modified peptides as therapeutic agents, WO 2000/024782; Rosen et al., Albumin fusion proteins, US Patent No. 6,926,898 and US 2005/0054051; Bridon et al., Protection of endogenous therapeutic peptides from peptidase activity through conjugation to blood components, US 6,887,470); Walker et al., Use of transthyretin peptide/protein fusions to increase the serum half-life of pharmacologically active peptides/proteins, US 2003/0195154 A1; 2003/0191056 A1). Such large fusion proteins have made possible the commercial expression of therapeutic peptides and provided the added advantage of dramatically extending the circulating half-lives of their peptide partners, thereby rendering them more efficacious *in vivo*.

[0009] While these fusion proteins often facilitate peptide expression at much higher levels, they can also present difficult refolding challenges that can affect their bioactivity. Protein recovery can be further complicated by undesirable domain-domain interactions between the fusion partners and disulphide bond isomerizations. In addition, the cost of producing a fusion protein with a large protein carrier moiety can affect the commercial viability of such a therapeutic agent.

[0010] Consequently, compositions and methods for high yield recombinant expression of bioactive fusion proteins with a relatively low mass ratio of carrier component to bioactive component are desirable. These and other benefits are provided by the present invention.

SUMMARY OF THE INVENTION

[0011] The present invention relates to compositions of matter involving recombinant fusion proteins. The inventive recombinant fusion protein includes: (a) a small pharmacologically inactive protein domain of human origin as described herein; and (b) a pharmacologically active protein. The present invention is also directed to nucleic acids (e.g., DNA constructs) encoding the fusion protein, and expression vectors and recombinant host cells for expression of the fusion protein.

[0012] Optionally, for modulation of the pharmacokinetic profile of the inventive recombinant fusion protein molecule to fit a particular therapeutic need by attaching or conjugating covalently one or more half-life extending moieties of various masses and configurations to the fusion protein. Thus, the invention encompasses a composition of matter of the formula:

[0013] $(F^1)_a-(X^2)_b$ (I)

[0014] and multimers thereof, wherein:

[0015] F^1 is a half-life extending moiety, a is 0 or 1, and b is 1;

[0016] X^2 is $D-(L)_c-(P^5)_d-(X^3)_e$, $(X^4)_f-(P^5)_d-(L)_c-D$, or $(X^4)_f-(P^5)_d-(L)_c-D-(L)_g-(P^6)_h-(X^3)_i$, wherein c and g are each independently 0 or 1, d and h are 1, and e , f , and i are each independently 0, 1, 2, 3, or 4;

[0017] X^3 is $-(L)_j-(P^7)$, j is 0 or 1;

[0018] X^4 is $(P^8)-(L)_k$, k is 0 or 1;

[0019] D is small pharmacologically inactive protein domain of human origin;

[0020] P^5 , P^6 , P^7 and P^8 are each independently a pharmacologically active protein; and

[0021] L is in each instance a peptidyl linker. Within the meaning of Formula I, the pharmaceutically active protein, "P" (i.e., P^5 , P^6 , P^7 and P^8), if more than one is present, can be independently the same or different from, any other P also present in the inventive composition; this includes a P^7 and/or a P^8 , if more than one is present, which can be the same or different from any other P^7 and/or P^8 . Similarly, the peptidyl linker moiety, "L" (i.e., $(L)_c$, $(L)_g$, $(L)_j$, and/or $(L)_k$), if present, can be independently the same or different from any other linker, or linkers, that may be present in the inventive composition.

[0022] The present invention also provides a high efficiency method of producing a pharmacologically active fusion protein in a host cell. The recombinant host cell of the invention is placed in a growth medium under physiologically suitable conditions such that the

recombinant fusion protein is expressed; and the fusion protein is then isolated or purified from the cells. This can involve separation from the cell by conventional biochemical techniques involving cell lysis and separation of the fusion protein from the cell extract. It may involve solubilization of the fusion protein released from inclusion bodies, after refolding, if necessary. Alternatively, if expression of the fusion protein involves its secretion from the recombinant host cell, isolating the fusion protein from the cell can simply be accomplished with centrifugation or filtration to separate the cells from the medium containing the secreted fusion protein, without lysing the cells, the recombinant fusion protein being in the supernatant or filtrate growth medium.

[0023] Typically, the method does not require post-expression cleavage of the pharmacologically active protein component from the small pharmacologically inactive protein domain in order to use the inventive recombinant fusion protein as a therapeutic, since the small pharmacologically inactive protein domain component has a human amino acid sequence posing a low immunogenic risk to a human patient to whom the therapeutic is administered. The present invention provides a useful alternative to the costly *in vitro* syntheses of large therapeutic peptides or proteins.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 shows a tree diagram that illustrates the amino acid sequence relatedness of various human PDZ domains that were identified in the Brookhaven Protein Databank. The four digit code is the accession number from the Brookhaven Protein Databank. Alignment was completed using Vector NTI Align-X.

[0025] Figure 2 shows a tree diagram that illustrates the amino acid sequence relatedness of various human SH3 domains that were identified in the Brookhaven Protein Databank. The four digit code is the accession number from the Brookhaven Protein Databank. Alignment was completed using Vector NTI Align-X.

[0026] Figure 3 shows a tree diagram that illustrates the amino acid sequence relatedness of various human SH2 domains that were identified in the Brookhaven Protein Databank. The four digit code is the accession number from the Brookhaven Protein Databank. Alignment was completed using Vector NTI Align-X.

[0027] Figure 4A illustrates the expression of various ShK (actually [desArg1]ShK) and OSK1 fusions with a Coomassie stained 18% Tris-Glycine SDS-PAGE. Lane contents were (left to right): Invitrogen Benchmark standards, uninduced lysate, 1N7F-OsK1, 1N7F-ShK, 1UEZ-OsK1, 1UEZ-ShK, 1WA7-OsK1, 1WA7-ShK, 1X2K-OsK1, 1X2K-ShK. Preparation of samples for electrophoresis involved measuring OD₆₀₀ of the cell culture, centrifugation of the cells, and resuspension in sufficient PBS (Dulbecco's Phosphate Buffered Saline (1X) (-Calcium Chloride, -Magnesium Chloride); GIBCO) to make a 10 OD₆₀₀/mL mixture. 15 µL of that was combined with 20 µL of loading buffer (80% Tris-Glycine SDS Sample Buffer (2X) [Novex] 20% β-mercaptoethanol), which was then heated at 99°C for 5 minutes. Aliquots (10 µL) of this heated sample material were then loaded into the wells of the gel.

[0028] Figure 4B illustrates the expression of various OSK1 fusions with a Coomassie stained 18% Tris-Glycine SDS-PAGE. Lane contents were (left to right): Invitrogen Benchmark standards, uninduced lysate, FN3-OsK1, 1WFV-OsK1, 1AB2-OsK1, 1JYQ-OsK1, 1PHT-OsK1. Preparation of samples for electrophoresis was as described above for Figure 4A.

[0029] Figure 5A illustrates expression of TMP(22-7Q) fusions with a Coomassie stained 18% Tris-Glycine SDS-PAGE. Lane contents were (left to right): uninduced lysate, SH3 lysate I+6, SH3 insoluble I+6, SH3 soluble I+6, uninduced lysate, SH2 lysate I+6, SH2 insoluble I+6, SH2 soluble I+6, Invitrogen Benchmark standards. Preparation of samples for electrophoresis involved measuring OD₆₀₀ of the cell culture and centrifugation of the cells to get a 1 mg pellet

using the formula $0.5291/\text{OD}$. The pellet was resuspended in 50 μL of Tris-EDTA (pH 8.0) buffer and 50 μL of loading buffer (50% Tris-Glycine SDS Sample Buffer (2X) from Novex, 50% β -mercaptoethanol), which was then heated at 99°C for 10 minutes. Aliquots (20 μL) of this heated sample material were then loaded into the wells of the gel.

[0030] Figure 5B illustrates expression of TMP(22-7Q) fusions with a Coomassie stained 18% Tris-Glycine SDS-PAGE. Lane contents were (left to right): uninduced lysate, PDZ lysate I+6, PDZ insoluble I+6, PDZ soluble I+6, uninduced lysate, Fn3 lysate I+6, Fn3 insoluble I+6, Fn3 soluble I+6, Invitrogen Benchmark standards. Preparation of samples for electrophoresis was as described above for Figure 5A.

[0031] Figure 6A-E illustrates shaker flask expression of small domain OsK1 fusions with Coomassie stained 4-20% tris-glycine SDS-PAGE. Lane contents in Figures 6A-C were (left to right): Novex Mark 12 standards, soluble fraction, deoxycholic acid wash, water wash, insoluble, Novex Mark 12 standards, soluble fraction, deoxycholic acid wash, water wash, and insoluble fraction. Lane contents in Figures 6D-E were (left to right): Novex Mark 12 standards, soluble fraction, deoxycholic acid wash, water wash, and insoluble fraction.

Preparation of samples for loading into wells for electrophoresis was as described in Example 2 (protein purification section) herein, and the material for each well was diluted with $\frac{1}{2}$ volume of reducing 3X SDS-PAGE sample buffer (167 mM Tris pH 6.8, 26.7% glycerol, 5.3% SDS, and 13.3% 2-mercaptoethanol); 2- μL aliquots of sample were loaded per well.

[0032] Figure 7A-F shows analytical SEC of various small domain OsK1 fusions SE-HPLC of OsK1 fusion proteins after refolding and purification using a Phenomenex BioSep-SEC 3000 column with 50 mM NaH_2PO_4 , 250 mM NaCl, pH 6.9 as the running buffer observing the absorbance at 280 nm.

[0033] Figure 8A-C illustrates product of the refolded and purified small domain OsK1 fusions with Coomassie stained 4-20% tris-glycine SDS-PAGE. Lane contents in Figures 8A-C were (left to right): Novex Mark 12 standards, 0.5 μg protein; blank, 2.0 μg protein; blank, 10 μg protein; Novex Mark 12 standards, 0.5 μg protein; blank, 2.0 μg protein; blank, 10 μg protein.

[0034] Figure 9A-E shows mass spectrometry of the refolded and purified small domain OsK1 fusions.

[0035] Figure 10 shows cation exchange purification of the 1UEZ-OsK1 fusion construct after PEGylation using SP-HP sepharose*, a 20 mM sodium acetate buffer pH 5.0, and a NaCl gradient from 0 to 1 M. The solid line traces the absorbance at 280 nm, while the broken line shows the conductivity.

*Trademark

[0036] Figure 11A-B shows SDS-PAGE of Purified PEGylated fusion proteins. Figure 11A (left to right): lanes #1 and 7 were molecular weight (MW) markers; lanes #2, 3, 8 and 9 were non-reduced, and lanes #5, 6, 11 and 12 were reduced. Lanes #2 and 5 were unconjugated 1UEZ-OSK1 fusion protein and lanes #3 and 6 were the purified 20kD PEG-1UEZ-OSK1 conjugate. Lanes #8 and 11 were unconjugated 1N7F-OSK1 fusion protein and lanes #9 and 12 were the purified 20kD PEG-1N7F-OSK1 conjugate. Figure 11B (left to right): Lanes #1 and 7 were MW markers. Lanes #2, 3, 8 and 9 were non-reduced, and lanes # 5, 6, 11 and 12 were reduced. Lanes #2 and 5 were unconjugated Fn3-OSK1 fusion protein and lanes #3 and 6 were the purified 20kD PEG-Fn3-OSK1 conjugate. Lanes #8 and 11 were unconjugated 1X2K-OSK1 fusion protein and lanes #8 and 12 were the purified 20kD PEG-1X2K-OSK1 conjugate.

[0037] Figure 12 illustrates the serum levels of the various OsK1 constructs 24 hours post- i.v. injection (2 mg/kg) in mice, as determined by ELISA using polyclonal rabbit anti-OsK1 antibodies for detection.

[0038] Figure 13 shows an alignment of chicken (ch; SEQ ID NO:60) and human (hu; SEQ ID NO:61) HP-35 sequences. Numbering is based on intact villin headpiece sequence: Leu42 >>Phe76. Helical sequences are underlined based on NMR structure.

[0039] Figure 14 shows a chromatogram from Ni-NTA purification of PTH-HP76 from E. coli lysate.

[0040] Figure 15 shows a 4-20% SDS-PAGE gel of eluted peak fractions from Ni-NTA column (Figure 14). Boxed fractions were confirmed as PTH-HP76 by western blot and were pooled.

[0041] Figure 16 shows a chromatogram from cation exchange purification of PEGylated PTH-HP76 using 1 ml SP Sepharose HP HiTrap^{*} column (GE Healthcare, Piscataway, NJ).

[0042] Figure 17 shows 4-20% SDS-PAGE gel of eluted peak fractions from SP Sepharose column (Figure 16). Boxed fractions representing purified PEG- PTH-HP76 were pooled.

[0043] Figure 18 shows the results of murine in vivo bioassay of the PTH-HP76 conjugates.

*Trademark

DETAILED DESCRIPTION

[0044] As used in this specification and the appended claims, the singular forms “a”, “an” and “the” include plural referents unless the context clearly indicates otherwise. Thus, for example, reference to “a protein” includes a plurality of proteins; reference to “a cell” includes populations of a plurality of cells.

[0045] “Polypeptide” and “protein” are used interchangeably herein and include a molecular chain of two or more amino acids linked covalently through peptide bonds. The terms do not refer to a specific length of the product. Thus, “peptides,” and “oligopeptides,” are included within the definition of polypeptide. The terms include post-translational modifications of the polypeptide, for example, glycosylations, acetylations, phosphorylations and the like. In addition, protein fragments, analogs, mutated or variant proteins, fusion proteins and the like are included within the meaning of polypeptide. The terms also include molecules in which one or more amino acid analogs or non-canonical or unnatural amino acids are included as can be expressed recombinantly using known protein engineering techniques. In addition, inventive fusion proteins can be derivatized as described herein by well-known organic chemistry techniques.

The term “fusion protein” indicates that the protein includes polypeptide components derived from more than one parental protein or polypeptide. Typically, a fusion protein is expressed from a fusion gene in which a nucleotide sequence encoding a polypeptide sequence from one protein is appended in frame with, and optionally separated by a linker from, a nucleotide sequence encoding a polypeptide sequence from a different protein. The fusion gene can then be expressed by a recombinant host cell as a single protein.

[0046] A “domain” of a protein is any portion of the entire protein, up to and including the complete protein, but typically comprising less than the complete protein. A domain can, but need not, fold independently of the rest of the protein chain and/or be correlated with a particular biological, biochemical, or structural function or location (e.g., a ligand binding domain, or a cytosolic, transmembrane or extracellular domain).

[0047] As used herein “soluble” when in reference to a protein produced by recombinant DNA technology in a host cell is a protein that exists in aqueous solution; if the protein contains a twin-arginine signal amino acid sequence the soluble protein is exported to the periplasmic space in gram negative bacterial hosts, or is secreted into the culture medium by eukaryotic host cells capable of secretion, or by bacterial host possessing the appropriate genes (e.g., the kil

gene). Thus, a soluble protein is a protein which is not found in an inclusion body inside the host cell. Alternatively, depending on the context, a soluble protein is a protein which is not found integrated in cellular membranes; in contrast, an insoluble protein is one which exists in denatured form inside cytoplasmic granules (called an inclusion body) in the host cell, or again depending on the context, an insoluble protein is one which is present in cell membranes, including but not limited to, cytoplasmic membranes, mitochondrial membranes, chloroplast membranes, endoplasmic reticulum membranes, etc.

[0048] A distinction is also drawn between proteins which are "soluble" (i.e., dissolved or capable of being dissolved) in an aqueous solution devoid of significant amounts of ionic detergents (e.g., SDS) or denaturants (e.g., urea, guanidine hydrochloride) and proteins which exist as a suspension of insoluble protein molecules dispersed within the solution. A "soluble" protein will not be removed from a solution containing the protein by centrifugation using conditions sufficient to remove cells present in a liquid medium (e.g., centrifugation at 5,000×g for 4-5 minutes). In some embodiments of the inventive composition, the recombinant fusion protein is synthesized by the host cell and segregated in an insoluble form within cellular inclusion bodies, which can then be purified from other cellular components in a cell extract with relative ease, and the recombinant fusion protein can in turn be solubilized, refolded and/or further purified.

[0049] A distinction is drawn between a "soluble" protein (i.e., a protein which when expressed in a host cell is produced in a soluble form) and a "solubilized" protein. An insoluble recombinant protein found inside an inclusion body or found integrated in a cell membrane may be solubilized (i.e., rendered into a soluble form) by treating purified inclusion bodies or cell membranes with denaturants such as guanidine hydrochloride, urea or sodium dodecyl sulfate (SDS). These denaturants must then be removed from the solubilized protein preparation to allow the recovered protein to renature (refold). Although the inventive compositions can be refolded in active form, not all proteins will refold into an active conformation after solubilization in a denaturant and removal of the denaturant. Many proteins precipitate upon removal of the denaturant. SDS may be used to solubilize inclusion bodies and cell membranes and will maintain the proteins in solution at low concentration. However, dialysis will not always remove all of the SDS (SDS can form micelles which do not dialyze out); therefore, SDS-solubilized inclusion body protein and SDS-solubilized cell membrane protein is soluble but not refolded.

[0050] A "secreted" protein refers to those proteins capable of being directed to the ER, secretory vesicles, or the extracellular space as a result of a secretory signal peptide sequence, as well as those proteins released into the extracellular space without necessarily containing a signal sequence. If the secreted protein is released into the extracellular space, the secreted protein can undergo extracellular processing to produce a "mature" protein. Release into the extracellular space can occur by many mechanisms, including exocytosis and proteolytic cleavage. In some other embodiments of the inventive composition, the recombinant fusion protein can be synthesized by the host cell as a secreted protein, which can then be further purified from the extracellular space and/or medium.

[0051] The term "recombinant" indicates that the material (e.g., a nucleic acid or a polypeptide) has been artificially or synthetically (i.e., non-naturally) altered by human intervention. The alteration can be performed on the material within, or removed from, its natural environment or state. For example, a "recombinant nucleic acid" is one that is made by recombining nucleic acids, e.g., during cloning, DNA shuffling or other well known molecular biological procedures. A "recombinant DNA molecule," is comprised of segments of DNA joined together by means of such molecular biological techniques. The term "recombinant protein" or "recombinant polypeptide" as used herein refers to a protein molecule which is expressed using a recombinant DNA molecule. A "recombinant host cell" is a cell that contains and/or expresses a recombinant nucleic acid.

[0052] A "polynucleotide sequence" or "nucleotide sequence" or "nucleic acid sequence," as used interchangeably herein, is a polymer of nucleotides, including an oligonucleotide, a DNA, and RNA, a nucleic acid, or a character string representing a nucleotide polymer, depending on context. From any specified polynucleotide sequence, either the given nucleic acid or the complementary polynucleotide sequence can be determined. Included are DNA or RNA of genomic or synthetic origin which may be single- or double-stranded, and represent the sense or antisense strand.

[0053] As used herein, the terms "nucleic acid molecule encoding," "DNA sequence encoding," and "DNA encoding" refer to the order or sequence of deoxyribonucleotides along a strand of deoxyribonucleic acid. The order of these deoxyribonucleotides determines the order of ribonucleotides along the mRNA chain, and also determines the order of amino acids along the polypeptide (protein) chain. The DNA sequence thus codes for the RNA sequence and for the amino acid sequence.

[0054] "Expression of a gene" or "expression of a nucleic acid" means transcription of DNA into RNA (optionally including modification of the RNA, e.g., splicing), translation of RNA into a polypeptide (possibly including subsequent post-translational modification of the polypeptide), or both transcription and translation, as indicated by the context.

[0055] The term "gene" is used broadly to refer to any nucleic acid associated with a biological function. Genes typically include coding sequences and/or the regulatory sequences required for expression of such coding sequences. The term "gene" applies to a specific genomic or recombinant sequence, as well as to a cDNA or mRNA encoded by that sequence. A "fusion gene" contains a coding region that encodes a fusion protein. Genes also include non-expressed nucleic acid segments that, for example, form recognition sequences for other proteins. Non-expressed regulatory sequences including transcriptional control elements to which regulatory proteins, such as transcription factors, bind, resulting in transcription of adjacent or nearby sequences.

[0056] As used herein the term "coding region" when used in reference to a structural gene refers to the nucleotide sequences which encode the amino acids found in the nascent polypeptide as a result of translation of an mRNA molecule. The coding region is bounded, in eukaryotes, on the 5' side by the nucleotide triplet "ATG" which encodes the initiator methionine and on the 3' side by one of the three triplets which specify stop codons (i.e., TAA, TAG, TGA).

[0057] Transcriptional control signals in eukaryotes comprise "promoter" and "enhancer" elements. Promoters and enhancers consist of short arrays of DNA sequences that interact specifically with cellular proteins involved in transcription (Maniatis, et al., Science 236:1237 (1987)). Promoter and enhancer elements have been isolated from a variety of eukaryotic sources including genes in yeast, insect and mammalian cells and viruses (analogous control elements, i.e., promoters, are also found in prokaryotes). The selection of a particular promoter and enhancer depends on what cell type is to be used to express the protein of interest. Some eukaryotic promoters and enhancers have a broad host range while others are functional in a limited subset of cell types (for review see Voss, et al., Trends Biochem. Sci., 11:287 (1986) and Maniatis, et al., Science 236:1237 (1987)).

[0058] The term "expression vector" as used herein refers to a recombinant DNA molecule containing a desired coding sequence and appropriate nucleic acid sequences necessary for the expression of the operably linked coding sequence in a particular host cell. Nucleic acid sequences necessary for expression in prokaryotes include a promoter, optionally an operator sequence, a ribosome binding site and possibly other sequences. Eukaryotic cells are known to

utilize promoters, enhancers, and termination and polyadenylation signals. A secretory signal peptide sequence can also, optionally, be encoded by the expression vector, operably linked to the coding sequence for the inventive recombinant fusion protein, so that the expressed fusion protein can be secreted by the recombinant host cell, for more facile isolation of the fusion protein from the cell, if desired. Such techniques are well known in the art. (E.g., Goodey, Andrew R.; et al., Peptide and DNA sequences, U.S. Patent No. 5,302,697; Weiner et al., Compositions and methods for protein secretion, U.S. Patent No. 6,022,952 and U.S. Patent No. 6,335,178; Uemura et al., Protein expression vector and utilization thereof, U.S. Patent No. 7,029,909; Ruben et al., 27 human secreted proteins, US 2003/0104400 A1).

[0059] The terms "in operable combination", "in operable order" and "operably linked" as used herein refer to the linkage of nucleic acid sequences in such a manner that a nucleic acid molecule capable of directing the transcription of a given gene and/or the synthesis of a desired protein molecule is produced. The term also refers to the linkage of amino acid sequences in such a manner so that a functional protein is produced.

[0060] Recombinant DNA- and/or RNA-mediated protein expression techniques, or any other methods of preparing peptides or, are applicable to the making of the inventive recombinant fusion proteins. For example, the peptides can be made in transformed host cells. Briefly, a recombinant DNA molecule, or construct, coding for the peptide is prepared. Methods of preparing such DNA molecules are well known in the art. For instance, sequences encoding the peptides can be excised from DNA using suitable restriction enzymes. Any of a large number of available and well-known host cells may be used in the practice of this invention. The selection of a particular host is dependent upon a number of factors recognized by the art. These include, for example, compatibility with the chosen expression vector, toxicity of the peptides encoded by the DNA molecule, rate of transformation, ease of recovery of the peptides, expression characteristics, bio-safety and costs. A balance of these factors must be struck with the understanding that not all hosts may be equally effective for the expression of a particular DNA sequence. Within these general guidelines, useful microbial host cells in culture include bacteria (such as Escherichia coli sp.), yeast (such as Saccharomyces sp.) and other fungal cells, insect cells, plant cells, mammalian (including human) cells, e.g., CHO cells and HEK293 cells. Modifications can be made at the DNA level, as well. The peptide-encoding DNA sequence may be changed to codons more compatible with the chosen host cell. For E. coli, optimized codons are known in the art. Codons can be substituted to eliminate restriction sites or to include silent restriction sites, which may aid in processing of the DNA in the selected host cell. Next, the

transformed host is cultured and purified. Host cells may be cultured under conventional fermentation conditions so that the desired compounds are expressed. Such fermentation conditions are well known in the art.

[0061] In further describing the fusion proteins herein, a one-letter abbreviation system is frequently applied to designate the identities of the twenty “canonical” amino acid residues generally incorporated into naturally occurring peptides and proteins (Table 1). Such one-letter abbreviations are entirely interchangeable in meaning with three-letter abbreviations, or non-abbreviated amino acid names. Within the one-letter abbreviation system used herein, an upper case letter indicates a L-amino acid, and a lower case letter indicates a D-amino acid. For example, the abbreviation “R” designates L-arginine and the abbreviation “r” designates D-arginine.

Table 1. One-letter abbreviations for the canonical amino acids.
Three-letter abbreviations are in parentheses.

Alanine (Ala)	A
Glutamine (Gln)	Q
Leucine (Leu)	L
Serine (Ser)	S
Arginine (Arg)	R
Glutamic Acid (Glu)	E
Lysine (Lys)	K
Threonine (Thr)	T
Asparagine (Asn)	N
Glycine (Gly)	G
Methionine (Met)	M
Tryptophan (Trp)	W
Aspartic Acid (Asp)	D
Histidine (His)	H
Phenylalanine (Phe)	F
Tyrosine (Tyr)	Y
Cysteine (Cys)	C
Isoleucine (Ile)	I
Proline (Pro)	P
Valine (Val)	V

[0062] An amino acid substitution in an amino acid sequence is typically designated herein with a one-letter abbreviation for the amino acid residue in a particular position, followed by the numerical amino acid position relative to a native sequence of interest, which is then followed by the one-letter symbol for the amino acid residue substituted in. For example, "T30D" symbolizes a substitution of a threonine residue by an aspartate residue at amino acid position 30, relative to the native sequence of interest.

[0063] Non-canonical amino acid residues can be incorporated into a peptide within the scope of the invention by employing known techniques of protein engineering that use recombinantly expressing cells. (See, e.g., Link et al., Non-canonical amino acids in protein engineering, Current Opinion in Biotechnology, 14(6):603-609 (2003)). The term "non-canonical amino acid residue" refers to amino acid residues in D- or L-form that are not among the 20 canonical amino acids generally incorporated into naturally occurring proteins, for example, β -amino acids, homoamino acids, cyclic amino acids and amino acids with derivatized side chains. Examples include (in the L-form or D-form; abbreviated as in parentheses): citrulline (Cit), homocitrulline (hCit), N^α -methylcitrulline (NMeCit), N^α -methylhomocitrulline (N^α -MeHoCit), ornithine (Orn), N^α -Methylornithine (N^α -MeOrn or NMeOrn), sarcosine (Sar), homolysine (hLys or hK), homoarginine (hArg or hR), homoglutamine (hQ), N^α -methylarginine (NMeR), N^α -methylleucine (N^α -MeL or NMeL), N -methylhomolysine (NMeHoK), N^α -methylglutamine (NMeQ), norleucine (Nle), norvaline (Nva), 1,2,3,4-tetrahydroisoquinoline (Tic), Octahydroindole-2-carboxylic acid (Oic), 3-(1-naphthyl)alanine (1-Nal), 3-(2-naphthyl)alanine (2-Nal), 1,2,3,4-tetrahydroisoquinoline (Tic), 2-indanylglycine (IgI), para-iodophenylalanine (pI-Phe), para-aminophenylalanine (4AmP or 4-Amino-Phe), 4-guanidino phenylalanine (Guf), nitrophenylalanine (nitrophe), aminophenylalanine (aminophe or Amino-Phe), benzylphenylalanine (benzylphe), γ -carboxyglutamic acid (γ -carboxyglu), hydroxyproline (hydroxypro), p -carboxyl-phenylalanine (Cpa), α -aminoadipic acid (Aad), $N\alpha$ -methyl valine (NMeVal), N - α -methyl leucine (NMeLeu), $N\alpha$ -methylnorleucine (NMeNle), cyclopentylglycine (Cpg), cyclohexylglycine (Chg), acetylarginine (acetylarg), α , β -diaminopropionic acid (Dpr), α , γ -diaminobutyric acid (Dab), diaminopropionic acid (Dap), cyclohexylalanine (Cha), 4-methyl-phenylalanine (MePhe), β , β -diphenyl-alanine (BiPhA), aminobutyric acid (Abu), 4-phenyl-phenylalanine (or biphenylalanine; 4Bip), α -amino-isobutyric acid (Aib), beta-alanine, beta-aminopropionic acid, piperidinic acid, aminocaproic acid, aminoheptanoic acid, aminopimelic acid, desmosine, diaminopimelic acid, N-ethylglycine, N-ethylasparagine,

hydroxylysine, allo-hydroxylysine, isodesmosine, allo-isoleucine, N-methylglycine, N-methylisoleucine, N-methylvaline, 4-hydroxyproline (Hyp), γ -carboxyglutamate, ϵ -N,N,N-trimethyllysine, ϵ -N-acetyllysine, O-phosphoserine, N-acetylserine, N-formylmethionine, 3-methylhistidine, 5-hydroxylysine, ω -methylarginine, and other similar amino acids, and derivatized forms of any of these as described herein. Table 2 contains some exemplary non-canonical amino acid residues that are useful in accordance with the present invention and associated abbreviations as typically used herein, although the skilled practitioner will understand that different abbreviations and nomenclatures may be applicable to the same substance and may appear interchangeably herein.

Table 2. Useful non-canonical amino acids for amino acid addition, insertion, or substitution into peptide sequences in accordance with the present invention. In the event an abbreviation listed in Table 2 differs from another abbreviation for the same substance disclosed elsewhere herein, both abbreviations are understood to be applicable.

<u>Abbreviation</u>	<u>Amino Acid</u>
Sar	Sarcosine
Nle	Norleucine
Ile	isoleucine
1-Nal	3-(1-naphthyl)alanine
2-Nal	3-(2-naphthyl)alanine
Bip	4,4'-biphenyl alanine
Dip	3,3-diphenylalanine
Nvl	norvaline
NMe-Val	N α -methyl valine
NMe-Leu	N α -methyl leucine
NMe-Nle	N α -methyl norleucine
Cpg	cyclopentyl glycine
Chg	cyclohexyl glycine
Hyp	hydroxy praline
Oic	Octahydroindole-2-Carboxylic Acid
Igl	Indanyl glycine
Aib	aminoisobutyric acid
Aic	2-aminoindane-2-carboxylic acid
Pip	pipecolic acid
BhTic	β -homo Tic
BhPro	β -homo praline
Tiq	1,2,3,4-L-Tetrahydroisoquinoline-1-Carboxylic acid
Nip	Nipectic Acid
Thz	Thiazolidine-4-carboxylic acid

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Thi	3-thienyl alanine
4GuaPr	4-guanidino proline
4Pip	4-Amino-1-piperidine-4-carboxylic acid
Idc	indoline-2-carboxylic acid
Hydroxyl-Tic	1,2,3,4-Tetrahydroisoquinoline-7-hydroxy-3-carboxylic acid
Bip	4,4'-biphenyl alanine
Ome-Tyr	O-methyl tyrosine
I-Tyr	Iodotyrosine
Tic	1,2,3,4-L-Tetrahydroisoquinoline-3-Carboxylic acid
Igl	Indanyl glycine
BhTic	β -homo Tic
BhPhe	β -homo phenylalanine
AMeF	α -methyl Phenylalanine
BPhe	β -phenylalanine
Phg	Phenylglycine
Anc	3-amino-2-naphthoic acid
Atc	2-aminotetraline-2-carboxylic acid
NMe-Phe	N α -methyl phenylalanine
NMe-Lys	N α -methyl lysine
Tpi	1,2,3,4-Tetrahydronorharman-3-Carboxylic acid
Cpg	cyclopentyl glycine
Dip	3,3-diphenylalanine
4Pal	4-pyridinylalanine
3Pal	3-pyridinylalanine
2Pal	2-pyridinylalanine
Idc	indoline-2-carboxylic acid
Chg	cyclohexyl glycine
hPhe	homophenylalanine
BhTrp	β -homotryptophan
pI-Phe	4-iodophenylalanine
Orn	ornithine
Dpr	2,3-Diaminopropionic acid
Dbu	2,4-Diaminobutyric acid
homoLys	homolysine
N-eMe-K	N ϵ -methyl-lysine
N-eEt-K	N ϵ -ethyl-lysine
N-eIPr-K	N ϵ -isopropyl-lysine
bhomoK	β -homolysine
rLys	Lys ψ (CH ₂ NH)-reduced amide bond
rOrn	Orn ψ (CH ₂ NH)-reduced amide bond
Acm	acetamidomethyl
Ahx	6-aminohexanoic acid
ϵ Ahx	6-aminohexanoic acid
K(NPeg11)	N ϵ -(O-(aminoethyl)-O'-(2-propanoyl)-undecaethyleneglycol)-Lysine
K(NPeg27)	N ϵ -(O-(aminoethyl)-O'-(2-propanoyl)-(ethyleneglycol)27-Lysine
Cit	Citrulline
hArg	homoarginine
hCit	homocitrulline
NMe-Arg	N α -methyl arginine (NMeR)

Guf	4-guanidinyl phenylalanine
bhArg	β -homoarginine
3G-Dpr	2-amino-3-guanidinopropanoic acid
4AmP	4-amino-phenylalanine
4AmPhe	4-amidino-phenylalanine
4AmPig	2-amino-2-(1-carbamimidoylpiperidin-4-yl)acetic acid
4GuaPr	4-guanidino proline
N-Arg	N α -[(CH ₂) ₃ NHCH(NH)NH ₂] substituted glycine
rArg	Arg ψ (CH ₂ NH) -reduced amide bond
4PipA	4-Piperidinyl alanine
NMe-Thr	N α -methyl threonine(or NMeThr)

[0064] Nomenclature and Symbolism for Amino Acids and Peptides by the UPAC-IUB Joint Commission on Biochemical Nomenclature (JCBN) have been published in the following documents: Biochem. J., 1984, 219, 345-373; Eur. J. Biochem., 1984, 138, 9-37; 1985, 152, 1; 1993, 213, 2; Internat. J. Pept. Prot. Res., 1984, 24, following p 84; J. Biol. Chem., 1985, 260, 14-42; Pure Appl. Chem., 1984, 56, 595-624; Amino Acids and Peptides, 1985, 16, 387-410; Biochemical Nomenclature and Related Documents, 2nd edition, Portland Press, 1992, pages 39-69.

[0065] The one or more useful modifications to peptide domains of the inventive recombinant fusion protein can include amino acid additions or insertions, amino acid deletions, peptide truncations, amino acid substitutions, and/or chemical derivatization of amino acid residues, accomplished by known chemical techniques. For example, the thusly modified amino acid sequence includes at least one amino acid residue inserted or substituted therein, relative to the amino acid sequence of the native sequence of interest, in which the inserted or substituted amino acid residue has a side chain comprising a nucleophilic or electrophilic reactive functional group by which the peptide is conjugated to a linker and/or half-life extending moiety. In accordance with the invention, useful examples of such a nucleophilic or electrophilic reactive functional group include, but are not limited to, a thiol, a primary amine, a seleno, a hydrazide, an aldehyde, a carboxylic acid, a ketone, an aminooxy, a masked (protected) aldehyde, or a masked (protected) keto functional group. Examples of amino acid residues having a side chain comprising a nucleophilic reactive functional group include, but are not limited to, a lysine residue, a homolysine, an α,β -diaminopropionic acid residue, an α,γ -diaminobutyric acid residue, an ornithine residue, a cysteine, a homocysteine, a glutamic acid residue, an aspartic acid residue, or a selenocysteine residue.

[0066] Amino acid residues are commonly categorized according to different chemical and/or physical characteristics. The term "acidic amino acid residue" refers to amino acid residues in D- or L-form having side chains comprising acidic groups. Exemplary acidic residues include aspartatic acid and glutamatic acid residues. The term "aromatic amino acid residue" refers to amino acid residues in D- or L-form having side chains comprising aromatic groups. Exemplary aromatic residues include tryptophan, tyrosine, 3-(1-naphthyl)alanine, or phenylalanine residues. The term "basic amino acid residue" refers to amino acid residues in D- or L-form having side chains comprising basic groups. Exemplary basic amino acid residues include histidine, lysine, homolysine, ornithine, arginine, N-methyl-arginine, ω -aminoarginine, ω -methyl-arginine, 1-methyl-histidine, 3-methyl-histidine, and homoarginine (hR) residues. The term "hydrophilic amino acid residue" refers to amino acid residues in D- or L-form having side chains comprising polar groups. Exemplary hydrophilic residues include cysteine, serine, threonine, histidine, lysine, asparagine, aspartate, glutamate, glutamine, and citrulline (Cit) residues. The terms "lipophilic amino acid residue" refers to amino acid residues in D- or L-form having sidechains comprising uncharged, aliphatic or aromatic groups. Exemplary lipophilic sidechains include phenylalanine, isoleucine, leucine, methionine, valine, tryptophan, and tyrosine. Alanine (A) is amphiphilic—it is capable of acting as a hydrophilic or lipophilic residue. Alanine, therefore, is included within the definition of both "lipophilic residue" and "hydrophilic residue." The term "nonfunctional amino acid residue" refers to amino acid residues in D- or L-form having side chains that lack acidic, basic, or aromatic groups. Exemplary neutral amino acid residues include methionine, glycine, alanine, valine, isoleucine, leucine, and norleucine (Nle) residues.

[0067] Additional useful embodiments of conjugated recombinant fusion proteins can result from conservative modifications of the amino acid sequences of the polypeptides disclosed herein. Conservative modifications will produce half-life extending moiety-conjugated peptides having functional, physical, and chemical characteristics similar to those of the conjugated (e.g., PEG-conjugated) peptide from which such modifications are made. Such conservatively modified forms of the vehicle- or PEG-conjugated peptides disclosed herein are also contemplated as being an embodiment of the present invention.

[0068] In contrast, substantial modifications in the functional and/or chemical characteristics of the fusion proteins may be accomplished by selecting substitutions in the amino acid sequence that differ significantly in their effect on maintaining (a) the structure of the

molecular backbone in the region of the substitution, for example, as an α -helical conformation, (b) the charge or hydrophobicity of the molecule at the target site, or (c) the size of the molecule.

[0069] For example, a "conservative amino acid substitution" may involve a substitution of a native amino acid residue with a nonnative residue such that there is little or no effect on the polarity or charge of the amino acid residue at that position. Furthermore, any native residue in the polypeptide may also be substituted with alanine, as has been previously described for "alanine scanning mutagenesis" (see, for example, MacLennan et al., *Acta Physiol. Scand. Suppl.*, 643:55-67 (1998); Sasaki et al., 1998, *Adv. Biophys.* 35:1-24 (1998), which discuss alanine scanning mutagenesis).

[0070] Desired amino acid substitutions (whether conservative or non-conservative) can be determined by those skilled in the art at the time such substitutions are desired. For example, amino acid substitutions can be used to identify important residues of the peptide sequence, or to increase or decrease the affinity of the peptide or vehicle-conjugated peptide molecules described herein.

[0071] Naturally occurring residues may be divided into classes based on common side chain properties:

- 1) hydrophobic: norleucine (Nor), Met, Ala, Val, Leu, Ile;
- 2) neutral hydrophilic: Cys, Ser, Thr, Asn, Gln;
- 3) acidic: Asp, Glu;
- 4) basic: His, Lys, Arg;
- 5) residues that influence chain orientation: Gly, Pro; and
- 6) aromatic: Trp, Tyr, Phe.

[0072] Conservative amino acid substitutions may involve exchange of a member of one of these classes with another member of the same class. Conservative amino acid substitutions may encompass non-naturally occurring amino acid residues, which are typically incorporated by chemical peptide synthesis rather than by synthesis in biological systems. These include peptidomimetics and other reversed or inverted forms of amino acid moieties.

[0073] Non-conservative substitutions may involve the exchange of a member of one of these classes for a member from another class. Such substituted residues may be introduced into regions of the fusion protein.

[0074] In making such changes, according to certain embodiments, the hydropathic index of amino acids may be considered. Each amino acid has been assigned a hydropathic index on the basis of its hydrophobicity and charge characteristics. They are: isoleucine (+4.5); valine

(+4.2); leucine (+3.8); phenylalanine (+2.8); cysteine/cystine (+2.5); methionine (+1.9); alanine (+1.8); glycine (-0.4); threonine (-0.7); serine (-0.8); tryptophan (-0.9); tyrosine (-1.3); proline (-1.6); histidine (-3.2); glutamate (-3.5); glutamine (-3.5); aspartate (-3.5); asparagine (-3.5); lysine (-3.9); and arginine (-4.5).

[0075] The importance of the hydropathic amino acid index in conferring interactive biological function on a protein is understood in the art (see, *for example*, Kyte *et al.*, 1982, *J. Mol. Biol.* 157:105-131). It is known that certain amino acids may be substituted for other amino acids having a similar hydropathic index or score and still retain a similar biological activity. In making changes based upon the hydropathic index, in certain embodiments, the substitution of amino acids whose hydropathic indices are within ± 2 is included. In certain embodiments, those that are within ± 1 are included, and in certain embodiments, those within ± 0.5 are included.

[0076] It is also understood in the art that the substitution of like amino acids can be made effectively on the basis of hydrophilicity, particularly where the biologically functional protein or peptide thereby created is intended for use in immunological embodiments, as disclosed herein. In certain embodiments, the greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of its adjacent amino acids, correlates with its immunogenicity and antigenicity, *i.e.*, with a biological property of the protein.

[0077] The following hydrophilicity values have been assigned to these amino acid residues: arginine (+3.0); lysine (+3.0); aspartate (+3.0 $\pm$ 1); glutamate (+3.0 $\pm$ 1); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); threonine (-0.4); proline (-0.5 $\pm$ 1); alanine (-0.5); histidine (-0.5); cysteine (-1.0); methionine (-1.3); valine (-1.5); leucine (-1.8); isoleucine (-1.8); tyrosine (-2.3); phenylalanine (-2.5) and tryptophan (-3.4). In making changes based upon similar hydrophilicity values, in certain embodiments, the substitution of amino acids whose hydrophilicity values are within ± 2 is included, in certain embodiments, those that are within ± 1 are included, and in certain embodiments, those within ± 0.5 are included. One may also identify epitopes from primary amino acid sequences on the basis of hydrophilicity. These regions are also referred to as "epitopic core regions."

[0078] Examples of conservative substitutions include the substitution of one non-polar (hydrophobic) amino acid residue such as isoleucine, valine, leucine norleucine, alanine, or methionine for another, the substitution of one polar (hydrophilic) amino acid residue for another such as between arginine and lysine, between glutamine and asparagine, between glycine and serine, the substitution of one basic amino acid residue such as lysine, arginine or histidine for

another, or the substitution of one acidic residue, such as aspartic acid or glutamic acid for another. The phrase "conservative amino acid substitution" also includes the use of a chemically derivatized residue in place of a non-derivatized residue, provided that such polypeptide displays the requisite bioactivity. Other exemplary amino acid substitutions that can be useful in accordance with the present invention are set forth in Table 2.

Table 2. Some Useful Amino Acid Substitutions.

Original Residues	Exemplary Substitutions
Ala	Val, Leu, Ile
Arg	Lys, Gln, Asn
Asn	Gln
Asp	Glu
Cys	Ser, Ala
Gln	Asn
Glu	Asp
Gly	Pro, Ala
His	Asn, Gln, Lys, Arg
Ile	Leu, Val, Met, Ala, Phe, Norleucine
Leu	Norleucine, Ile, Val, Met, Ala, Phe
Lys	Arg, 1,4-Diaminobutyric Acid, Gln, Asn
Met	Leu, Phe, Ile
Phe	Leu, Val, Ile, Ala, Tyr
Pro	Ala
Ser	Thr, Ala, Cys
Thr	Ser
Trp	Tyr, Phe

Tyr	Trp, Phe, Thr, Ser
Val	Ile, Met, Leu, Phe, Ala, Norleucine

[0079] As stated herein above, in accordance with the present invention, the peptide portions of the inventive fusion protein can also be chemically derivatized at one or more amino acid residues by known organic chemistry techniques. "Chemical derivative" or "chemically derivatized" refers to a subject peptide having one or more residues chemically derivatized by reaction of a functional side group. Such derivatized molecules include, for example, those molecules in which free amino groups have been derivatized to form amine hydrochlorides, p-toluene sulfonyl groups, carbobenzoxy groups, t-butyloxycarbonyl groups, chloroacetyl groups or formyl groups. Free carboxyl groups may be derivatized to form salts, methyl and ethyl esters or other types of esters or hydrazides. Free hydroxyl groups may be derivatized to form O-acyl or O-alkyl derivatives. The imidazole nitrogen of histidine may be derivatized to form N-im-benzylhistidine. Also included as chemical derivatives are those peptides which contain one or more naturally occurring amino acid derivatives of the twenty canonical amino acids, whether in L- or D- form. For example, 4-hydroxyproline may be substituted for proline; 5-hydroxylysine maybe substituted for lysine; 3-methylhistidine may be substituted for histidine; homoserine may be substituted for serine; and ornithine may be substituted for lysine.

[0080] Useful derivatizations include, in some embodiments, those in which the amino terminal of the peptide is chemically blocked so that conjugation with the vehicle will be prevented from taking place at an N-terminal free amino group. There may also be other beneficial effects of such a modification, for example a reduction in the fusion protein's susceptibility to enzymatic proteolysis. The N-terminus can be acylated or modified to a substituted amine, or derivatized with another functional group, such as an aromatic moiety (e.g., an indole acid, benzyl (Bzl or Bn), dibenzyl (DiBzl or Bn₂), or benzyloxycarbonyl (Cbz or Z)), *N,N*-dimethylglycine or creatine. For example, in some embodiments, an acyl moiety, such as, but not limited to, a formyl, acetyl (Ac), propanoyl, butanyl, heptanyl, hexanoyl, octanoyl, or nonanoyl, can be covalently linked to the N-terminal end of the peptide, which can prevent undesired side reactions during conjugation of the vehicle to the peptide. Other exemplary N-terminal derivative groups include -NRR¹ (other than -NH₂), -NRC(O)R¹, -NRC(O)OR¹, -NRS(O)₂R¹, -NHC(O)NHR¹, succinimide, or benzyloxycarbonyl-NH- (Cbz-NH-), wherein R and R¹ are each independently hydrogen or lower alkyl and wherein the phenyl ring may be substituted with 1 to 3 substituents selected from C₁-C₄ alkyl, C₁-C₄ alkoxy, chloro, and bromo.

[0081] In some embodiments, one or more peptidyl [-C(O)NR-] linkages (bonds) between amino acid residues can be replaced by a non-peptidyl linkage. Exemplary non-peptidyl linkages are -CH₂-carbamate [-CH₂-OC(O)NR-], phosphonate, -CH₂-sulfonamide [-CH₂-S(O)₂NR-], urea [-NHC(O)NH-], -CH₂-secondary amine, and alkylated peptide [-C(O)NR⁶- wherein R⁶ is lower alkyl].

[0082] In some embodiments, one or more individual amino acid residues can be derivatized. Various derivatizing agents are known to react specifically with selected sidechains or terminal residues, as described in detail below by way of example.

[0083] Lysinyl residues and amino terminal residues may be reacted with succinic or other carboxylic acid anhydrides, which reverse the charge of the lysinyl residues. Other suitable reagents for derivatizing alpha-amino-containing residues include imidoesters such as methyl picolinimide; pyridoxal phosphate; pyridoxal; chloroborohydride; trinitrobenzenesulfonic acid; O-methylisourea; 2,4 pentanedione; and transaminase-catalyzed reaction with glyoxylate.

[0084] Arginyl residues may be modified by reaction with any one or combination of several conventional reagents, including phenylglyoxal, 2,3-butanedione, 1,2-cyclohexanedione, and ninhydrin. Derivatization of arginyl residues requires that the reaction be performed in alkaline conditions because of the high pK_a of the guanidine functional group. Furthermore, these reagents may react with the groups of lysine as well as the arginine epsilon-amino group.

[0085] Specific modification of tyrosyl residues has been studied extensively, with particular interest in introducing spectral labels into tyrosyl residues by reaction with aromatic diazonium compounds or tetranitromethane. Most commonly, N-acetylimidazole and tetranitromethane are used to form O-acetyl tyrosyl species and 3-nitro derivatives, respectively.

[0086] Carboxyl sidechain groups (aspartyl or glutamyl) may be selectively modified by reaction with carbodiimides (R'-N=C=N-R') such as 1-cyclohexyl-3-(2-morpholinyl-(4-ethyl) carbodiimide or 1-ethyl-3-(4-azonia-4,4-dimethylpentyl) carbodiimide. Furthermore, aspartyl and glutamyl residues may be converted to asparaginyl and glutaminyl residues by reaction with ammonium ions.

[0087] Glutaminyl and asparaginyl residues may be deamidated to the corresponding glutamyl and aspartyl residues. Alternatively, these residues are deamidated under mildly acidic conditions. Either form of these residues falls within the scope of this invention.

[0088] Cysteinyl residues can be replaced by amino acid residues or other moieties either to eliminate disulfide bonding or, conversely, to stabilize cross-linking. (See, e.g., Bhatnagar et al., J. Med. Chem., 39:3814-3819 (1996)).

[0089] Derivatization with bifunctional agents is useful for cross-linking the peptides or their functional derivatives to a water-insoluble support matrix, if desired, or to other macromolecular vehicles. Commonly used cross-linking agents include, e.g., 1,1-bis(diazoacetyl)-2-phenylethane, glutaraldehyde, N-hydroxysuccinimide esters, for example, esters with 4-azidosalicylic acid, homobifunctional imidoesters, including disuccinimidyl esters such as 3,3'-dithiobis(succinimidylpropionate), and bifunctional maleimides such as bis-N-maleimido-1,8-octane. Derivatizing agents such as methyl-3-[(p-azidophenyl)dithio]propioimide yield photoactivatable intermediates that are capable of forming crosslinks in the presence of light. Alternatively, reactive water-insoluble matrices such as cyanogen bromide-activated carbohydrates and the reactive substrates, e.g., as described in U.S. Pat. Nos. 3,969,287; 3,691,016; 4,195,128; 4,247,642; 4,229,537; and 4,330,440, are employed for protein immobilization.

[0090] Other possible modifications include hydroxylation of proline and lysine, phosphorylation of hydroxyl groups of seryl or threonyl residues, oxidation of the sulfur atom in Cys, methylation of the alpha-amino groups of lysine, arginine, and histidine side chains. Creighton, *Proteins: Structure and Molecule Properties* (W. H. Freeman & Co., San Francisco), 79-86 (1983).

[0091] The above examples of derivatizations are not intended to be an exhaustive treatment, but merely illustrative.

[0092] The production of the recombinant fusion protein can also involve suitable protein purification techniques, when applicable. In some embodiments of the fusion proteins of the invention, the molecule can be prepared to include a suitable isotopic label (e.g., ^{125}I , ^{14}C , ^{13}C , ^{35}S , ^3H , ^2H , ^{13}N , ^{15}N , ^{18}O , ^{17}O , *etc.*), for ease of quantification or detection.

[0093] The placement of the small pharmacologically inactive protein domain ("D") within the inventive recombinant fusion protein can be closer to the N-terminal end of the fusion protein than the pharmacologically active protein ("P") part of the fusion protein. Alternatively, other useful embodiments of the inventive recombinant fusion protein have the pharmacologically active protein situated closer to the N-terminal end of the fusion protein than the small pharmacologically inactive protein domain. Optionally, there can be a peptidyl linker between the two fusion partners, as described herein, or there can be additional peptide domains, or "tails", fused on either, or both, of the N-terminal and C-terminal ends of the fusion protein.

[0094] The small pharmacologically inactive protein domain is of human origin, but also encompassed is an amino acid sequence of human origin that is modified in one or more ways

relative to the native human sequence of interest to facilitate covalent conjugation to a linker or half-life extending moiety, such as an activated PEG. For example, a nucleophilic or electrophilic reactive functional group can be added to a side chain and/or a terminus, such as, but not limited to, a thiol, a primary amine, a seleno, a hydrazide, an aldehyde, a carboxylic acid, a ketone, an aminooxy, a masked (protected) aldehyde, or a masked (protected) keto functional group. For example, a cysteine residue, or a residue that provides a reactive primary or secondary amino group, can be inserted into the sequence or can be substituted for another residue in the native human sequence.

[0095] Small pharmacologically inactive protein domains suitable for use within the present invention are selected for their small size, which can range from about 3 to about 20 kDa, and typically is about 4 to about 12 kDa, which can aid in high level expression in prokaryotic hosts. In addition, such a useful small pharmacologically inactive protein domain is of human origin. This has the advantage of minimizing immunogenicity when the inventive composition is employed as part of a therapeutic molecule for administration to humans. The small pharmacologically inactive protein domain is characterized by forming a stable "stand-alone" protein domain, i.e., a domain that maintains its ability to fold into its native, or near-native, secondary and/or tertiary structure in a pharmaceutically acceptable aqueous formulation buffer of interest, and is soluble in such a buffer when folded (or refolded, if necessary). Thus, a small pharmacologically inactive protein domain suitable for use in the present invention should be one that forms insignificant amounts of insoluble aggregates (aggregates less than about 10%, and typically less than about 5%, of total protein) when it is suspended without other proteins (at physiologically compatible temperature) in a pharmaceutically acceptable aqueous formulation buffer of interest, not containing a detergent or chaotropic agent, such as urea, guanidinium hydrochloride, or lithium perchlorate. Such a formulation buffer is one that is suitable for administration to a mammal by injection or other drug delivery route (if need be, after sterile re-hydration or thawing of the lyophilized or frozen formulation buffer). Such pharmaceutically acceptable formulation buffers, suitable for the administration of protein therapeutic agents, are well known in the biopharmaceutical art and can be selected from various compositions and pH (e.g., between about pH 5.0 to about pH 8.2), involving, for example, but not limited to, acetate, citrate, tris(hydroxymethyl)aminomethane, or phosphate buffer systems, and optionally containing various other excipient, cryoprotectant, surfactant, tonicifying and/or stabilizing components (e.g., polysorbate 20, polysorbate 80) known in the biopharmaceutical art. (See, e.g., Lam et al., U.S. Patent No. 6,171,586; Pearlman et al., U.S. Patent No. 5,096,885;

O'Connor et al. U.S. Patent No. 5,981,485; Castensson et al. U.S. Patent No. 5,567,677; Brych et al. US20070190047A1).

Other examples of pharmaceutically acceptable formulation buffers that may be of interest include: 10 mM acetic acid, 9% sucrose, pH 5.0; 10 mM Tris, 150 mM NaCl, pH 8.0; and 10 mM NaH₂PO₄, 140 mM NaCl, pH 7.2.

[0096] Within the present invention, useful embodiments of the small pharmacologically inactive protein domain include fragments or modifications of the native sequence of human origin, including amino acid additions or insertions, amino acid deletions, peptide truncations, amino acid substitutions, or chemical derivatization of amino acid residues (accomplished by known chemical techniques), as long as the preceding characteristics of a stable stand-alone domain are maintained.

[0097] Useful examples of the small pharmacologically inactive protein domain include a 10th fibronectin III domain, a SH3 domain, a SH2 domain, a CH2 domain of IgG1, a PDZ domain, a thrombospondin repeat domain, an ubiquitin domain, a leucine-rich repeat domain a villin headpiece HP35 domain, or a villin headpiece HP76 domain, or a fragment or a modification of any of these that is soluble and maintains its native, or near-native, secondary or tertiary structure, in a biologically compatible aqueous buffer at physiological pH (i.e., about pH 6.8–7.4) and temperature. Amino acid sequences for some of these include the following:

1. CH2 Domain of Human IgG1 sequence:

GPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ
YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKG// SEQ ID NO:1;

or a truncated fragment of CH2 Domain of Human IgG1, such as:

GPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ
YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTIS// SEQ ID NO:107

or

PSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQY
NSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTIS// SEQ ID NO:108; or

2. Human Tenth Fibronectin III Domain (also designated "FN3" or "FnIII" or "10thFn3") sequences:

VSDVPRDLEVVAATPTSLISWDAPAVTVRYRITYGETGGNSPVQEFTVPGSKSTATIS
GLKPGVDYTITVYAVTGRGDSPASSKPISINYRTEIDKPSQ// SEQ ID NO:2

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or a truncated fragment thereof, such as:

VSDVPRDLEVVAATPTSLLISWDAPAVTVRYRITYGETGGNSPVQEFTVPGSKSTATIS
GLKPGVDYTITVYAVTGRGDSPASSKPISINYRTE// SEQ ID NO:13

or an extension, such as:

TVSDVPRDLEVVAATPTSLLISWDAPAVTVRYRITYGETGGNSPVQEFTVPGSKSTATIS
GLKPGVDYTITVYAVTGRGDSPASSKPISINYRTE// SEQ ID NO:50; or

3. Human PDZ Domain (Erbin):

GSMEIRVRVEKDPELGFSISGGVGGRGNPFRPDDDGIFVTRVQPEGPASKLLQPGDKIIQA
NGYSFINIEHGQAVSLLKTFQNTVELIIVREVSS// SEQ ID NO:3, or

PDZ(1N7F):

SSGAIITYVELKRYGGPLGITISGTEEPFDPIISSLTKGGLAERTGAIHIGDRILAINSSSLKG
KPLSEAIHLLQMAGETVTLKIKKQTDASASSP// SEQ ID NO:102,

PDZ(1UEZ):

PGEVRLVSLRRAKAHEGLGFSIRGGSEHGVGIYVSLVEPGSLAEKEGLRVGDQILRVNDK
SLARVTHAEAVKALKGSKKLVLSVYSAGRIP// SEQ ID NO:103,

PDZ(1WV):

PQDFDYFTVD MEKGAKGFGF SIRGGREYKM DLYVLRLAED GPAIRNGRMR
VGDQIIEING ESTRDMTHAR AIELIKSGGR RVRLLLKRG T GQVP// SEQ ID NO:104;

4. Human SH3 Domain (Fyn):

VTLFVALYDYEARTEDDLFSFKGGEKFQILNSSEGDDWWEARSLTTGETGYIPSNYVAPV//
SEQ ID NO:4;

SH3(1PHT):

SAEGYQYRALYDYKKEREEDIDLHLGDILTVNKGSLVALGFSDGQEARPEEIGWLNGYN
ETTGERGDFPGTYVEYIGRKKISP// SEQ ID NO:105,

SH3(1WA7):

PEEQGDIVVA LYPYDGIHPD DLSFKKGEKM KVL EEHGEWW KAKSLLTKKE
GFIPSNYVAK LNT// SEQ ID NO:106

SH3(1X2K):

KVFRALYTFE PRTPDELYFE EGDIIYITDM SDTNWWKGTS KGRTGLIPSN YVAEQ//
SEQ ID NO:94

5. Human SH2 Domain (Grb2):

GSMAWFFGKIPRAKAEEMLSKQRHDGAFLIRESESAPGDFSLSVKFGNDVQHFKVLRDG
AGKYFLWVVKFNSLNELVDYHRSTSVSRNQIFLRDI// SEQ ID NO:5

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SH2(1AB2):

NSLEKHSWYH GPVSRNAAEY LLSSGINGSF LVRESESSPG QRSISLRYEG
RVYHYRINTA SDGKLYVSSE SRFNTLAELV HHHSTVADGL ITTLHYPAP//SEQ ID
NO:109;

SH2(1JYQ):

PWFFGKIPRA KAEEMLSKQR HDGAFLIRES ESAPGDFSLS VKFGNDVQHF
KVLRDGAGKY FLWVVKFNSL NELVDYHRST SVSRNQQIFL RDIEQ// SEQ ID NO:110;

Ubiquitin:

MQIFVKTLTGKTITLEVEPSDTIENVKAKIQDKEGIPPDQQRLLFAGKQLEDGRTLSDYNI
QKESTLHLVLRRLRGG// SEQ ID NO:6;

Thrombospondin repeat domain:

QDGGWSHWSPWSSCSVTCGDGVITRIRLCNSPSPQMNGKPCEGEARETKACKKDACP//
SEQ ID NO:7;

Leucine-rich repeat domain:

LHLSENLLYTFSLATLMPYTRLTQNLDRCELTKLQVDGTLPLVLGTLDSLHNQLQSLPLL
GQTLPALTVLDVSNRLTSLPLGALRGLGELQELYLKGNELKTLPPGLLTPTPKLEKLSL
ANNLTELPAGLLNLENLDTLLLQENSLYTIPKGFFGSHLLPFA// SEQ ID NO:8; and
Villin headpiece domain, such as the HP-35 subdomain (Figure 13; SEQ ID NO:61) or HP-76
subdomain, which is the following sequence:

VFNANSNLSS GPLPIFPLEQ LVNKPVEELP EGVDPSRKEE HLSIEDFTQA
FGMTPAAFSALPRWKQQNLK KEKGLF// SEQ ID NO:89; or a
modified sequence for facilitating PEGylation, e.g., VFNANSNLSS GPLPIFPLEQ
LVNKPVEELP EGVDPSRKEE HLSIEDFTQA FGMTPAAFSALPRWKQQCLK KEKGLF//
SEQ ID NO:90.

[0098] The four digit code following a domain family name herein is the coordinate dataset identifier for that particular protein deposited in the RCSB Protein Databank (www.rcsb.org/pdb/). For example, PDZ (1N7F) refers to the sixth PDZ domain of GRIP1; PDZ (1UEZ) refers to the first PDZ domain of human KIAA1526 protein; PDZ(1WFV) refers to the fifth PDZ domain of human membrane associated guanylate kinase inverted-2; SH2(1AB2) refers to the SRC homology 2 domain of C-ABL; SH2(1JYQ) refers to the Grb2 SRC homology 2 domain; SH3(1PHT) refers to the phosphatidylinositol 3-kinase P85-alpha subunit SH3 domain; SH3(1WA7) refers to SH3 domain of human LYN tyrosine kinase; and SH3(1X2K) refers to SH3 domain of human osteoclast stimulating factor 1.

[0099] The inventive compositions involve a pharmacologically active protein ("P") part of the recombinant fusion protein. The term "pharmacologically active" means that a substance so described is determined to have activity that affects a medical parameter (e.g., blood pressure, blood cell count, cholesterol level, pain perception) or disease state (e.g., cancer, autoimmune disorders, chronic pain). Conversely, the term "pharmacologically inactive" means that no activity affecting a medical parameter or disease state can be determined for that substance. Thus, pharmacologically active peptides or proteins comprise agonistic or mimetic and antagonistic peptides as defined below. The present invention encompasses the use of any pharmacologically active protein, which has an amino acid sequence ranging from about 5 to about 80 amino acid residues in length, and which is amenable to recombinant expression. In some useful embodiments of the invention, the pharmacologically active protein is modified in one or more ways relative to a native sequence of interest, including amino acid additions or insertions, amino acid deletions, peptide truncations, amino acid substitutions, or chemical derivatization of amino acid residues (accomplished by known chemical techniques), so long as the requisite bioactivity is maintained.

[00100] The terms "-mimetic peptide," "peptide mimetic," and "-agonist peptide" refer to a peptide or protein having biological activity comparable to a naturally occurring protein of interest, for example, but not limited to, a toxin peptide molecule, e.g., naturally occurring OSK1 toxin peptide. These terms further include peptides that indirectly mimic the activity of a naturally occurring peptide molecule, such as by potentiating the effects of the naturally occurring molecule.

[00101] The term "-antagonist peptide," "peptide antagonist," and "inhibitor peptide" refer to a peptide that blocks or in some way interferes with the biological activity of a receptor of interest, or has biological activity comparable to a known antagonist or inhibitor of a receptor of interest (such as, but not limited to, an ion channel or a G-Protein Coupled Receptor (GPCR)).

[00102] Examples of pharmacologically active proteins that can be used within the present invention include, but are not limited to, a toxin peptide (e.g., OSK1 or an OSK1 peptide analog; ShK or an ShK peptide analog), a CGRP peptide antagonist, a bradykinin B1 receptor peptide antagonist, a parathyroid hormone (PTH) agonist peptide, a parathyroid hormone (PTH) antagonist peptide, an ang-2 binding peptide, a myostatin binding peptide, an erythropoietin-mimetic (EPO-mimetic) peptide, a thrombopoietin-mimetic (TPO-mimetic) peptide, a nerve growth factor (NGF) binding peptide, a B cell activating factor (BAFF) binding peptide, and a

glucagon-like peptide (GLP)-1 or a peptide mimetic thereof or GLP-2 or a peptide mimetic thereof.

Glucagon-like peptide 1 (GLP-1) and the related peptide glucagon are produced via differential processing of proglucagon and have opposing biological activities. Proglucagon itself is produced in α -cells of the pancreas and in the enteroendocrine L-cells, which are located primarily in the distal small intestine and colon. In the pancreas, glucagon is selectively cleaved from proglucagon. In the intestine, in contrast, proglucagon is processed to form GLP-1 and glucagon-like peptide 2 (GLP-2), which correspond to amino acid residues 78-107 and 126-158 of proglucagon, respectively (see, e.g., Irwin and Wong, 1995, *Mol. Endocrinol.* 9:267-277 and Bell *et al.*, 1983, *Nature* 304:368-371). By convention, the numbering of the amino acids of GLP-1 is based on the GLP-1 (1-37) formed from cleavage of proglucagon. The biologically active forms are generated from further processing of this peptide, which, in one numbering convention, yields GLP-1 (7-37)-OH and GLP-1 (7-36)-NH₂. Both GLP-1 (7-37)-OH (or simply GLP-1 (7-37)) and GLP-1 (7-36)-NH₂ have the same activities. For convenience, the term "GLP-1", is used to refer to both of these forms. The first amino acid of these processed peptides is His7 in this numbering convention. Another numbering convention recognized in the art, however, assumes that the numbering of the processed peptide begins with His as position 1 rather than position 7. Thus, in this numbering scheme, GLP-1 (1-31) is the same as GLP-1(7-37), and GLP-1(1-30) is the same as GLP-1 (7-36). Examples of GLP-1 mimetic polypeptide sequences include:

HGEGTFTSDQSSYLEGQAAKEFIAWLVKGRG// (SEQ ID NO:45);
 HGEGTFTSDQSSYLEGQAAKEFIAWLQKGRG// (SEQ ID NO:46);
 HGEGTFTSDVSSYQEGQAAKEFIAWLVKGRG// (SEQ ID NO:47);
 HGEGTFTSDVSSYLEGQAAKEFIAQLVKGRG// (SEQ ID NO:48);
 HGEGTFTSDVSSYLEGQAAKEFIAQLQKGRG// (SEQ ID NO:91);
 HGEGTFTSDVSSYLEGQAAKEFIAWLQKGRG// (SEQ ID NO:92);
 HNETTFTSDVSSYLEGQAAKEFIAWLVKGRG// (SEQ ID NO:93)
 HGEGTFTSDVSSYLENQTAKEFIAWLVKGRG// (SEQ ID NO:95);
 HGEGTFTSDVSSYLEGNATKEFIAWLVKGRG// (SEQ ID NO:96);
 HGEGTFTSDVSSYLEGQAAKEFIAWLVNGTG// (SEQ ID NO:97);
 HGEGTFTSDVSSYLEGQAAKEFIAWLVKNRT// (SEQ ID NO:98);
 HGEGTFTSDVSSYLEGQAAKEFIAWLVKGRNGT// (SEQ ID NO:99);
 HGEGTFTSDVSSYLEGQAAKEFIAWLVKGRGGTGNGT// (SEQ ID NO:100); and

HGEGTFTSDVSSYLEGQAAKEFIAWLVKGRGGSGNGT// (SEQ ID NO:101).

[00103] Human GLP-2 and GLP-2-mimetic analogs are also known in the art. (See, e.g., Prasad et al., Glucagonlike peptide-2 analogue enhances intestinal mucosal mass after ischemia and reperfusion, J. Pediatr. Surg. 2000 Feb;35(2):357-59 (2000); Yusta et al., Glucagon-like peptide-2 receptor activation engages bad and glycogen synthase kinase-3 in a protein kinase A-dependent manner and prevents apoptosis following inhibition of phosphatidylinositol 3-kinase, J. Biol. Chem. 277(28):24896-906 (2002)).

[00104] "Toxin peptides" include peptides and polypeptides having the same amino acid sequence of a naturally occurring pharmacologically active peptide or polypeptide that can be isolated from a venom, and also include modified peptide analogs of such naturally occurring molecules. (See, e.g., Kalman et al., ShK-Dap22, a potent Kv1.3-specific immunosuppressive polypeptide, J. Biol. Chem. 273(49):32697-707 (1998); Kem et al., US Patent No. 6,077,680; Mouhat et al., OsK1 derivatives, WO 2006/002850 A2; Chandy et al., Analogs of SHK toxin and their uses in selective inhibition of Kv1.3 potassium channels, WO 2006/042151; Sullivan et al., Toxin Peptide therapeutic agents, WO 2006/116156 A2). Snakes, scorpions, spiders, bees, snails and sea anemone are a few examples of organisms that produce venom that can serve as a rich source of small bioactive toxin peptides or "toxins" that potently and selectively target ion channels and receptors. An example of a toxin peptide is OSK1 (also known as OsK1), a toxin peptide isolated from Orthochirus scrobiculosus scorpion venom. (e.g., Mouhat et al., K⁺ channel types targeted by synthetic OSK1, a toxin from Orthochirus scrobiculosus scorpion venom, Biochem. J. 385:95-104 (2005); Mouhat et al., Pharmacological profiling of Orthochirus scrobiculosus toxin 1 analogs with a trimmed N-terminal domain, Molec. Pharmacol. 69:354- 62 (2006); Mouhat et al., OsK1 derivatives, WO 2006/002850 A2). Another example is ShK, isolated from the venom of the sea anemone Stichodactyla helianthus. (E.g., Tudor et al., Ionisation behaviour and solution properties of the potassium-channel blocker ShK toxin, Eur. J. Biochem. 251(1-2):133-41(1998); Pennington et al., Role of disulfide bonds in the structure and potassium channel blocking activity of ShK toxin, Biochem. 38(44): 14549-58 (1999); Kem et al., ShK toxin compositions and methods of use, US Patent No. 6,077,680; Lebrun et al., Neuropeptides originating in scorpion, US Patent No. 6,689,749; Beeton et al., Targeting effector memory T cells with a selective peptide inhibitor of Kv1.3 channels for therapy of autoimmune diseases, Molec. Pharmacol. 67(4):1369-81 (2005)).

[00105] The toxin peptides are usually between about 20 and about 80 amino acids in length, contain 2-5 disulfide linkages and form a very compact structure. Toxin peptides (e.g., from the venom of scorpions, sea anemones and cone snails) have been isolated and characterized for their impact on ion channels. Such peptides appear to have evolved from a relatively small number of structural frameworks that are particularly well suited to addressing the critical issues of potency and stability. The majority of scorpion and Conus toxin peptides, for example, contain 10-40 amino acids and up to five disulfide bonds, forming extremely compact and constrained structure (microproteins) often resistant to proteolysis. The conotoxin and scorpion toxin peptides can be divided into a number of superfamilies based on their disulfide connections and peptide folds. The solution structure of many of these has been determined by NMR spectroscopy, illustrating their compact structure and verifying conservation of their family fold. (E.g., Tudor et al., Ionisation behaviour and solution properties of the potassium-channel blocker ShK toxin, *Eur. J. Biochem.* 251(1-2):133-41(1998); Pennington et al., Role of disulfide bonds in the structure and potassium channel blocking activity of ShK toxin, *Biochem.* 38(44): 14549-58 (1999); Jaravine et al., Three-dimensional structure of toxin OSK1 from *Orthochirus scrobiculosus* scorpion venom, *Biochem.* 36(6):1223-32 (1997); del Rio-Portillo et al.; NMR solution structure of Cn12, a novel peptide from the Mexican scorpion *Centruroides noxius* with a typical beta-toxin sequence but with alpha-like physiological activity, *Eur. J. Biochem.* 271(12): 2504-16 (2004); Prochnicka-Chalufour et al., Solution structure of discrepin, a new K⁺-channel blocking peptide from the alpha-KTx15 subfamily, *Biochem.* 45(6):1795-1804 (2006)). Examples of pharmacologically active toxin peptides for which the practice of the present invention can be useful include, but are not limited to ShK, OSK1, charybdotoxin (ChTx), kaliotoxin1 KTX1), or maurotoxin, or toxin peptide analogs of any of these, modified from the native sequences at one or more amino acid residues. Other examples are known in the art, or can be found in Sullivan et al., WO06116156 A2 or U.S. Patent Application No. 11/406,454 (titled: Toxin Peptide Therapeutic Agents, published as US 2007/0071764); Mouhat et al., OsK1 derivatives, WO 2006/002850 A2; Sullivan et al., U.S. Patent Application No. 11/978,076 (titled: Conjugated Toxin Peptide Therapeutic Agents, filed 25 October 2007), Lebrun et al., U.S. Patent No. 6,689,749.

[00106] The term "peptide analog" refers to a peptide having a sequence that differs from a peptide sequence existing in nature by at least one amino acid residue substitution, internal addition, or internal deletion of at least one amino acid, and/or amino- or carboxy- terminal end

truncations, or additions). An "internal deletion" refers to absence of an amino acid from a sequence existing in nature at a position other than the N- or C-terminus. Likewise, an "internal addition" refers to presence of an amino acid in a sequence existing in nature at a position other than the N- or C-terminus. "Toxin peptide analogs", such as, but not limited to, an OSK1 peptide analog, ShK peptide analog, or ChTx peptide analog, contain modifications of a native toxin peptide sequence of interest (e.g., amino acid residue substitutions, internal additions or insertions, internal deletions, and/or amino- or carboxy- terminal end truncations, or additions as previously described above) relative to a native toxin peptide sequence of interest, which is in the case of OSK1: GVIINVKCKISRQCLEPCKKAGMRFGKCMNGKCHCTPK// SEQ ID NO:111; and in the case of ShK is RSCIDTIPKSRCTAFQCKHSMKYRLSFCRKTCGTC// SEQ ID NO:112.

[00107] A "CGRP peptide antagonist" is a peptide that preferentially binds the CGRP₁ receptor, such as, but not limited to, a CGRP peptide analog, and that antagonizes, blocks, decreases, reduces, impedes, or inhibits CGRP₁ receptor activation by full length native human α CGRP or β CGRP under physiological conditions of temperature, pH, and ionic strength. CGRP peptide antagonists include full and partial antagonists. Such antagonist activity can be detected by known *in vitro* methods or *in vivo* functional assay methods. (See, e.g., Smith et al., Modifications to the N-terminus but not the C-terminus of calcitonin gene-related peptide(8-37) produce antagonists with increased affinity, J. Med. Chem., 46:2427-2435 (2003)). Examples of useful CGRP peptide antagonists are disclosed in Gegg et al., CGRP peptide antagonists and conjugates, WO 2007/048026 A2 and U.S. Serial No. 11/584,177, filed on October 19, 2006. published as US 2008/0020978 A1.

[00108] The terms "parathyroid hormone (PTH) agonist" and "PTH agonist" refer to a molecule that binds to PTH-1 or PTH-2 receptor and increases or decreases one or more PTH activity assay parameters as does full-length native human parathyroid hormone. Examples of useful PTH agonist peptides are disclosed in Table 1 of U.S. Patent No. 6,756,480, titled Modulators of receptors for parathyroid hormone and parathyroid hormone-related protein. An exemplary PTH activity assay is disclosed in Example 1 of U.S. Patent No. 6,756,480.

[00109] The term "parathyroid hormone (PTH) antagonist" refers to a molecule that binds to PTH-1 or PTH-2 receptor and blocks or prevents the normal effect on those parameters by full length native human parathyroid hormone. Examples of useful PTH antagonist peptides are disclosed in Table 2 of U.S. Patent No. 6,756,480.

An exemplary PTH activity assay is disclosed in Example 2 of U.S.

Patent No. 6,756,480.

[00110] The terms “bradykinin B1 receptor antagonist peptide” and “bradykinin B1 receptor peptide antagonist” mean a peptide with antagonist activity with respect to human bradykinin B1 receptor (hB1). Useful bradykinin B1 receptor antagonist peptides can be identified or derived as described in Ng et al., Antagonist of the bradykinin B1 receptor, US 2005/0215470 A1, published September 29, 2005, or U.S. Patent Nos. 5,834,431 or 5,849,863. An exemplary B1 receptor activity assays are disclosed in Examples 6-8 of US 2005/0215470 A1.

[00111] The terms “thrombopoietin (TPO)-mimetic peptide” and “TPO-mimetic peptide” refer to peptides that can be identified or derived as described in Cwirla et al. (1997), *Science* 276:1696-9, U.S. Pat. Nos. 5,869,451 and 5,932,946; U.S. Pat. App. No. 2003/0176352, published Sept. 18, 2003; WO 03/031589, published April 17, 2003; WO 00/24770, published May 4, 2000; and any peptides appearing in Table 5 of published application US 2006/0140934 (U.S. Serial No. 11/234,731, filed September 23, 2005, titled Modified Fc Molecules). Those of ordinary skill in the art appreciate that each of these references enables one to select different peptides than actually disclosed therein by following the disclosed procedures with different peptide libraries.

[00112] The terms “EPO-mimetic peptide” and “erythropoietin-mimetic peptide” refers to peptides that can be identified or derived as described in Wrighton et al. (1996), *Science* 273: 458-63, and Naranda et al. (1999), *Proc. Natl. Acad. Sci. USA* 96: 7569 -74. Useful EPO-mimetic peptides include EPO-mimetic peptides listed in Table 5 of published U.S. patent application US 2007/0269369 A1 and in U.S. Pat. No. 6,660,843.

[00113] The term “ang-2-binding peptide” comprises peptides that can be identified or derived as described in U.S. Pat. App. No. 2003/0229023, published Dec. 11, 2003; WO 03/057134, published July, 17, 2003; U.S. 2003/0236193, published Dec. 25, 2003; and any peptides appearing in Table 6 of published application US 2006/0140934 (U.S. Serial No. 11/234,731, filed September 23, 2005, titled Modified Fc Molecules).

Those of ordinary skill in the art appreciate that each of these references enables one to select

different peptides than actually disclosed therein by following the disclosed procedures with different peptide libraries.

[00114] The terms “nerve growth factor (NGF) binding peptide” and “NGF-binding peptide” comprise peptides that can be identified or derived as described in WO 04/026329, published April 1, 2004 and any peptides identified in Table 7 of published application US 2006/0140934 (U.S. Serial No. 11/234,731, filed September 23, 2005, titled Modified Fc Molecules). Those of ordinary skill in the art appreciate that this reference enables one to select different peptides than actually disclosed therein by following the disclosed procedures with different peptide libraries.

[00115] The term “myostatin-binding peptide” comprises peptides that can be identified or derived as described in U.S. Ser. No. 10/742,379, filed December 19, 2003, and peptides appearing in Table 8 of published application US 2006/0140934 (U.S. Serial No. 11/234,731, filed September 23, 2005, titled Modified Fc Molecules). Those of ordinary skill in the art appreciate that each of these references enables one to select different peptides than actually disclosed therein by following the disclosed procedures with different peptide libraries.

[00116] The terms “BAFF-antagonist peptide” and “BAFF binding peptide” comprise peptides that can be identified or derived as described in U.S. Pat. Appln. No. 2003/0195156 A1, which is incorporated herein by reference in its entirety and those peptides appearing in Table 9 of published application US 2006/0140934 (U.S. Serial No. 11/234,731, filed September 23, 2005, titled Modified Fc Molecules).

Those of ordinary skill in the art appreciate that the foregoing references enable one to select different peptides than actually disclosed therein by following the disclosed procedures with different peptide libraries.

[00117] The small size of the small pharmacologically inactive protein domain (D) selected typically results in a short serum half-life for the fusion protein molecule, which can allow, optionally, for modulation of the pharmacokinetic profile of the molecule to fit the therapeutic need by attaching or conjugating covalently one or more half-life extending moieties of various masses and configurations to the fusion protein. A “half-life extending moiety” (or “F¹”) refers to a molecule that prevents or mitigates in vivo degradation by proteolysis or other activity-diminishing chemical modification, increases in vivo half-life or other pharmacokinetic properties such as but not limited to increasing the rate of absorption, reduces toxicity, reduces

immunogenicity, improves solubility, increases biological activity and/or target selectivity of the fusion protein with respect to a target of interest, and/or increases manufacturability, compared to an unconjugated form of the fusion protein. In accordance with the invention, the half-life extending moiety is one that is pharmaceutically acceptable. The half-life extending moiety should be selected such that the conjugated fusion protein (i.e., fusion protein with half-life extending moiety covalently attached thereto) achieves a sufficient hydrodynamic size to reduce clearance by renal filtration in vivo. For example, a half-life extending moiety can be selected that is a polymeric macromolecule, which is substantially straight chain, branched-chain, or dendritic in form. Alternatively, a half-life extending moiety can be selected such that, in vivo, the inventive composition of matter will bind to a plasma protein to form a complex, such that the complex thus formed avoids or reduces substantial renal clearance.

[00118] Exemplary half-life extending moiety that can be used, in accordance with the present invention, include a polyalkylene glycol compound, such as a polyethylene glycol (PEG) or a polypropylene glycol. Other appropriate polyalkylene glycol compounds include, but are not limited to, charged or neutral polymers of the following types: dextran, colominic acids or other carbohydrate based polymers, polymers of amino acids, and biotin derivatives.

[00119] Other examples of the half-life extending moiety, in accordance with the invention, include a copolymer of ethylene glycol, a copolymer of propylene glycol, a carboxymethylcellulose, a polyvinyl pyrrolidone, a poly-1,3-dioxolane, a poly-1,3,6-trioxane, an ethylene/maleic anhydride copolymer, a polyaminoacid (e.g., polylysine or polyornithine), a dextran n-vinyl pyrrolidone, a poly n-vinyl pyrrolidone, a propylene glycol homopolymer, a propylene oxide polymer, an ethylene oxide polymer, a polyoxyethylated polyol, a polyvinyl alcohol, a linear or branched glycosylated chain, a polyacetal, a long chain fatty acid, a long chain hydrophobic aliphatic group.

[00120] Other embodiments of the half-life extending moiety, in accordance with the invention, include peptide ligands or small (organic) molecule ligands that have binding affinity for a long half-life plasma protein under physiological conditions of temperature, pH, and ionic strength. Examples include an albumin-binding peptide or small molecule (i.e., organic non-peptidyl) ligand, a transthyretin-binding peptide or small molecule ligand, a thyroxine-binding globulin-binding peptide or small molecule ligand, an antibody-binding peptide or small molecule ligand, or another peptide or small molecule that has an affinity for a long half-life plasma protein. (See, e.g., Blaney et al., Method and compositions for increasing the serum half-life of pharmacologically active agents by binding to transthyretin-selective ligands, US

Patent. No. 5,714,142; Sato et al., Serum albumin binding moieties, US 2003/0069395 A1; Jones et al., Pharmaceutical active conjugates, US Patent No. 6,342,225). A "long half-life plasma protein" is one of the hundreds of different proteins dissolved in mammalian blood plasma, including so-called "carrier proteins" (such as albumin, transferrin and haptoglobin), fibrinogen and other blood coagulation factors, complement components, immunoglobulins, enzyme inhibitors, precursors of substances such as angiotensin and bradykinin and many other types of proteins.

[00121] The invention encompasses the use of any single species of pharmaceutically acceptable half-life extending moiety, such as, but not limited to, those described herein, in conjugation with the fusion protein, or the use of a combination of two or more like or different half-life extending moieties.

[00122] In being conjugated, the half-life extending moiety, as described herein, is covalently bound directly to an amino acid residue of the fusion protein itself, or optionally, to a peptidyl or non-peptidyl linker (including but not limited to aromatic or aryl linkers) that is covalently bound to an amino acid residue of the fusion protein. Any "linker" group is optional. When present, its chemical structure is not critical, since it serves primarily as a spacer, which can be useful in optimizing pharmacological activity of some embodiments of the inventive composition. The linker is preferably made up of amino acids linked together by peptide bonds. The linker moiety, if present, can be independently the same or different from any other linker, or linkers, that may be present in the inventive composition.

[00123] As stated above, the linker, if present (whether within the primary amino acid sequence of the recombinant fusion protein, or as a linker for attaching a half-life extending moiety to the fusion protein), can be peptidyl in nature (i.e., made up of amino acids linked together by peptide bonds) and made up in length, preferably, of from 1 up to about 40 amino acid residues, more preferably, of from 1 up to about 20 amino acid residues, and most preferably of from 1 to about 10 amino acid residues. Preferably, but not necessarily, the amino acid residues in the linker are from among the twenty canonical amino acids, more preferably, cysteine, glycine, alanine, proline, asparagine, glutamine, and /or serine. Even more preferably, a peptidyl linker is made up of a majority of amino acids that are sterically unhindered, such as glycine, serine, and alanine linked by a peptide bond. It is also desirable that, if present, a peptidyl linker be selected that avoids rapid proteolytic turnover in circulation *in vivo*. Some of these amino acids may be glycosylated, as is well understood by those in the art. For example, a

useful linker sequence constituting a sialylation site is $X_1X_2NX_4X_5G$ (SEQ ID NO:9), wherein X_1 , X_2 , X_4 and X_5 are each independently any amino acid residue.

[00124] In other embodiments, the 1 to 40 amino acids are selected from glycine, alanine, proline, asparagine, glutamine, and lysine. Preferably, a linker is made up of a majority of amino acids that are sterically unhindered, such as glycine and alanine. Thus, preferred linkers include polyglycines, polyserines, and polyalanines, or combinations of any of these. Some exemplary peptidyl linkers are poly(Gly)₁₋₈, particularly (Gly)₃, (Gly)₄ (SEQ ID NO:10), (Gly)₅ (SEQ ID NO:11) and (Gly)₇ (SEQ ID NO:12), as well as, poly(Gly)₄Ser (SEQ ID NO:21), poly(Gly-Ala)₂₋₄ and poly(Ala)₁₋₈. Other specific examples of peptidyl linkers include (Gly)₅Lys (SEQ ID NO:14), and (Gly)₅LysArg (SEQ ID NO:15). Other specific examples of linkers are: Other examples of useful peptidyl linkers are:

[00125] (Gly)₃Lys(Gly)₄ (SEQ ID NO:16);

[00126] (Gly)₃AsnGlySer(Gly)₂ (SEQ ID NO:17);

[00127] (Gly)₃Cys(Gly)₄ (SEQ ID NO:18); and

[00128] GlyProAsnGlyGly (SEQ ID NO:19).

[00129] To explain the above nomenclature, for example, (Gly)₃Lys(Gly)₄ means Gly-Gly-Gly-Lys-Gly-Gly-Gly-Gly (SEQ ID NO:20). Other combinations of Gly and Ala are also useful.

[00130] Other preferred linkers are those identified herein as "L5" (GGGGGS; SEQ ID NO:21), "L10" (GGGGSGGGGS; SEQ ID NO:22), "L25" (GGGGSGGGGSGGGGSGGGGSGGGGSGGGGS; SEQ ID NO:23) and any linkers used in the working examples hereinafter.

[00131] In some embodiments of the compositions of this invention, which comprise a peptide linker moiety ("L"), acidic residues, for example, glutamate or aspartate residues, are placed in the amino acid sequence of the linker moiety (L). Examples include the following peptide linker sequences:

[00132] GGEGGG (SEQ ID NO:24);

[00133] GGEEEGGG (SEQ ID NO:25);

[00134] GEEEG (SEQ ID NO:26);

[00135] GEEE (SEQ ID NO:27);

[00136] GGDGGG (SEQ ID NO:28);

[00137] GGDDDGG (SEQ ID NO:29);

[00138] GDDDG (SEQ ID NO:30);

- [00139] GDDD (SEQ ID NO:31);
- [00140] GGGGSDDSDGSDGEDGGGGS (SEQ ID NO:32);
- [00141] WEWEW (SEQ ID NO:33);
- [00142] FEFEF (SEQ ID NO:34);
- [00143] EEEWWW (SEQ ID NO:35);
- [00144] EEEFFF (SEQ ID NO:36);
- [00145] WWEEWW (SEQ ID NO:37); or
- [00146] FFEEFF (SEQ ID NO:38).
- [00147] In other embodiments, the linker constitutes a phosphorylation site, e.g., $X_1X_2YX_4X_5G$ (SEQ ID NO:39), wherein X_1 , X_2 , X_4 , and X_5 are each independently any amino acid residue; $X_1X_2SX_4X_5G$ (SEQ ID NO:40), wherein X_1 , X_2 , X_4 and X_5 are each independently any amino acid residue; or $X_1X_2TX_4X_5G$ (SEQ ID NO:41), wherein X_1 , X_2 , X_4 and X_5 are each independently any amino acid residue.
- [00148] The linkers shown here are exemplary; peptidyl linkers within the scope of this invention may be much longer and may include other residues. A peptidyl linker can contain, e.g., a cysteine, another thiol, or nucleophile for conjugation with a half-life extending moiety. In another embodiment, the linker contains a cysteine or homocysteine residue, or other 2-amino-ethanethiol or 3-amino-propanethiol moiety for conjugation to maleimide, iodoacetaamide or thioester, functionalized half-life extending moiety.
- Another useful peptidyl linker is a large, flexible linker comprising a random Gly/Ser/Thr sequence, for example: GSGSATGGSGSTASSGSGSATH (SEQ ID NO:42) or HGSGSATGGSGSTASSGSGSAT (SEQ ID NO:43), that is estimated to be about the size of a 1 kDa PEG molecule. Alternatively, a useful peptidyl linker may be comprised of amino acid sequences known in the art to form rigid helical structures (e.g., Rigid linker: -AEAAAKEAAAKEAAAKAGG-)(SEQ ID NO:44). Additionally, a peptidyl linker can also comprise a non-peptidyl segment such as a 6 carbon aliphatic molecule of the formula $-CH_2-CH_2-CH_2-CH_2-CH_2-$. The peptidyl linkers can be altered to form derivatives as described herein.
- [00149] Optionally, non-peptidyl linkers are also useful for conjugating the half-life extending moiety to the peptide portion of the half-life extending moiety-conjugated fusion protein. For example, alkyl linkers such as $-NH-(CH_2)_s-C(O)-$, wherein $s = 2-20$ can be used. These alkyl linkers may further be substituted by any non-sterically hindering group such as

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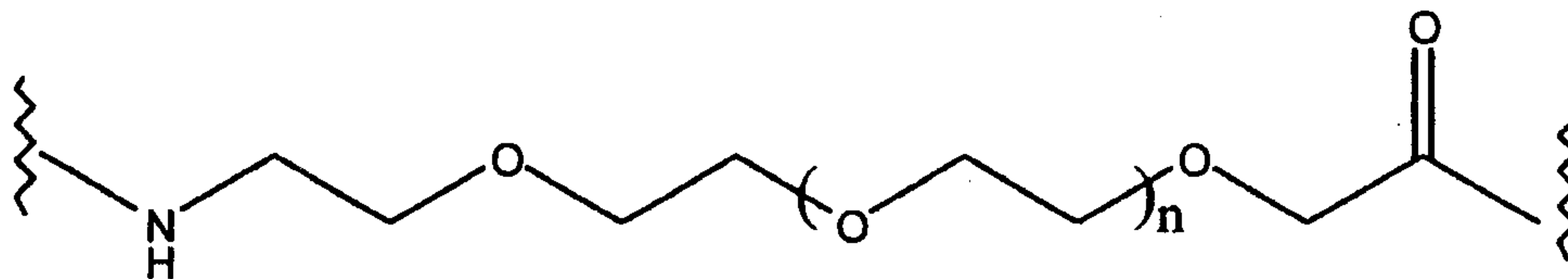
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lower alkyl (e.g., C₁-C₆) lower acyl, halogen (e.g., Cl, Br), CN, NH₂, phenyl, *etc.* Exemplary non-peptidyl linkers are PEG linkers (e.g., shown below):

[00150]

(II)



wherein n is such that the linker has a molecular weight of about 100 to about 5000 kilodaltons (kDa), preferably about 100 to about 500 kDa.

[00151] In one embodiment, the non-peptidyl linker is aryl. The linkers may be altered to form derivatives in the same manner as described herein. In addition, PEG moieties may be attached to the N-terminal amine or selected side chain amines by either reductive alkylation using PEG aldehydes or acylation using hydroxysuccinimido or carbonate esters of PEG, or by thiol conjugation.

[00152] "Aryl" is phenyl or phenyl vicinally-fused with a saturated, partially-saturated, or unsaturated 3-, 4-, or 5 membered carbon bridge, the phenyl or bridge being substituted by 0, 1, 2 or 3 substituents selected from C₁₋₈ alkyl, C₁₋₄ haloalkyl or halo.

[00153] "Heteroaryl" is an unsaturated 5, 6 or 7 membered monocyclic or partially-saturated or unsaturated 6-, 7-, 8-, 9-, 10- or 11 membered bicyclic ring, wherein at least one ring is unsaturated, the monocyclic and the bicyclic rings containing 1, 2, 3 or 4 atoms selected from N, O and S, wherein the ring is substituted by 0, 1, 2 or 3 substituents selected from C₁₋₈ alkyl, C₁₋₄ haloalkyl and halo.

[00154] Non-peptide portions of the inventive composition of matter, such as non-peptidyl linkers or non-peptide half-life extending moieties can be synthesized by conventional organic chemistry reactions.

[00155] The above is merely illustrative and not an exhaustive treatment of the kinds of linkers that can optionally be employed in accordance with the present invention.

[00156] In another useful embodiment of the inventive composition of matter and/or the method of producing a composition of matter, involving an inventive half-life extending moiety-conjugated fusion protein, the fusion protein is conjugated at the amino acid residue at the

peptide's amino terminal end to the half-life extending moiety. (See, e.g., Kinstler et al., N-terminally chemically modified protein compositions and methods, US Patent Nos. 5,985,265, and 5,824,784).

[00157] It will be appreciated that "multimers" of Formula I, $(F^1)_a-(X^2)_b$ can be made, since the half-life extending moiety, F^1 , employed for conjugation to the fusion protein can be multivalent (e.g., bivalent, trivalent, tetravalent or a higher order valency), as to the number of amino acid residues at which the half-life extending moiety can be conjugated. In some embodiments the peptide portion of the inventive composition of matter can be multivalent (e.g., bivalent, trivalent, tetravalent or a higher order valency), and, thus, some "multimers" of the inventive composition may have more than one F^1 . Consequently, it is possible by the inventive method of producing a composition of matter to produce a variety of conjugated half-life extending moiety:peptide structures. By way of example, a univalent half-life extending moiety and a univalent peptide will produce a 1:1 conjugate; a bivalent peptide and a univalent half-life extending moiety may form conjugates wherein the peptide conjugates bear two half-life extending moiety moieties, whereas a bivalent half-life extending moiety and a univalent peptide may produce species where two peptide entities are linked to a single half-life extending moiety; use of higher-valence half-life extending moiety can lead to the formation of clusters of peptide entities bound to a single half-life extending moiety, whereas higher-valence peptides may become encrusted with a plurality of half-life extending moiety moieties. By way of further example, if the site of conjugation of a multivalent half-life extending moiety to the fusion protein is a cysteine or other aminothiols the methods disclosed by D'Amico et al. may be employed (US Serial No. 60/646,685, Method of conjugating aminothiols containing molecules to water-soluble polymers).

[00158] The peptide moieties may have more than one reactive group which will react with the activated half-life extending moiety and the possibility of forming complex structures must always be considered; when it is desired to form simple structures such as 1:1 adducts of half-life extending moiety and peptide, or to use bivalent half-life extending moiety to form peptide:half-life extending moiety:peptide adducts, it will be beneficial to use predetermined ratios of activated half-life extending moiety and peptide material, predetermined concentrations thereof and to conduct the reaction under predetermined conditions (such as duration, temperature, pH, etc.) so as to form a proportion of the described product and then to separate the described product from the other reaction products. The reaction conditions, proportions and concentrations of the reagents can be obtained by relatively simple trial-and-error experiments

which are within the ability of an ordinarily skilled artisan with appropriate scaling-up as necessary. Purification and separation of the products is similarly achieved by conventional techniques well known to those skilled in the art.

[00159] Additionally, physiologically acceptable salts of the half-life extending moiety-conjugated or unconjugated fusion proteins of this invention are also encompassed within the present invention. By “physiologically acceptable salts” is meant any salts that are known or later discovered to be pharmaceutically acceptable. Some specific examples are: acetate; trifluoroacetate; hydrohalides, such as hydrochloride and hydrobromide; sulfate; citrate; maleate; tartrate; glycolate; gluconate; succinate; mesylate; besylate; pamoate, tannate, gallic acid ester, cholesteryl sulfate, and oxalate salts.

[00160] As an illustration, in some embodiments of the inventive composition of matter and/or the method of producing a composition of matter, the half-life extending moiety is poly(ethylene glycol) (PEG). Covalent conjugation of proteins with poly(ethylene glycol) (PEG) has been widely recognized as an approach to significantly extend the *in vivo* circulating half-lives of therapeutic proteins. PEGylation achieves this effect predominately by retarding renal clearance, since the PEG moiety adds considerable hydrodynamic radius to the protein. (Zalipsky, S., et al., Use of functionalized poly(ethylene glycol)s for modification of polypeptides., in poly(ethylene glycol) chemistry: Biotechnical and biomedical applications., J.M. Harris, Ed., Plenum Press: New York., 347-370 (1992)). Additional benefits often conferred by PEGylation of proteins include increased solubility, resistance to proteolytic degradation, and reduced immunogenicity of the therapeutic polypeptide. The merits of protein PEGylation are evidenced by the commercialization of several PEGylated proteins including PEG-Adenosine deaminase (AdagenTM/Enzon Corp.), PEG-L-asparaginase (OncasparTM/Enzon Corp.), PEG-Interferon α -2b (PEG-IntronTM/Schering/Enzon), PEG-Interferon α -2a (PEGASYSTM/Roche) and PEG-G-CSF (NeulastaTM/Amgen) as well as many others in clinical trials.

[00161] By “PEGylated peptide” or “PEGylated protein” is meant a peptide having a polyethylene glycol (PEG) moiety covalently bound to an amino acid residue of the peptide itself or to a peptidyl or non-peptidyl linker that is covalently bound to a residue of the peptide.

[00162] By “polyethylene glycol” or “PEG” is meant a polyalkylene glycol compound or a derivative thereof, with or without coupling agents or derivatization with coupling or activating moieties (e.g., with aldehyde, hydroxysuccinimidyl, hydrazide, thiol, triflate, tresylate, aziridine, oxirane, orthopyridyl disulphide, vinylsulfone, iodoacetamide or a maleimide moiety). In

accordance with the present invention, useful PEG includes substantially linear, straight chain PEG, branched PEG, or dendritic PEG. (See, e.g., Merrill, US Patent No. 5,171,264; Harris et al., Multiarmed, monofunctional, polymer for coupling to molecules and surfaces, US Patent No. 5,932,462; Shen, N-maleimidyl polymer derivatives, US Patent No. 6,602,498).

[00163] PEG is a well-known, water soluble polymer that is commercially available or can be prepared by ring-opening polymerization of ethylene glycol according to methods well known in the art (Sandler and Karo, Polymer Synthesis, Academic Press, New York, Vol. 3, pages 138-161). In the present application, the term "PEG" is used broadly to encompass any polyethylene glycol molecule, in mono-, bi-, or poly- functional form, without regard to size or to modification at an end of the PEG, and can be represented by the formula:



where n is 20 to 2300 and X is H or a terminal modification, e.g., a C₁₋₄ alkyl.

[00165] In some useful embodiments, a PEG used in the invention terminates on one end with hydroxy or methoxy, i.e., X is H or CH₃ ("methoxy PEG"). It is noted that the other end of the PEG, which is shown in formula (II) terminating in OH, covalently attaches to an activating moiety via an ether oxygen bond, an amine linkage, or amide linkage. When used in a chemical structure, the term "PEG" includes the formula (II) above without the hydrogen of the hydroxyl group shown, leaving the oxygen available to react with a free carbon atom of a linker to form an ether bond. More specifically, in order to conjugate PEG to a peptide, the peptide must be reacted with PEG in an "activated" form. Activated PEG can be represented by the formula:



where PEG (defined *supra*) covalently attaches to a carbon atom of the activation moiety (A) to form an ether bond, an amine linkage, or amide linkage, and (A) contains a reactive group which can react with an amino, imino, or thiol group on an amino acid residue of a peptide or a linker moiety covalently attached to the peptide.

[00167] Techniques for the preparation of activated PEG and its conjugation to biologically active peptides are well known in the art. (E.g., see U.S. Pat. Nos. 5,643,575, 5,919,455, 5,932,462, and 5,990,237; Thompson et al., PEGylation of polypeptides, EP 0575545 B1; Petit, Site specific protein modification, US Patent Nos. 6,451,986, and 6,548,644; S. Herman et al., Poly(ethylene glycol) with reactive endgroups: I. Modification of proteins, J. Bioactive Compatible Polymers, 10:145-187 (1995); Y. Lu et al., Pegylated peptides III: Solid-phase synthesis with PEGylating reagents of varying molecular weight: synthesis of multiply PEGylated peptides, Reactive Polymers, 22:221-229 (1994); A.M. Felix et al., PEGylated

Peptides IV: Enhanced biological activity of site-directed PEGylated GRF analogs, *Int. J. Peptide Protein Res.*, 46:253-264 (1995); A.M. Felix, Site-specific poly(ethylene glycol)ylation of peptides, *ACS Symposium Series 680*(poly(ethylene glycol)): 218-238 (1997); Y. Ikeda et al., Polyethylene glycol derivatives, their modified peptides, methods for producing them and use of the modified peptides, EP 0473084 B1; G.E. Means et al., Selected techniques for the modification of protein side chains, in: *Chemical modification of proteins*, Holden Day, Inc., 219 (1971)).

[00168] Activated PEG, such as PEG-aldehydes or PEG-aldehyde hydrates, can be chemically synthesized by known means or obtained from commercial sources, e.g., Shearwater Polymers, (Huntsville, Al) or Enzon, Inc. (Piscataway, N.J.).

[00169] An example of a useful activated PEG for purposes of the present invention is a PEG-aldehyde compound (e.g., a methoxy PEG-aldehyde), such as PEG-propionaldehyde, which is commercially available from Shearwater Polymers (Huntsville, Al). PEG-propionaldehyde is represented by the formula $\text{PEG-CH}_2\text{CH}_2\text{CHO}$. (See, e.g., U.S. Pat. No. 5,252,714). Also included within the meaning of "PEG aldehyde compound" are PEG aldehyde hydrates, e.g., PEG acetaldehyde hydrate and PEG bis aldehyde hydrate, which latter yields a bifunctionally activated structure. (See., e.g., Bentley et al., Poly(ethylene glycol) aldehyde hydrates and related polymers and applications in modifying amines, US Patent No. 5,990,237) (See., e.g., Bentley et al., Poly(ethylene glycol) aldehyde hydrates and related polymers and applications in modifying amines, US Patent No. 5,990,237). An activated multi-branched PEG-aldehyde compound can be used (PEG derivatives comprising multiple arms to give divalent, trivalent,, tetravalent, octavalent constructs). Using a 4-arm PEG derivative four (4) fusion proteins are attached to each PEG molecule. For example, in accordance with the present invention, the recombinant fusion protein can be conjugated to a polyethylene glycol (PEG) at 1, 2, 3 or 4 amino functionalized sites of the PEG.

[00170] In being conjugated in accordance with the inventive method, the polyethylene glycol (PEG), as described herein, is covalently bound by reductive amination directly to at least one solvent-exposed free amine moiety of an amino acid residue of the fusion protein itself. In some embodiments of the inventive method, the fusion protein is conjugated to a PEG at one or more primary or secondary amines on the recombinant fusion protein, or to two PEG groups at a single primary amine site on the fusion protein (e.g., this can occur when the reductive amination reaction involves the presence of excess PEG-aldehyde compound). We have observed that when PEGylation by reductive amination is at a primary amine on the peptide, it is not

uncommon to have amounts (1 to 100% range) of reaction product that have two or more PEGs present per molecule, and if the desired PEGylation product is one with only one PEG per molecule, then this "over-PEGylation" may be undesirable. When PEGylated product with a single PEG per PEGylation product molecule is desired, an embodiment of the inventive method can be employed that involves PEGylation using secondary amines of the pharmacologically active peptide, because only one PEG group per molecule will be transferred in the reductive amination reaction.

[00171] Amino acid residues that can provide a primary amine moiety include residues of lysine, homolysine, ornithine, α , β -diaminopropionic acid (Dap), α , β -diaminopropionic acid (Dpr), and α , γ -diaminobutyric acid (Dab), aminobutyric acid (Abu), and α -amino-isobutyric acid (Aib). The polypeptide N-terminus also provides a useful α -amino group for PEGylation. Amino acid residues that can provide a secondary amine moiety include ϵ -N-alkyl lysine, α -N-alkyl lysine, δ -N-alkyl ornithine, α -N-alkyl ornithine, or an N-terminal proline, where the alkyl is C_1 to C_6 .

[00172] Another useful activated PEG for generating the PEGylated recombinant fusion proteins of the present invention is a PEG-maleimide compound, such as, but not limited to, a methoxy PEG-maleimide, such as maleimido monomethoxy PEG, are particularly useful for generating the PEG-conjugated peptides of the invention. (E.g., Shen, *N*-maleimidyl polymer derivatives, US Patent No. 6,602,498; C. Delgado et al., The uses and properties of PEG-linked proteins., Crit. Rev. Therap. Drug Carrier Systems, 9:249-304 (1992); S. Zalipsky et al., Use of functionalized poly(ethylene glycol)s for modification of polypeptides, in: Poly(ethylene glycol) chemistry: Biotechnical and biomedical applications (J.M. Harris, Editor, Plenum Press: New York, 347-370 (1992); S. Herman et al., Poly(ethylene glycol) with reactive endgroups: I. Modification of proteins, J. Bioactive Compatible Polymers, 10:145-187 (1995); P.J. Shadle et al., Conjugation of polymer to colony stimulating factor-1, U.S. Patent No. 4,847,325; G. Shaw et al., Cysteine added variants IL-3 and chemical modifications thereof, U.S. Patent No. 5,166,322 and EP 0469074 B1; G. Shaw et al., Cysteine added variants of EPO and chemical modifications thereof, EP 0668353 A1; G. Shaw et al., Cysteine added variants G-CSF and chemical modifications thereof, EP 0668354 A1; N.V. Katre et al., Interleukin-2 muteins and polymer conjugation thereof, U.S. Patent No. 5,206,344; R.J. Goodson and N.V. Katre, Site-directed pegylation of recombinant interleukin-2 at its glycosylation site, Biotechnology, 8:343-346 (1990)).

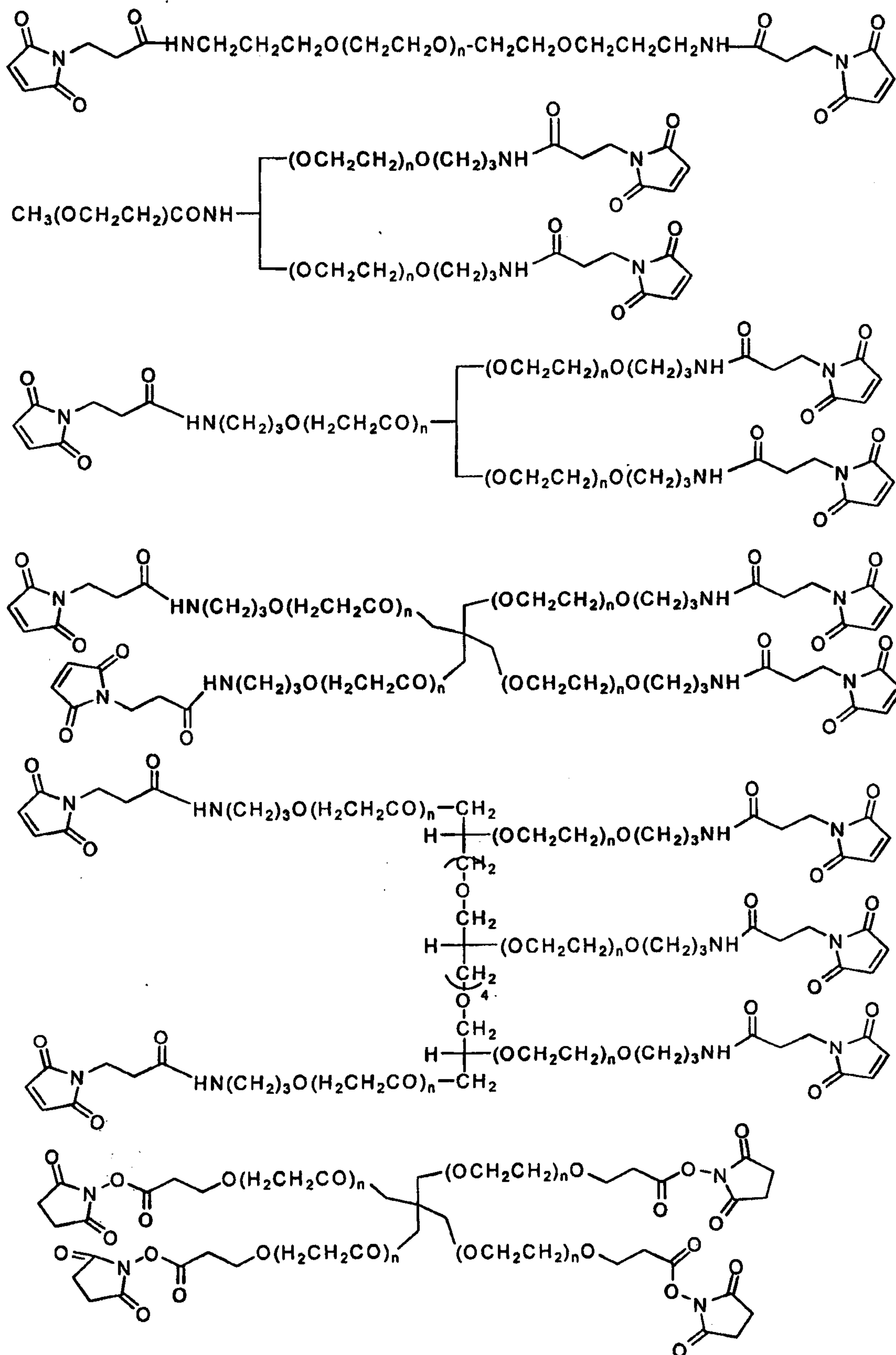
[00173] A poly(ethylene glycol) vinyl sulfone is another useful activated PEG for generating the PEG-conjugated fusion proteins of the present invention by conjugation at thiolated amino acid residues, e.g., at C residues. (E.g., M. Morpurgo et al., Preparation and characterization of poly(ethylene glycol) vinyl sulfone, *Bioconj. Chem.*, 7:363-368 (1996); see also Harris, Functionalization of polyethylene glycol for formation of active sulfone-terminated PEG derivatives for binding to proteins and biologically compatible materials, U.S. Patent Nos. 5,446,090; 5,739,208; 5,900,461; 6,610,281 and 6,894,025; and Harris, Water soluble active sulfones of poly(ethylene glycol), WO 95/13312 A1).

[00174] Another activated form of PEG that is useful in accordance with the present invention, is a PEG-N-hydroxysuccinimide ester compound, for example, methoxy PEG-N-hydroxysuccinimidyl (NHS) ester.

[00175] Heterobifunctionally activated forms of PEG are also useful. (See, e.g., Thompson et al., PEGylation reagents and biologically active compounds formed therewith, U.S. Patent No. 6,552,170).

[00176] In still other embodiments of the inventive method of producing a composition of matter, the recombinant fusion protein is reacted by known chemical techniques with an activated PEG compound, such as but not limited to, a thiol-activated PEG compound, a diol-activated PEG compound, a PEG-hydrazide compound, a PEG-oxyamine compound, or a PEG-bromoacetyl compound. (See, e.g., S. Herman, Poly(ethylene glycol) with Reactive Endgroups: I. Modification of Proteins, *J. Bioactive and Compatible Polymers*, 10:145-187 (1995); S. Zalipsky, Chemistry of Polyethylene Glycol Conjugates with Biologically Active Molecules, *Advanced Drug Delivery Reviews*, 16:157-182 (1995); R. Greenwald et al., Poly(ethylene glycol) conjugated drugs and prodrugs: a comprehensive review, *Critical Reviews in Therapeutic Drug Carrier Systems*, 17:101-161 (2000)).

[00177] An even more preferred activated PEG for generating the PEG-conjugated fusion proteins of the present invention is a multivalent PEG having more than one activated residues. Preferred multivalent PEG moieties include, but are not limited to, those shown below:



[00178] The smallest practical size of PEG is about 500 Daltons (Da), below which PEG becomes toxic. Above about 500 Da, any molecular mass for a PEG can be used as practically desired, e.g., from about 1,000 Daltons (Da) to 100,000 Da (n is 20 to 2300). The number of PEG monomers (n) is approximated from the average molecular mass using a $MW = 44Da$ for each monomer. It is preferred that the combined molecular mass of PEG on an activated linker is suitable for pharmaceutical use. Thus, the combined molecular mass of the PEG molecule should not exceed about 100,000 Da.

[00179] In still other embodiments of the inventive method of producing a composition of matter, the inventive recombinant fusion protein is reacted by known chemical techniques with an activated multi-branched PEG compound (PEG derivatives comprising multiple arms to give divalent, trivalent,, tetravalent, octavalent constructs), such as but not limited to, pentaerythritol tetra-polyethyleneglycol ether. Functionalization and activated derivatives, such as, but not limited to, N-succinimidylloxycarbonyl)propyl, p-nitrophenyloxycarbonyl, ($—CO_2-p-C_6H_4NO_2$), 3-(N-maleimido)propanamido, 2-sulfanylethyl, and 3-aminopropyl. Using a 4-arm PEG derivative, four recombinant fusion proteins are attached to each PEG molecule. For example, in accordance with the present invention, the fusion protein can be conjugated to a polyethylene glycol (PEG) at:

- (a) 1, 2, 3 or 4 amino functionalized sites of the PEG;
- (b) 1, 2, 3 or 4 thiol functionalized sites of the PEG;
- (c) 1, 2, 3 or 4 maleimido functionalized sites of the PEG;
- (d) 1, 2, 3 or 4 N-succinimidyl functionalized sites of the PEG;
- (e) 1, 2, 3 or 4 carboxyl functionalized sites of the PEG; or
- (f) 1, 2, 3 or 4 *p*-nitrophenyloxycarbonyl functionalized sites of the PEG.

[00180] Preferably, the combined or total average molecular mass of PEG used in a PEG-conjugated recombinant fusion protein of the present invention is from about 3,000 Da to 60,000 Da (total n is from 70 to 1,400), more preferably from about 10,000 Da to 40,000 Da (total n is about 230 to about 910). The most preferred combined mass for PEG is from about 20,000 Da to 30,000 Da (total n is about 450 to about 680).

[00181] Uses of the inventive compounds

[00182] In general. The fusion protein compounds of this invention have pharmacologic activity resulting from their ability to bind to proteins of interest as agonists, mimetics or antagonists of the native ligands of such proteins of interest. The activity of these compounds can be measured by assays known in the art.

[00183] In addition to therapeutic uses, the compounds of the present invention are useful in diagnosing diseases characterized by dysfunction of their associated protein of interest. For some of these diagnostic embodiments and for other detection (including semi-quantitative and quantitative) purposes, covalent conjugation of the active fusion protein to an immobilized substrate as an additional functional moiety, such as but not limited to, a plate surface, a chip, a bead, a matrix or a particle, can be useful. Also a moiety detectably labeled with a radioisotope, an enzyme (e.g., a peroxidase or a kinase), a biotinyl moiety, a fluorophore, or a chromophore can be useful for such purposes.

[00184] In one embodiment, a method of detecting in a biological sample a protein of interest (e.g., a receptor) that is capable of being activated comprising the steps of: (a) contacting the sample with a compound of this invention; and (b) detecting activation of the protein of interest by the compound. The biological samples include tissue specimens, intact cells, or extracts thereof. The compounds of this invention may be used as part of a kit to detect the presence of their associated proteins of interest in a biological sample. Such kits employ the compounds of the invention having an attached label to allow for detection. The compounds are useful for identifying normal or abnormal proteins of interest. For the EPO-mimetic compounds, for example, presence of abnormal protein of interest in a biological sample may be indicative of such disorders as Diamond Blackfan anemia, where it is believed that the EPO receptor is dysfunctional.

[00185] In addition, embodiments of the compositions of matter of the present invention, including the fusion proteins and pharmaceutical compositions or medicaments containing them are also useful in treating, alleviating, preventing or mitigating symptoms of a wide variety of diseases, disorders, or medical conditions in a patient. "Alleviated" with respect to a symptom means to be lessened, lightened, diminished, softened, mitigated (i.e., made more mild or gentle), quieted, assuaged, abated, relieved, nullified, or allayed, regardless of whether the symptom is entirely erased, eradicated, eliminated, or prevented in a particular patient.

[00186] Therapeutic uses of CGRP antagonist molecules

[00187] The CGRP antagonist compounds of the invention are useful for treating migraine, and preventing or mitigating migraine and are of benefit in preventing, alleviating and/or mitigating symptoms of migraine. (See, e.g., Gegg et al., CGRP peptide antagonists and conjugates, WO 2007/048026 A2).

[00188] If desired, the therapeutic or prophylactic efficacy of CGRP antagonists may be tested preclinically, prior to clinical use in humans, using any appropriate animal model known to

those skilled in the art related to a particular condition of interest. (See, e.g., Wang and Wang, Animal and cellular models of chronic pain, *Advanced Drug Delivery Reviews* 55:949-965 (2003)). An appropriate animal model for migraine can be selected from numerous methods, as described, for example, in Bergerot et al., Review Article: Animal models of migraine: looking at the component parts of a complex disorder, *European Journal of Neuroscience* 24:1517-1534 (2006); and Akerman, S and Goadsby PJ, The role of dopamine in a model of trigeminovascular nociception, *Pharmacol. Exp. Ther.* 314(1):162-169 (2005).

[00189] A patient in need of treatment for migraine, or a patient who has previously experienced a migraine, are well-recognizable and/or diagnosed by the skilled practitioner, such as a physician, familiar with migraine and its symptoms.

[00190] There are several types of migraine, each with unique features or symptoms well known to those of skill in the art, but the present invention is not limited to any one type and can be useful in treating, alleviating, preventing or mitigating symptoms of any type of migraine. Classic migraine and common migraine are the two major varieties. Common migraine (without aura) is the most frequent type, accounting for about 80 - 85% of migraines. Unlike other headaches, migraines usually occur on one side of the head, although the side that is affected can shift with each new attack. Migraines are also often accompanied by symptoms of abnormal sensitivity to light and/or sound. The pain symptoms of a migraine headache are often described as an intense throbbing or pounding felt in the forehead/temple, ear/jaw or around the eyes. Although migraine pain usually appears on one side of the head, 30 - 40% of migraines occur on both sides. A migraine attack typically lasts about 4 to 72 hours. Migraine symptoms may also include speech difficulty, nausea, vomiting, confusion, weakness of an arm or leg and tingling of face or hands.

[00191] The basic difference between common and classic types of migraine is the appearance of an "aura." The aura is the occurrence of neurological symptoms 10 - 30 minutes before the classic migraine attack. During migraine aura, the migraineur may see flashing or shimmering lights, zigzag lines, geometric shapes, or may temporarily lose vision (e.g., hemianopsia), or experience blind spots called scotomas, experience speech disturbances, or experience other sensory phenomena, such as gustatory and/or olfactory hallucinations. Other symptoms of migraine aura may include numbness, tingling, speech difficulties and muscle weakness on one side of the body.

[00192] Another type of migraine is basilar migraine, which is accompanied by transient brainstem signs thought to be due to vasospastic narrowing of the basilar artery. In basilar-type migraine, the migraine sufferer meets the general criteria for migraine with aura and has two or more of the following symptoms: dysarthria, vertigo, tinnitus, hypacusia, double vision (diplopia), bilateral visual symptoms, ataxia, perioral numbness, decreased level of consciousness, and/or simultaneously bilateral paraesthesias.

[00193] The above-described symptoms of migraine are merely illustrative and are not intended to be an exhaustive description of all possible migraine symptoms experienced by a single patient or by several migraine sufferers in composite, and to which the present invention is directed. Those skilled in the art are aware of various other migraine symptoms and constellations of migraine symptoms suffered by individual patients, and to those migraine symptoms are also directed the present inventive methods of treating migraine, or preventing or mitigating migraine.

[00194] In addition, CGRP antagonists can be useful in the treatment, amelioration, and prevention of sleep disorders, such as sleep apneas and other sleep-related breathing disorders. (e.g., Carley et al., Pharmacological treatments for sleep disorders, WO 2007/047577 A2).

[00195] Therapeutic uses of molecules comprising GLP-1 and GLP-2 and mimetics thereof

[00196] Glucagon is secreted from the α -cells of the pancreas in response to low blood sugar, with the main target organ for glucagon being the liver. Glucagon stimulates glycogen breakdown and inhibits glycogen biosynthesis. It also inhibits fatty acid synthesis, but enhances gluconeogenesis. The net result of these actions is to significantly increase the release of glucose to the liver. GLP-1, in contrast, lowers glucagon secretion, while stimulating insulin secretion, glucose uptake and cyclic-AMP (cAMP) formation in response to absorption of nutrients by the gut. Various clinical data provide evidence of these activities. The administration of GLP, for example, to poorly controlled type 2 diabetics normalized their fasting blood glucose levels (see, e.g., Gutniak, et al., 1992, *New Eng. J. Med.* 326:1316-1322).

[00197] GLP-1 has a number of other important activities. For instance, GLP-1 also inhibits gastric motility and gastric secretion (see, e.g., Tolessa, 1998, *J. Clin. Invest.* 102:764-774). This effect, sometimes referred to as the ileal brake effect, results in a lag phase in the availability of nutrients, thus significantly reducing the need for rapid insulin response.

[00198] Studies also indicate that GLP-1 can promote cell differentiation and replication, which in turn aids in the preservation of pancreatic islet cells and an increase in β -cell mass (See,

e.g., Andreasen *et al.*, 1994, *Digestion* 55:221-228; Wang, *et al.*, 1997, *J. Clin. Invest.* 99:2883-2889; Mojsov, 1992, *Int. J. Pep. Prot. Res.* 40:333-343; and Xu *et al.*, 1999, *Diabetes* 48:2270-2276). Evidence also indicates that GLP-1 can increase satiety and decrease food intake (see, e.g., Toft-Nielsen *et al.*, 1999, *Diabetes Care* 22:1137-1143; Flint *et al.*, 1998, *J. Clin. Invest.* 101:515-520; Gutzwiller *et al.*, 1999 *Gut* 44:81-86). Other research indicates that GLP-1 induces β -cell-specific genes, including GLUT-1 transporter, insulin receptor and hexokinase-1 (see, e.g., Perfetti and Merkel, 2000, *Eur. J. Endocrinol.* 143:717-725). Such induction could reverse glucose intolerance often associated with aging. Because it plays a key role in regulating metabolic homeostasis, GLP-1 is an attractive target for treating a variety of metabolic disorders, including diabetes, obesity and metabolic syndrome.

[00199] Glucagon-like peptide-1 (GLP-1) is a hormone that stimulates insulin secretion and simultaneously decreases glucagon secretion. The insulintropic effect is glucose dependent. Because GLP-1 stimulates insulin secretion primarily at elevated glucose levels, GLP-1 therapy of type 2 diabetes may present a low risk of hypoglycemia. GLP-1 can also decrease hepatic glucose production indirectly, delay gastric emptying, and suppress appetite in type 2 diabetic patients. This array of effects gives GLP-1 the potential to be an efficacious and safe glucose-lowering agent for type 2 diabetes. In addition, GLP-1 has been shown to stimulate the differentiation of islet progenitor cells into insulin-producing cells and may be important for β -cell neogenesis. Short-term (12-h) infusion of GLP-1 as well as 6-week continuous subcutaneous infusion of GLP-1 has been shown to significantly improve insulin secretion in type 2 diabetic patients. While the main target of action of GLP-1 is the islet, where the hormone stimulates insulin secretion, promotes beta cell proliferation and neogenesis, and inhibits glucagon secretion, GLP-1 receptors are also expressed outside the islets, increasing the likelihood that GLP-1 also plays a role in other organs. These functions are mainly the inhibition of gastric emptying, gastric acid secretion and exocrine pancreatic secretion, indicating that the hormone acts as an enterogastrone--a hormone released from the distal portion of the small intestine that inhibits proximal gastrointestinal events. Another important action of GLP-1 is to induce satiety. Other effects of the hormone include cardioprotection, neuroprotection, induction of learning and memory, stimulation of afferent, sensory nerves, stimulation of surfactant production in the lung, dilatation of pulmonary vessels, induction of diuresis, and also under some conditions, induction of antidiabetic actions unrelated to islet function. Thus, GLP-1 clearly has several manifestations of pharmacologic activity. (See, e.g., Vrang *et al.*, Characterization of brainstem preproglucagon projections to the paraventricular and dorsomedial

hypothalamic nuclei, Brain Res. 1149:118-26 (2007); Korner et al., GLP-1 receptor expression in human tumors and human normal tissues: potential for in vivo targeting, J. Nucl. Med. 48(5):736-43 (2007)).

[00200] Glucagonlike peptide-2 (GLP-2), a product of the posttranslational processing of proglucagon, has been shown to enhance mucosal mass and function in both normal intestine and in the residual intestine after massive small bowel resection. Activation of glucagon-like peptide-2 receptor (GLP-2R) signaling by GLP-2 and GLP-2 mimetic protein analogs promotes expansion of the mucosal epithelium indirectly via activation of growth and anti-apoptotic pathways. GLP-2 and GLP-2 (GLP-2 α)-mimetic analogs can enhance mucosal mass in small intestine after ischemia and reperfusion (I/R) injury. (See, e.g., Prasad et al., Glucagonlike peptide-2 analogue enhances intestinal mucosal mass after ischemia and reperfusion, J. Pediatr. Surg. 2000 Feb;35(2):357-59 (2000).

[00201] Therapeutic uses of bradykinin B1 receptor antagonist molecules

[00202] Bradykinin B1 receptor antagonist compounds of the present invention are useful in the treatment, amelioration and/or prevention of diseases, disorders, medical conditions and symptoms mediated by the B1 receptor, e.g., in the prevention or treatment of inflammation and chronic pain (including, but not limited to, inflammatory pain and associated hyperalgesia and allodynia). The fusion proteins and/or conjugated fusion proteins of the invention also have therapeutic value for the prevention or treatment of other painful conditions associated with or mediated by B1 activation, including, but not limited to, thalamic pain syndrome, diabetes, toxins and chemotherapy, septic shock, arthritis, mixed-vascular and non-vascular syndromes, general inflammation, arthritis, rheumatic diseases, lupus, osteoarthritis, inflammatory bowel disorders, inflammatory eye disorders, inflammatory or unstable bladder disorders, psoriasis, skin complaints with inflammatory components, sunburn, carditis, inflammatory bowel disease, dermatitis, myositis, neuritis, collagen vascular diseases, chronic inflammatory conditions, epithelial tissue damage or dysfunction, herpes simplex, diabetic neuropathy pain, post-herpetic neuralgia, causalgia, sympathetically maintained pain, , deafferentation syndromes, tension headache, angina, migraine, surgical pain, disturbances of visceral motility at respiratory, genitourinary, gastrointestinal or vascular regions, wounds, burns, allergic rhinitis, asthma, allergic skin reactions, pruritis, vitiligo, general gastrointestinal disorders, colitis, gastric ulceration, duodenal ulcers, or vasomotor or allergic rhinitis.

[00203] The invention also provides for the use of the inventive bradykinin B1 receptor antagonist fusion proteins and/or conjugated recombinant fusion proteins of the present

invention for the prevention or treatment of acute pain, dental pain, back pain, lower back pain, pain from trauma, surgical pain, pain resulting from amputation or abscess, causalgia, demyelinating diseases, trigeminal neuralgia, cancer, chronic alcoholism, stroke, thalamic pain syndrome, diabetes, acquired immune deficiency syndrome ("AIDS"), toxins and chemotherapy, general headache, migraine, cluster headache, mixed-vascular and non-vascular syndromes, tension headache, general inflammation, arthritis, rheumatic diseases, lupus, osteoarthritis, inflammatory bowel disorders, inflammatory eye disorders, inflammatory or unstable bladder disorders, psoriasis, skin complaints with inflammatory components, sunburn, carditis, dermatitis, myositis, neuritis, collagen vascular diseases, chronic inflammatory conditions, inflammatory pain and associated hyperalgesia and allodynia, neuropathic pain and associated hyperalgesia and allodynia, diabetic neuropathy pain, causalgia, sympathetically maintained pain, deafferentation syndromes, asthma, allergic rhinitis, epithelial tissue damage or dysfunction, herpes simplex, post-herpetic neuralgia, disturbances of visceral motility at respiratory, genitourinary, gastrointestinal or vascular regions, wounds, burns, allergic skin reactions, pruritis, vitiligo, general gastrointestinal disorders, colitis, gastric ulceration, duodenal ulcers, and bronchial disorders.

[00204] Therapeutic uses of PTH antagonist or agonist molecules. PTH agonist fusion proteins of this invention have pharmacologic activity resulting from their interaction with PTH-1 receptor or PTH-2 receptor. Mannstadt et al. (1999), Am. J. Physiol. 277. 5Pt 2. F665-75. PTH and agonists thereof increase bone resorption, increase renal calcium reabsorption, decrease epidermal proliferation, and decrease hair growth. Holick et al. (1994) Proc. Natl. Sci. USA 91 (17): 8014-6; Schilli et al. (1997), J. Invest. Dermatol. 108(6): 928-32. Thus, antagonists of PTH-1 receptor and/or PTH-2 receptor are useful in treating:

- primary and secondary hyperparathyroidism;
- hypercalcemia, including hypercalcemia resulting from solid tumors (breast, lung and kidney) and hematologic malignancies (multiple myeloma, lymphoma and leukemia); idiopathic hypercalcemia, and hypercalcemia associated with hyperthyroidism and renal function disorders; tumor metastases, particularly metastases to bone, and particularly related to breast and prostate cancer;
- cachexia and anorexia, particularly as associated with cancer;
- osteopenia that is related to or aggravated by aberrant PTH receptor signaling, including various forms of osteoporosis, such as:
- primary osteoporosis;

post-menopausal and age-related osteoporosis;
endocrine osteoporosis (hyperthyroidism, hyperparathyroidism, Cushing's syndrome, and acromegaly);
hereditary and congenital forms of osteoporosis (e.g., osteogenesis imperfecta, homocystinuria, Menkes' syndrome, and Riley-Day syndrome);
osteoporosis due to immobilization of extremities;
osteoporosis secondary to other disorders, such as hemochromatosis, hyperprolactinemia, anorexia nervosa, thyrotoxicosis, diabetes mellitus, celiac disease, inflammatory bowel disease, primary biliary cirrhosis, rheumatoid arthritis, ankylosing spondylitis, multiple myeloma, lymphoproliferative diseases, and systemic mastocytosis;
osteoporosis secondary to surgery (e.g., gastrectomy) or to drug therapy, such as chemotherapy, anticonvulsant therapy, immunosuppressive therapy, and anticoagulant therapy;
osteoporosis secondary to glucocorticosteroid treatment for such diseases as rheumatoid arthritis (RA), systemic lupus erythematosus (SLE), asthma, temporal arteritis, vasculitis, chronic obstructive pulmonary disease, polymyalgia rheumatica, polymyositis, chronic interstitial lung disease;
osteoporosis secondary to glucocorticosteroid and/or immunomodulatory treatment to prevent organ rejection following organ transplant such as kidney, liver, lung, heart transplants;
osteoporosis due to submission to microgravity, such as observed during space travel;
osteoporosis associated with malignant disease, such as breast cancer, prostate cancer;
Paget's disease of bone (osteitis deformans) in adults and juveniles;
osteomyelitis, or an infectious lesion in bone, leading to bone loss;
osteopenia following surgery, induced by steroid administration, and associated with disorders of the small and large intestine and with chronic hepatic and renal diseases.
Osteonecrosis, or bone cell death, associated with traumatic injury or nontraumatic necrosis associated with Gaucher's disease, sickle cell anemia, systemic lupus erythematosus, rheumatoid arthritis, periodontal disease, osteolytic metastasis, and other conditions;
alopecia (deficient hair growth or partial or complete hair loss), including androgenic alopecia (male pattern baldness), toxic alopecia, alopecia senilis, alopecia areata, alopecia pelada, and trichotillomania;
and the like.

[00205] There are other conditions wherein a patient would benefit from the activity of PTH or PTHrP. For those indications, PTH receptor agonists are useful as a therapeutic

treatment. In particular, such indications include fracture repair (including healing of non-union fractures), osteopenia, including various forms of osteoporosis, such as:

- primary osteoporosis;
- post-menopausal and age-related osteoporosis;
- endocrine osteoporosis (hyperthyroidism, Cushing's syndrome, and acromegaly);
- hereditary and congenital forms of osteoporosis (e.g., osteogenesis imperfecta, homocystinuria, Menkes' syndrome, and Riley-Day syndrome);
- osteoporosis due to immobilization of extremities;
- osteoporosis secondary to other disorders, such as hemochromatosis, hyperprolactinemia, anorexia nervosa, thyrotoxicosis, diabetes mellitus, celiac disease, inflammatory bowel disease, primary biliary cirrhosis, rheumatoid arthritis, ankylosing spondylitis, multiple myeloma, lymphoproliferative diseases, and systemic mastocytosis;
- osteoporosis secondary to surgery (e.g., gastrectomy) or to drug therapy, such as chemotherapy, anticonvulsant therapy, immunosuppressive therapy, and anticoagulant therapy;
- osteoporosis secondary to glucocorticosteroid treatment for diseases such as RA, SLE, asthma, temporal arteritis, vasculitis, chronic obstructive pulmonary disease, polymyalgia rheumatica, polymyositis, chronic interstitial lung disease;
- osteoporosis secondary to glucocorticosteroid and/or immunomodulatory treatment to prevent organ rejection following organ transplant such as kidney, liver, lung, heart transplants;
- osteoporosis due to submission to microgravity, such as observed during space travel;
- osteoporosis associated with malignant disease, such as breast cancer, prostate cancer;

PTH agonists with extended half-life (e.g., those linked to Fc domains) may be used with an inhibitor of bone resorption. Inhibitors of bone resorption include OPG and OPG derivatives, OPG-L (RANKL) antibody, calcitonin (e.g., Miacalcin®, Calcimar®), bisphosphonates (e.g., APD, alendronate, risedronate, etidronate, pamidronate, tiludronate, clodronate, neridronate, ibandronate, zoledronate), estrogens (e.g., Premarin®, Estraderm®, Prempro®, Alora®, Climara®, Vivelle®, Estratab®, Ogen®), selective estrogen receptor modulators (e.g., raloxifene, droloxifene, lasofoxifene), tibolone, and the like. Exemplary bone resorption inhibitors are described in WO98/46751 and WO97/23614.

[00206] Therapeutic uses of EPO-mimetic molecules

[00207] The EPO-mimetic compounds of the invention are useful for treating disorders characterized by low red blood cell levels. Included in the invention are methods of modulating

the endogenous activity of an EPO receptor in a mammal, preferably methods of increasing the activity of an EPO receptor. In general, any condition treatable by erythropoietin, such as anemia, may also be treated by the EPO-mimetic compounds of the invention. These compounds are administered by an amount and route of delivery that is appropriate for the nature and severity of the condition being treated and may be ascertained by one skilled in the art. Preferably, administration is by injection, either subcutaneous, intramuscular, or intravenous.

[00208] Therapeutic uses of TPO-mimetic compounds

[00209] For the TPO-mimetic compounds, one can utilize such standard assays as those described in WO95/26746 entitled "Compositions and Methods for Stimulating Megakaryocyte Growth and Differentiation." The conditions to be treated are generally those that involve an existing megakaryocyte/platelet deficiency or an expected megakaryocyte/platelet deficiency (e.g., because of planned surgery or platelet donation). Such conditions will usually be the result of a deficiency (temporary or permanent) of active Mpl ligand in vivo. The generic term for platelet deficiency is thrombocytopenia, and hence the methods and compositions of the present invention are generally available for treating thrombocytopenia in patients in need thereof.

[00210] Thrombocytopenia (platelet deficiencies) may be present for various reasons, including chemotherapy and other therapy with a variety of drugs, radiation therapy, surgery, accidental blood loss, and other specific disease conditions. Exemplary specific disease conditions that involve thrombocytopenia and may be treated in accordance with this invention are: aplastic anemia, idiopathic thrombocytopenia, metastatic tumors which result in thrombocytopenia, systemic lupus erythematosus, splenomegaly, Fanconi's syndrome, vitamin B12 deficiency, folic acid deficiency, May-Hegglin anomaly, Wiskott-Aldrich syndrome, and paroxysmal nocturnal hemoglobinuria. Also, certain treatments for AIDS result in thrombocytopenia (e.g., AZT). Certain wound healing disorders might also benefit from an increase in platelet numbers.

[00211] With regard to anticipated platelet deficiencies, e.g., due to future surgery, a compound of the present invention could be administered several days to several hours prior to the need for platelets. With regard to acute situations, e.g., accidental and massive blood loss, a compound of this invention could be administered along with blood or purified platelets.

[00212] The TPO-mimetic compounds of this invention may also be useful in stimulating certain cell types other than megakaryocytes if such cells are found to express Mpl receptor. Conditions associated with such cells that express the Mpl receptor, which are responsive to stimulation by the Mpl ligand, are also within the scope of this invention.

[00213] The TPO-mimetic compounds of this invention may be used in any situation in which production of platelets or platelet precursor cells is desired, or in which stimulation of the c-Mpl receptor is desired. Thus, for example, the compounds of this invention may be used to treat any condition in a mammal wherein there is a need of platelets, megakaryocytes, and the like. Such conditions are described in detail in the following exemplary sources: WO95/26746; WO95/21919; WO95/18858; WO95/21920.

[00214] The TPO-mimetic compounds of this invention may also be useful in maintaining the viability or storage life of platelets and/or megakaryocytes and related cells. Accordingly, it could be useful to include an effective amount of one or more such compounds in a composition containing such cells.

[00215] Therapeutic uses of Ang-2 binding molecules

[00216] Agents that modulate Ang-2 binding activity, or other cellular activity, may be used in combination with other therapeutic agents to enhance their therapeutic effects or decrease potential side effects.

[00217] In one aspect, the present invention provides reagents and methods useful for treating diseases and conditions characterized by undesirable or aberrant levels of Ang-2 activity in a cell. These diseases include cancers, and other hyperproliferative conditions, such as hyperplasia, psoriasis, contact dermatitis, immunological disorders, and infertility.

[00218] The present invention also provides methods of treating cancer in an animal, including humans, comprising administering to the animal an effective amount of a specific binding agent, such as a peptibody, that inhibits or decreases Ang-2 activity. The invention is further directed to methods of inhibiting cancer cell growth, including processes of cellular proliferation, invasiveness, and metastasis in biological systems. Methods include use of a compound of the invention as an inhibitor of cancer cell growth. Preferably, the methods are employed to inhibit or reduce cancer cell growth, invasiveness, metastasis, or tumor incidence in living animals, such as mammals. Methods of the invention are also readily adaptable for use in assay systems, e.g., assaying cancer cell growth and properties thereof, as well as identifying compounds that affect cancer cell growth.

[00219] The cancers treatable by methods of the present invention preferably occur in mammals. Mammals include, for example, humans and other primates, as well as pet or companion animals such as dogs and cats, laboratory animals such as rats, mice and rabbits, and farm animals such as horses, pigs, sheep, and cattle.

[00220] Tumors or neoplasms include growths of tissue cells in which the multiplication of the cells is uncontrolled and progressive. Some such growths are benign, but others are termed malignant and may lead to death of the organism. Malignant neoplasms or cancers are distinguished from benign growths in that, in addition to exhibiting aggressive cellular proliferation, they may invade surrounding tissues and metastasize. Moreover, malignant neoplasms are characterized in that they show a greater loss of differentiation (greater dedifferentiation), and of their organization relative to one another and their surrounding tissues. This property is also called "anaplasia."

[00221] Neoplasms treatable by the present invention also include solid tumors, i.e., carcinomas and sarcomas. Carcinomas include those malignant neoplasms derived from epithelial cells that infiltrate (invade) the surrounding tissues and give rise to metastases. Adenocarcinomas are carcinomas derived from glandular tissue, or which form recognizable glandular structures. Another broad category of cancers includes sarcomas, which are tumors whose cells are embedded in a fibrillar or homogeneous substance like embryonic connective tissue. The invention also enables treatment of cancers of the myeloid or lymphoid systems, including leukemias, lymphomas and other cancers that typically do not present as a tumor mass, but are distributed in the vascular or lymphoreticular systems.

[00222] The ang-2 binding molecules of this invention are thus useful for the treatment of a wide variety of cancers, including solid tumors and leukemias. Types of cancer or tumor cells amenable to treatment according to the invention include, for example, ACTH-producing tumor; acute lymphocytic leukemia; acute nonlymphocytic leukemia; adenoma; cancer of the adrenal cortex; adenocarcinoma of the breast, prostate, and colon; ameloblastoma; apudoma; bladder cancer; brain cancer; branchioma; breast cancer; all forms of bronchogenic carcinoma of the lung; carcinoid heart disease; carcinoma (e.g., Walker, basal cell, basosquamous, Brown-Pearce, ductal, Ehrlich tumor, Krebs 2, merkel cell, mucinous, non-small cell lung, oat cell, papillary, scirrhous, bronchiolar, bronchogenic, squamous cell, and transitional cell); malignant carcinoid syndrome; immunoproliferative small lung cell carcinoma; cementoma; cervical cancer; chondroblastoma; chondroma; chondrosarcoma; choristoma; chronic lymphocytic leukemia; chronic myelocytic leukemia; colorectal cancer; chordoma; craniopharyngioma; cutaneous T-cell lymphoma; dysgerminoma; endometrial cancer; esophageal cancer; Ewing's sarcoma; fibroma; fibrosarcoma; gallbladder cancer; giant cell tumors; glioma; hairy cell leukemia; hamartoma; head and neck cancer; hepatoma; histiocytic disorders; histiocytosis; Hodgkin's lymphoma; Kaposi's sarcoma; kidney cancer; lipoma; liposarcoma; liver cancer; lung cancer

(small and non-small cell); malignant peritoneal effusion; malignant pleural effusion; melanoma; mesenchymoma; mesonephroma; mesothelioma; multiple myeloma; myosarcoma; myxoma; myxosarcoma; neuroblastoma; non-Hodgkin's lymphoma; odontoma; osteoma; osteosarcoma; ovarian cancer; ovarian (germ cell) cancer; pancreatic cancer; papilloma; penile cancer; plasmacytoma; prostate cancer; reticuloendotheliosis; retinoblastoma; skin cancer; soft tissue sarcoma; squamous cell carcinomas; stomach cancer; teratoma; testicular cancer; thymoma; thyroid cancer; trophoblastic neoplasms; uterine cancer; vaginal cancer; cancer of the vulva; Wilms' tumor.

[00223] Further, the following types of cancers may also be treated: cholangioma; cholesteatoma; cyclindroma; cystadenocarcinoma; cystadenoma; granulosa cell tumor; gynandroblastoma; hidradenoma; islet cell tumor; Leydig cell tumor; papilloma; Sertoli cell tumor; theca cell tumor; leiomyoma; leiomyosarcoma; myoblastoma; myoma; myosarcoma; rhabdomyoma; rhabdomyosarcoma; ependymoma; ganglioneuroma; glioma; medulloblastoma; meningioma; neurilemmoma; neuroblastoma; neuroepithelioma; neurofibroma; neuroma; paraganglioma; paraganglioma nonchromaffin; angiokeratoma; angiolymphoid hyperplasia with eosinophilia; angioma sclerosing; angiomatosis; glomangioma; hemangioendothelioma; hemangioma; hemangiopericytoma; hemangiosarcoma; lymphangioma; lymphangiomyoma; lymphangiosarcoma; pinealoma; carcinosarcoma; chondrosarcoma; cystosarcoma phyllodes; fibrosarcoma; hemangiosarcoma; leiomyosarcoma; leukosarcoma; liposarcoma; lymphangiosarcoma; myosarcoma; myxosarcoma; ovarian carcinoma; rhabdomyosarcoma; sarcoma; neoplasms; neurofibromatosis; and cervical dysplasia.

[00224] Therapeutic uses of NGF binding molecules

[00225] The NGF binding molecules may be used in the prevention or treatment of NGF-related diseases and disorders. Such indications include but are not limited to pain (including, but not limited to, inflammatory pain and associated hyperalgesia and allodynia, neuropathic pain and associated hyperalgesia and allodynia, diabetic neuropathy pain, causalgia, sympathetically maintained pain, deafferentation syndromes, acute pain, tension headache, migraine, dental pain, pain from trauma, surgical pain, pain resulting from amputation or abscess, causalgia, demyelinating diseases, and trigeminal neuralgia). The peptides and modified peptides of the invention have therapeutic value for the prevention or treatment of other diseases linked to NGF as a causative agent, including, but not limited to, asthma, urge incontinence (i.e., hyperactive bladder), psoriasis, cancer (especially, pancreatic cancer and melanoma), chronic alcoholism, stroke, thalamic pain syndrome, diabetes, acquired immune deficiency syndrome ("AIDS"),

toxins and chemotherapy, general headache, migraine, cluster headache, mixed-vascular and non-vascular syndromes, general inflammation, arthritis, rheumatic diseases, lupus, osteoarthritis, inflammatory bowel disorders, inflammatory eye disorders, inflammatory or unstable bladder disorders, psoriasis, skin complaints with inflammatory components, sunburn, carditis, dermatitis, myositis, neuritis, collagen vascular diseases, chronic inflammatory conditions, asthma, epithelial tissue damage or dysfunction, herpes simplex, disturbances of visceral motility at respiratory, genitourinary, gastrointestinal or vascular regions, wounds, burns, allergic skin reactions, pruritis, vitiligo, general gastrointestinal disorders, colitis, gastric ulceration, duodenal ulcers, vasomotor or allergic rhinitis, or bronchial disorders.

[00226] Therapeutic uses of myostatin binding molecules

[00227] The myostatin binding agents of the present invention bind to myostatin and block or inhibit myostatin signaling within targeted cells. The present invention provides methods and reagents for reducing the amount or activity of myostatin in an animal by administering an effective dosage of one or more myostatin binding agents to the animal. In one aspect, the present invention provides methods and reagents for treating myostatin-related disorders in an animal comprising administering an effective dosage of one or more binding agents to the animal. These myostatin-related disorders include but are not limited to various forms of muscle wasting, as well as metabolic disorders such as diabetes and related disorders, and bone degenerative diseases such as osteoporosis.

[00228] Muscle wasting disorders include dystrophies such as Duchenne's muscular dystrophy, progressive muscular dystrophy, Becker's type muscular dystrophy, Dejerine-Landouzy muscular dystrophy, Erb's muscular dystrophy, and infantile neuroaxonal muscular dystrophy. For example, blocking myostatin through use of antibodies in vivo improved the dystrophic phenotype of the mdx mouse model of Duchenne muscular dystrophy (Bogdanovich et al. (2002), Nature 420: 28).

[00229] Additional muscle wasting disorders arise from chronic disease such as amyotrophic lateral sclerosis, congestive obstructive pulmonary disease, cancer, AIDS, renal failure, and rheumatoid arthritis. For example, cachexia or muscle wasting and loss of body weight was induced in athymic nude mice by a systemically administered myostatin (Zimmers et al., supra). In another example, serum and intramuscular concentrations of myostatin-immunoreactive protein was found to be increased in men exhibiting AIDS-related muscle wasting and was inversely related to fat-free mass (Gonzalez-Cadavid et al. (1998), PNAS USA 95: 14938-14943). Additional conditions resulting in muscle wasting may arise from inactivity

due to disability such as confinement in a wheelchair, prolonged bedrest due to stroke, illness, bone fracture or trauma, and muscular atrophy in a microgravity environment (space flight). For example, plasma myostatin immunoreactive protein was found to increase after prolonged bedrest (Zachwieja et al. J Gravit Physiol. 6(2):11(1999). It was also found that the muscles of rats exposed to a microgravity environment during a space shuttle flight expressed an increased amount of myostatin compared with the muscles of rats which were not exposed (Lalani et al. (2000), J.Endocrin. 167(3):417-28).

[00230] In addition, age-related increases in fat to muscle ratios, and age-related muscular atrophy appear to be related to myostatin. For example, the average serum myostatin-immunoreactive protein increased with age in groups of young (19-35 yr old), middle-aged (36-75 yr old), and elderly (76-92 yr old) men and women, while the average muscle mass and fat-free mass declined with age in these groups (Yarasheski et al. J Nutr Aging 6(5):343-8 (2002)). It has also been shown that myostatin gene knockout in mice increased myogenesis and decreased adipogenesis (Lin et al. (2002), Biochem Biophys Res Commun 291(3):701-6, resulting in adults with increased muscle mass and decreased fat accumulation and leptin secretion.

[00231] In addition, myostatin has now been found to be expressed at low levels in heart muscle and expression is upregulated after cardiomyocytes after infarct (Sharma et al. (1999), J Cell Physiol. 180(1):1-9). Therefore, reducing myostatin levels in the heart muscle may improve recovery of heart muscle after infarct.

[00232] Myostatin also appears to influence metabolic disorders including type 2 diabetes, noninsulin-dependent diabetes mellitus, hyperglycemia, and obesity. For example, lack of myostatin has been shown to improve the obese and diabetic phenotypes of two mouse models (Yen et al. supra). In addition, increasing muscle mass by reducing myostatin levels may improve bone strength and reduce osteoporosis and other degenerative bone diseases. It has been found, for example, that myostatin-deficient mice showed increased mineral content and density of the mouse humerus and increased mineral content of both trabecular and cortical bone at the regions where the muscles attach, as well as increased muscle mass (Hamrick et al. (2002), Calcif Tissue Int 71(1): 63-8).

[00233] The present invention also provides methods and reagents for increasing muscle mass in food animals by administering an effective dosage of the myostatin binding agent to the animal. Since the mature C-terminal myostatin polypeptide is identical in all species tested,

myostatin binding agents would be expected to be effective for increasing muscle mass and reducing fat in any agriculturally important species including cattle, chicken, turkeys, and pigs.

[00234] The myostatin-binding molecules of the present invention may be used alone or in combination with other therapeutic agents to enhance their therapeutic effects or decrease potential side effects. The molecules of the present invention possess one or more desirable but unexpected combination of properties to improve the therapeutic value of the agents. These properties include increased activity, increased solubility, reduced degradation, increased half-life, reduced toxicity, and reduced immunogenicity. Thus the molecules of the present invention are useful for extended treatment regimes. In addition, the properties of hydrophilicity and hydrophobicity of the compounds of the invention are well balanced, thereby enhancing their utility for both in vitro and especially in vivo uses. Specifically, compounds of the invention have an appropriate degree of solubility in aqueous media that permits absorption and bioavailability in the body, while also having a degree of solubility in lipids that permits the compounds to traverse the cell membrane to a putative site of action, such as a particular muscle mass.

[00235] The myostatin-binding molecules of the present invention are useful for treating a "subject" or any animal, including humans, when administered in an effective dosages in a suitable composition.

[00236] In addition, the myostatin-binding molecules of the present invention are useful for detecting and quantitating myostatin in a number of assays. These assays are described in detail in U.S. Ser. No. 10/742,379, filed December 19, 2003 (published as US 2004/0181033 A1).

[00237] In general, the myostatin-binding molecules of the present invention are useful as capture agents to bind and immobilize myostatin in a variety of assays, similar to those described, for example, in Asai, ed., Methods in Cell Biology, 37, Antibodies in Cell Biology, Academic Press, Inc., New York (1993). The myostatin-binding molecule may be labeled in some manner or may react with a third molecule such as an anti-binding molecule antibody which is labeled to enable myostatin to be detected and quantitated. For example, a myostatin-binding molecule or a third molecule can be modified with a detectable moiety, such as biotin, which can then be bound by a fourth molecule, such as enzyme-labeled streptavidin, or other proteins. (Akerstrom (1985), J Immunol 135:2589; Chaubert (1997), Mod Pathol 10:585).

[00238] Throughout any particular assay, incubation and/or washing steps may be required after each combination of reagents. Incubation steps can vary from about 5 seconds to several hours, preferably from about 5 minutes to about 24 hours. However, the incubation time will

depend upon the assay format, volume of solution, concentrations, and the like. Usually, the assays will be carried out at ambient temperature, although they can be conducted over a range of temperatures.

[00239] Therapeutic uses of BAFF-binding molecules. BAFF-binding molecules of this invention may be particularly useful in treatment of B-cell mediated autoimmune diseases. In particular, they may be useful in treating, preventing, ameliorating, diagnosing or prognosing lupus, including systemic lupus erythematosus (SLE), and lupus-associated diseases and conditions. Other preferred indications include B-cell mediated cancers, including B-cell lymphoma.

[00240] The compounds of this invention can also be used to treat inflammatory conditions of the joints. Inflammatory conditions of a joint are chronic joint diseases that afflict and disable, to varying degrees, millions of people worldwide. Rheumatoid arthritis is a disease of articular joints in which the cartilage and bone are slowly eroded away by a proliferative, invasive connective tissue called pannus, which is derived from the synovial membrane. The disease may involve peri-articular structures such as bursae, tendon sheaths and tendons as well as extra-articular tissues such as the subcutis, cardiovascular system, lungs, spleen, lymph nodes, skeletal muscles, nervous system (central and peripheral) and eyes (Silberberg (1985), Anderson's Pathology, Kissane (ed.), II:1828). Osteoarthritis is a common joint disease characterized by degenerative changes in articular cartilage and reactive proliferation of bone and cartilage around the joint. Osteoarthritis is a cell-mediated active process that may result from the inappropriate response of chondrocytes to catabolic and anabolic stimuli. Changes in some matrix molecules of articular cartilage reportedly occur in early osteoarthritis (Thonar *et al.* (1993), Rheumatic disease clinics of North America, Moskowitz (ed.), 19:635-657 and Shinmei *et al.* (1992), *Arthritis Rheum.*, 35:1304-1308). TALL-1, TALL-1R and modulators thereof are believed to be useful in the treatment of these and related conditions.

[00241] BAFF-binding molecules may also be useful in treatment of a number of additional diseases and disorders, including acute pancreatitis; ALS; Alzheimer's disease; asthma; atherosclerosis; autoimmune hemolytic anemia; cancer, particularly cancers related to B cells; cachexia/anorexia; chronic fatigue syndrome; cirrhosis (e.g., primary biliary cirrhosis); diabetes (e.g., insulin diabetes); fever; glomerulonephritis, including IgA glomerulonephritis and primary glomerulonephritis; Goodpasture's syndrome; Guillain-Barre syndrome; graft versus host disease; Hashimoto's thyroiditis; hemorrhagic shock; hyperalgesia; inflammatory bowel disease; inflammatory conditions of a joint, including osteoarthritis, psoriatic arthritis and

rheumatoid arthritis; inflammatory conditions resulting from strain, sprain, cartilage damage, trauma, orthopedic surgery, infection or other disease processes; insulin-dependent diabetes mellitus; ischemic injury, including cerebral ischemia (e.g., brain injury as a result of trauma, epilepsy, hemorrhage or stroke, each of which may lead to neurodegeneration); learning impairment; lung diseases (e.g., ARDS); lupus, particularly systemic lupus erythematosus (SLE); multiple myeloma; multiple sclerosis; Myasthenia gravis; myelogenous (e.g., AML and CML) and other leukemias; myopathies (e.g., muscle protein metabolism, esp. in sepsis); neurotoxicity (e.g., as induced by HIV); osteoporosis; pain; Parkinson's disease; Pemphigus; polymyositis/dermatomyositis; pulmonary inflammation, including autoimmune pulmonary inflammation; pre-term labor; psoriasis; Reiter's disease; reperfusion injury; septic shock; side effects from radiation therapy; Sjogren's syndrome; sleep disturbance; temporal mandibular joint disease; thrombocytopenia, including idiopathic thrombocytopenia and autoimmune neonatal thrombocytopenia; tumor metastasis; uveitis; and vasculitis.

[00242] Combination Therapy. The therapeutic methods, compositions and compounds of the present invention may also be employed, alone or in combination with other cytokines, soluble Mpl receptor, hematopoietic factors, interleukins, growth factors or antibodies in the treatment of disease states characterized by other symptoms as well as platelet deficiencies. It is anticipated that the inventive compound will prove useful in treating some forms of thrombocytopenia in combination with general stimulators of hematopoiesis, such as IL-3 or GM-CSF. Other megakaryocytic stimulatory factors, i.e., meg-CSF, stem cell factor (SCF), leukemia inhibitory factor (LIF), oncostatin M (OSM), or other molecules with megakaryocyte stimulating activity may also be employed with Mpl ligand. Additional exemplary cytokines or hematopoietic factors for such co-administration include IL-1 alpha, IL-1 beta, IL-2, IL-3, IL-4, IL-5, IL-6, IL-11, colony stimulating factor-1 (CSF-1), SCF, GM-CSF, granulocyte colony stimulating factor (G-CSF), EPO, interferon-alpha (IFN-alpha), consensus interferon, IFN-beta, or IFN-gamma. It may further be useful to administer, either simultaneously or sequentially, an effective amount of a soluble mammalian Mpl receptor, which appears to have an effect of causing megakaryocytes to fragment into platelets once the megakaryocytes have reached mature form. Thus, administration of an inventive compound (to enhance the number of mature megakaryocytes) followed by administration of the soluble Mpl receptor (to inactivate the ligand and allow the mature megakaryocytes to produce platelets) is expected to be a particularly effective means of stimulating platelet production. The dosage recited above would be adjusted

to compensate for such additional components in the therapeutic composition. Progress of the treated patient can be monitored by conventional methods.

[00243] In cases where the inventive compounds are added to compositions of platelets and/or megakaryocytes and related cells, the amount to be included will generally be ascertained experimentally by techniques and assays known in the art. An exemplary range of amounts is 0.1 μg —1 mg inventive compound per 10^6 cells.

[00244] Therapeutics incorporating toxin peptides.

[00245] Some embodiments of the inventive composition of matter incorporate toxin peptides as additional functional moieties, which toxin peptides can have pharmacologic activity resulting from the ability to bind to ion channels of interest as agonists, mimetics or antagonists of the native ligands of such ion channels of interest. Consequently such embodiments of the inventive composition of matter can have utility in the treatment of pathologies associated with ion channels. Heritable diseases that have a known linkage to ion channels ("channelopathies") cover various fields of medicine, some of which include neurology, nephrology, myology and cardiology. A list of inherited disorders attributed to ion channels (channel types in parentheses) includes:

cystic fibrosis (Cl^- channel; CFTR);

Dent's disease (proteinuria and hypercalciuria; Cl^- channel; CLCN5);

osteopetrosis (Cl^- channel; CLCN7); familial hyperinsulinemia (SUR1; KCNJ11; K channel);

diabetes (KATP / SUR channel);

Andersen syndrome (KCNJ2, Kir2.1 K channel);

Bartter syndrome (KCNJ1; Kir1.1/ROMK; K channel);

hereditary hearing loss (KCNQ4; K channel);

hereditary hypertension (Liddle's syndrome; SCNN1; epithelial Na channel);

dilated cardiomyopathy (SUR2, K channel);

long-QT syndrome or cardiac arrhythmias (cardiac potassium and sodium channels);

Thymothy syndrome (CACNA1C, Cav1.2);

myasthenic syndromes (CHRNA, CHRNB, CNRNE; nAChR), and a variety of other myopathies;

hyperkalemic periodic paralysis (Na and K channels);

epilepsy (Na^+ and K^+ channels);

hemiplegic migraine (CACNA1A, Cav2.1 Ca^{2+} channel and ATP1A2);

central core disease (RYR1, RyR1; Ca^{2+} channel), and

paramyotonia and myotonia (Na^+ , Cl^- channels)

(See L.J. Ptacek and Y-H Fu (2004), Arch. Neurol. 61: 166-8; B.A. Niemeyer et al. (2001), EMBO reports 21: 568-73; F. Lehmann-Horn and K. Jurkat-Rott (1999), Physiol. Rev. 79: 1317-72.) Although the foregoing list concerned disorders of inherited origin, molecules targeting the channels cited in these disorders can also be useful in treating related disorders of other, or indeterminate, origin.

[00246] In addition to the aforementioned disorders, evidence has also been provided supporting ion channels as targets for treatment of:

sickle cell anemia (IKCa1) – in sickle cell anemia, water loss from erythrocytes leads to hemoglobin polymerization and subsequent hemolysis and vascular obstruction. The water loss is consequent to potassium efflux through the so-called Gardos channel i.e., IKCa1. Therefore, block of IKCa1 is a potential therapeutic treatment for sickle cell anemia.

glaucoma (BKCa), – in glaucoma the intraocular pressure is too high leading to optic nerve damage, abnormal eye function and possibly blindness. Block of BKCa potassium channels can reduce intraocular fluid secretion and increase smooth muscle contraction, possibly leading to lower intraocular pressure and neuroprotection in the eye;

multiple sclerosis (Kv, KCa);

psoriasis (Kv, KCa);

arthritis (Kv, KCa);

asthma (KCa, Kv);

allergy(KCa, Kv);

COPD (KCa, Kv, Ca);

allergic rhinitis (KCa, Kv);

pulmonary fibrosis;

lupus (IKCa1, Kv);

transplantation, GvHD (KCa, Kv);

inflammatory bone resorption (KCa, Kv);

periodontal disease (KCa, Kv);

diabetes, type I (Kv), – type I diabetes is an autoimmune disease that is characterized by abnormal glucose, protein and lipid metabolism and is associated with insulin deficiency or resistance. In this disease, Kv1.3-expressing T-lymphocytes attack and destroy pancreatic islets leading to loss of beta-cells. Block of Kv1.3 decreases inflammatory cytokines. In addition block of Kv1.3 facilitates the translocation of GLUT4 to the plasma membrane, thereby increasing insulin sensitivity;

obesity (Kv), – Kv1.3 appears to play a critical role in controlling energy homeostasis and in protecting against diet-induced obesity. Consequently, Kv1.3 blockers could increase metabolic rate, leading to greater energy utilization and decreased body weight;

restenosis (KCa, Ca^{2+}), – proliferation and migration of vascular smooth muscle cells can lead to neointimal thickening and vascular restenosis. Excessive neointimal vascular smooth muscle cell proliferation is associated with elevated expression of IKCa1. Therefore, block of IKCa1 could represent a therapeutic strategy to prevent restenosis after angioplasty;

ischaemia (KCa, Ca^{2+}), – in neuronal or cardiac ischemia, depolarization of cell membranes leads to opening of voltage-gated sodium and calcium channels. In turn this can lead to calcium overload, which is cytotoxic. Block of voltage-gated sodium and/or calcium channels can reduce calcium overload and provide cytoprotective effects. In addition, due to their critical role in controlling and stabilizing cell membrane potential, modulators of voltage- and calcium-activated potassium channels can also act to reduce calcium overload and protect cells;

renal incontinence (KCa), renal incontinence is associated with overactive bladder smooth muscle cells. Calcium-activated potassium channels are expressed in bladder smooth muscle cells, where they control the membrane potential and indirectly control the force and frequency of cell contraction. Openers of calcium-activated potassium channels therefore provide a mechanism to dampen electrical and contractile activity in bladder, leading to reduced urge to urinate;

osteoporosis (Kv);

pain, including migraine (Na_v , TRP [transient receptor potential channels], P2X, Ca^{2+}), N-type voltage-gated calcium channels are key regulators of nociceptive neurotransmission in the spinal cord. Ziconotide, a peptide blocker of N-type calcium channels reduces nociceptive neurotransmission and is approved worldwide for the symptomatic alleviation of severe chronic pain in humans. Novel blockers of nociceptor-specific N-type calcium channels would be improved analgesics with reduced side-effect profiles;

hypertension (Ca^{2+}), – L-type and T-type voltage-gated calcium channels are expressed in vascular smooth muscle cells where they control excitation-contraction coupling and cellular proliferation. In particular, T-type calcium channel activity has been linked to neointima formation during hypertension. Blockers of L-type and T-type calcium channels are useful for the clinical treatment of hypertension because they reduce calcium influx and inhibit smooth muscle cell contraction;

wound healing, cell migration serves a key role in wound healing. Intracellular calcium gradients have been implicated as important regulators of cellular migration machinery in keratinocytes and fibroblasts. In addition, ion flux across cell membranes is associated with cell volume changes. By controlling cell volume, ion channels contribute to the intracellular environment that is required for operation of the cellular migration machinery. In particular, IKCa1 appears to be required universally for cell migration. In addition, Kv1.3, Kv3.1, NMDA receptors and N-type calcium channels are associated with the migration of lymphocytes and neurons; stroke;

Alzheimer's Disease;

Parkinson's Disease (nAChR, Nav);

Bipolar Disorder (Nav, Cav);

cancer, many potassium channel genes are amplified and protein subunits are upregulated in many cancerous condition. Consistent with a pathophysiological role for potassium channel upregulation, potassium channel blockers have been shown to suppress proliferation of uterine cancer cells and hepatocarcinoma cells, presumably through inhibition of calcium influx and effects on calcium-dependent gene expression; and

a variety of neurological, cardiovascular, metabolic and autoimmune diseases.

[00247] Both agonists and antagonists of ion channels can achieve therapeutic benefit. Therapeutic benefits can result, for example, from antagonizing Kv1.3, IKCa1, SKCa, BKCa, N-type or T-type Ca^{2+} channels and the like. Small molecule and peptide antagonists of these channels have been shown to possess utility in vitro and in vivo.

[00248] Compositions of this invention incorporating peptide antagonists of the voltage-gated potassium channel Kv1.3, in particular recombinant fusion proteins comprising OSK1 peptide analogs, whether or not conjugated to a half-life extending moiety, are useful as immunosuppressive agents with therapeutic value for autoimmune diseases. For example, such molecules are useful in treating multiple sclerosis, type 1 diabetes, psoriasis, inflammatory bowel disease, and rheumatoid arthritis. (See, e.g., H. Wulff et al. (2003) J. Clin. Invest. 111, 1703-1713 and H. Rus et al. (2005) PNAS 102, 11094-11099; Beeton et al., Targeting effector memory T cells with a selective inhibitor peptide of Kv1.3 channels for therapy of autoimmune diseases, Molec. Pharmacol. 67(4):1369-81 (2005); Beeton et al. (2006), Kv1.3: therapeutic target for cell-mediated autoimmune disease, electronic preprint at [//webfiles.uci.edu/xythoswfs/webui/2670029.1](http://webfiles.uci.edu/xythoswfs/webui/2670029.1)). Inhibitors of the voltage-gated potassium channel Kv1.3 have been examined in a variety of preclinical animal models of inflammation.

Small molecule and peptide inhibitors of Kv1.3 have been shown to block delayed type hypersensitivity responses to ovalbumin [C. Beeton et al. (2005) *Mol. Pharmacol.* 67, 1369] and tetanus toxoid [G.C. Koo et al. (1999) *Clin. Immunol.* 197, 99]. In addition to suppressing inflammation in the skin, inhibitors also reduced antibody production [G.C. Koo et al. (1997) *J. Immunol.* 158, 5120]. Kv1.3 antagonists have shown efficacy in a rat adoptive-transfer experimental autoimmune encephalomyelitis (AT-EAE) model of multiple sclerosis (MS). The Kv1.3 channel is overexpressed on myelin-specific T cells from MS patients, lending further support to the utility Kv1.3 inhibitors may provide in treating MS. Inflammatory bone resorption was also suppressed by Kv1.3 inhibitors in a preclinical adoptive-transfer model of periodontal disease [P. Valverde et al. (2004) *J. Bone Mineral Res.* 19, 155]. In this study, inhibitors additionally blocked antibody production to a bacterial outer membrane protein, - one component of the bacteria used to induce gingival inflammation. Recently in preclinical rat models, efficacy of Kv1.3 inhibitors was shown in treating pristane-induced arthritis and diabetes [C. Beeton et al. (2006) preprint available at [//webfiles.uci.edu/xythoswfs/webui/_xy-2670029_1.](http://webfiles.uci.edu/xythoswfs/webui/_xy-2670029_1.)]. The Kv1.3 channel is expressed on all subsets of T cells and B cells, but effector memory T cells and class-switched memory B cells are particularly dependent on Kv1.3 [H. Wulff et al. (2004) *J. Immunol.* 173, 776]. Gad5 / insulin-specific T cells from patients with new onset type 1 diabetes, myelin-specific T cells from MS patients and T cells from the synovium of rheumatoid arthritis patients all overexpress Kv1.3 [C. Beeton et al. (2006) preprint at [//webfiles.uci.edu/xythoswfs/webui/_xy-2670029_1.](http://webfiles.uci.edu/xythoswfs/webui/_xy-2670029_1.)]. Because mice deficient in Kv1.3 gained less weight when placed on a high fat diet [J. Xu et al. (2003) *Human Mol. Genet.* 12, 551] and showed altered glucose utilization [J. Xu et al. (2004) *Proc. Natl. Acad. Sci.* 101, 3112], Kv1.3 is also being investigated for the treatment of obesity and diabetes. Breast cancer specimens [M. Abdul et al. (2003) *Anticancer Res.* 23, 3347] and prostate cancer cell lines [S.P. Fraser et al. (2003) *Pflugers Arch.* 446, 559] have also been shown to express Kv1.3, and Kv1.3 blockade may be of utility for treatment of cancer. Disorders that can be treated with the inventive fusions proteins, involving Kv1.3 inhibitor toxin peptide(s), include multiple sclerosis, type 1 diabetes, psoriasis, inflammatory bowel disease, contact-mediated dermatitis, rheumatoid arthritis, psoriatic arthritis, asthma, allergy, restinosis, systemic sclerosis, fibrosis, scleroderma, glomerulonephritis, Sjogren syndrome, inflammatory bone resorption, transplant rejection, graft-versus-host disease, and systemic lupus erythematosus (SLE) and other forms of lupus.

[00249] Some of the cells that express the calcium-activated potassium of intermediate conductance IKCa1 include T cells, B cells, mast cells and red blood cells (RBCs). T cells and

RBCs from mice deficient in IKCa1 show defects in volume regulation [T. Begenisich et al. (2004) J. Biol. Chem. 279, 47681]. Preclinical and clinical studies have demonstrated IKCa1 inhibitors utility in treating sickle cell anemia [J. W. Stocker et al. (2003) Blood 101, 2412; www.icagen.com]. Blockers of the IKCa1 channel have also been shown to block EAE, indicating they may possess utility in treatment of MS [E. P. Reich et al. (2005) Eur. J. Immunol. 35, 1027]. IgE-mediated histamine production from mast cells is also blocked by IKCa1 inhibitors [S. Mark Duffy et al. (2004) J. Allergy Clin. Immunol. 114, 66], therefore they may also be of benefit in treating asthma. The IKCa1 channel is overexpressed on activated T and B lymphocytes [H. Wulff et al. (2004) J. Immunol. 173, 776] and thus may show utility in treatment of a wide variety of immune disorders. Outside of the immune system, IKCa1 inhibitors have also shown efficacy in a rat model of vascular restinosis and thus might represent a new therapeutic strategy to prevent restenosis after angioplasty [R. Kohler et al. (2003) Circulation 108, 1119]. It is also thought that IKCa1 antagonists are of utility in treatment of tumor angiogenesis since inhibitors suppressed endothelial cell proliferation and angionenesis in vivo [I. Grgic et al. (2005) Arterioscler. Thromb. Vasc. Biol. 25, 704]. The IKCa1 channel is upregulated in pancreatic tumors and inhibitors blocked proliferation of pancreatic tumor cell lines [H. Jager et al. (2004) Mol Pharmacol. 65, 630]. IKCa1 antagonists may also represent an approach to attenuate acute brain damage caused by traumatic brain injury [F. Mauler (2004) Eur. J. Neurosci. 20, 1761]. Disorders that can be treated with the inventive recombinant fusion proteins comprising IKCa1 inhibitors include multiple sclerosis, asthma, allergy, psoriasis, contact-mediated dermatitis, rheumatoid arthritis, psoriatic arthritis, type 1 diabetes, inflammatory bowel disease, fibrosis, scleroderma, glomerulonephritis, Sjogren syndrome, inflammatory bone resorption, systemic sclerosis, transplant rejection, graft-versus-host disease, systemic lupus erythematosus (SLE) and other forms of lupus, restinosis, pancreatic cancer, tumor angiogenesis and traumatic brain injury.

[00250] Accordingly, molecules of this invention incorporating peptide antagonists of the calcium-activated potassium channel of intermediate conductance, IKCa can be used to treat,

[00251] The diseases and pharmacologically active compositions described herein are merely exemplary and in no way limit the range of inventive pharmacologically active compounds and compositions that can be prepared using the inventive method or the diseases and disorders that can be treated with the benefit of the present invention.

[00252] Accordingly, the present invention also relates to the use of one or more of the inventive compositions of matter in the manufacture of a medicament for the treatment or prevention of a disease, disorder, or other medical condition described herein.

[00253] Such pharmaceutical compositions can be configured for administration to a patient by a wide variety of delivery routes, e.g., an intravascular delivery route such as by injection or infusion, subcutaneous, intramuscular, intraperitoneal, epidural, or intrathecal delivery routes, or for oral, enteral, pulmonary (e.g., inhalant), intranasal, transmucosal (e.g., sublingual administration), transdermal or other delivery routes and/or forms of administration known in the art. The inventive pharmaceutical compositions may be prepared in liquid form, or may be in dried powder form, such as lyophilized form. For oral or enteral use, the pharmaceutical compositions can be configured, for example, as tablets, troches, lozenges, aqueous or oily suspensions, dispersible powders or granules, emulsions, hard or soft capsules, syrups, elixirs or enteral formulas.

[00254] Pharmaceutical Compositions

[00255] In General. The present invention also provides pharmaceutical compositions comprising the inventive composition of matter and a pharmaceutically acceptable carrier. Such pharmaceutical compositions can be configured for administration to a patient by a wide variety of delivery routes, e.g., an intravascular delivery route such as by injection or infusion, subcutaneous, intramuscular, intraperitoneal, epidural, or intrathecal delivery routes, or for oral, enteral, pulmonary (e.g., inhalant), intranasal, transmucosal (e.g., sublingual administration), transdermal or other delivery routes and/or forms of administration known in the art. The inventive pharmaceutical compositions may be prepared in liquid form, or may be in dried powder form, such as lyophilized form. For oral or enteral use, the pharmaceutical compositions can be configured, for example, as tablets, troches, lozenges, aqueous or oily suspensions, dispersible powders or granules, emulsions, hard or soft capsules, syrups, elixirs or enteral formulas.

[00256] In the practice of this invention the "pharmaceutically acceptable carrier" is any physiologically tolerated substance known to those of ordinary skill in the art useful in formulating pharmaceutical compositions, including, any pharmaceutically acceptable diluents, excipients, dispersants, binders, fillers, glidants, anti-frictional agents, compression aids, tablet-disintegrating agents (disintegrants), suspending agents, lubricants, flavorants, odorants, sweeteners, permeation or penetration enhancers, preservatives, surfactants, solubilizers, emulsifiers, thickeners, adjuvants, dyes, coatings, encapsulating material(s), and/or other

additives singly or in combination. Such pharmaceutical compositions can include diluents of various buffer content (*e.g.*, Tris-HCl, acetate, phosphate), pH and ionic strength; additives such as detergents and solubilizing agents (*e.g.*, Tween[®] 80, Polysorbate 80), anti-oxidants (*e.g.*, ascorbic acid, sodium metabisulfite), preservatives (*e.g.*, Thimersol[®], benzyl alcohol) and bulking substances (*e.g.*, lactose, mannitol); incorporation of the material into particulate preparations of polymeric compounds such as polylactic acid, polyglycolic acid, etc. or into liposomes. Hyaluronic acid can also be used, and this can have the effect of promoting sustained duration in the circulation. Such compositions can influence the physical state, stability, rate of in vivo release, and rate of in vivo clearance of the present proteins and derivatives. See, *e.g.*, Remington's Pharmaceutical Sciences, 18th Ed. (1990, Mack Publishing Co., Easton, PA 18042) pages 1435-1712. The compositions can be prepared in liquid form, or can be in dried powder, such as lyophilized form. Implantable sustained release formulations are also useful, as are transdermal or transmucosal formulations. Additionally (or alternatively), the present invention provides compositions for use in any of the various slow or sustained release formulations or microparticle formulations known to the skilled artisan, for example, sustained release microparticle formulations, which can be administered via pulmonary, intranasal, or subcutaneous delivery routes. (See, *e.g.*, Murthy et al., Injectable compositions for the controlled delivery of pharmacologically active compound, U.S. Patent No. 6,887,487; Manning et al., Solubilization of pharmaceutical substances in an organic solvent and preparation of pharmaceutical powders using the same, U.S. Patent Nos. 5,770,559 and 5,981,474; Lieberman et al., Lipophilic complexes of pharmacologically active inorganic mineral acid esters of organic compounds, U.S. Patent No. 5,002,936; Gen, Formative agent of protein complex, US 2002/0119946 A1; Goldenberg et al., Sustained release formulations, WO 2005/105057 A1).

[00257] One can dilute the inventive compositions or increase the volume of the pharmaceutical compositions of the invention with an inert material. Such diluents can include carbohydrates, especially, mannitol, α -lactose, anhydrous lactose, cellulose, sucrose, modified dextrans and starch. Certain inorganic salts may also be used as fillers, including calcium triphosphate, magnesium carbonate and sodium chloride. Some commercially available diluents are Fast-Flo^{*}, Emdex^{*}, STA-Rx 1500, Emcompress^{*} and Avicell.

[00258] A variety of conventional thickeners are useful in creams, ointments, suppository and gel configurations of the pharmaceutical composition, such as, but not limited to, alginate, xanthan gum, or petrolatum, may also be employed in such configurations of the pharmaceutical

*Trademark

composition of the present invention. A permeation or penetration enhancer, such as polyethylene glycol monolaurate, dimethyl sulfoxide, N-vinyl-2-pyrrolidone, N-(2-hydroxyethyl)-pyrrolidone, or 3-hydroxy-N-methyl-2-pyrrolidone can also be employed. Useful techniques for producing hydrogel matrices are known. (E.g., Feijen, Biodegradable hydrogel matrices for the controlled release of pharmacologically active agents, U.S. Patent No. 4,925,677; Shah et al., Biodegradable pH/thermosensitive hydrogels for sustained delivery of biologically active agents, WO 00/38651 A1). Such biodegradable gel matrices can be formed, for example, by crosslinking a proteinaceous component and a polysaccharide or mucopolysaccharide component, then loading with the inventive composition of matter to be delivered.

[00259] Liquid pharmaceutical compositions of the present invention that are sterile solutions or suspensions can be administered to a patient by injection, for example, intramuscularly, intrathecally, epidurally, intravascularly (e.g., intravenously or intraarterially), intraperitoneally or subcutaneously. (See, e.g., Goldenberg et al., Suspensions for the sustained release of proteins, U.S. Patent No. 6,245,740 and WO 00/38652 A1). Sterile solutions can also be administered by intravenous infusion. The inventive composition can be included in a sterile solid pharmaceutical composition, such as a lyophilized powder, which can be dissolved or suspended at a convenient time before administration to a patient using sterile water, saline, buffered saline or other appropriate sterile injectable medium.

[00260] Implantable sustained release formulations are also useful embodiments of the inventive pharmaceutical compositions. For example, the pharmaceutically acceptable carrier, being a biodegradable matrix implanted within the body or under the skin of a human or non-human vertebrate, can be a hydrogel similar to those described above. Alternatively, it may be formed from a poly-alpha-amino acid component. (Sidman, Biodegradable, implantable drug delivery device, and process for preparing and using same, U.S. Patent No. 4,351,337). Other techniques for making implants for delivery of drugs are also known and useful in accordance with the present invention.

[00261] In powder forms, the pharmaceutically acceptable carrier is a finely divided solid, which is in admixture with finely divided active ingredient(s), including the inventive composition. For example, in some embodiments, a powder form is useful when the pharmaceutical composition is configured as an inhalant. (See, e.g., Zeng et al., Method of preparing dry powder inhalation compositions, WO 2004/017918; Trunk et al., Salts of the CGRP antagonist BIBN4096 and inhalable powdered medicaments containing them, U.S. Patent No. 6,900,317).

[00262] One can dilute or increase the volume of the compound of the invention with an inert material. These diluents could include carbohydrates, especially mannitol, α -lactose, anhydrous lactose, cellulose, sucrose, modified dextrans and starch. Certain inorganic salts can also be used as fillers including calcium triphosphate, magnesium carbonate and sodium chloride. Some commercially available diluents are Fast-Flo™, Emdex™, STA-Rx™ 1500, Emcompress™ and Avicell™.

[00263] Disintegrants can be included in the formulation of the pharmaceutical composition into a solid dosage form. Materials used as disintegrants include but are not limited to starch including the commercial disintegrant based on starch, Explotab™. Sodium starch glycolate, Amberlite™, sodium carboxymethylcellulose, ultramylopectin, sodium alginate, gelatin, orange peel, acid carboxymethyl cellulose, natural sponge and bentonite can all be used. Insoluble cationic exchange resin is another form of disintegrant. Powdered gums can be used as disintegrants and as binders and these can include powdered gums such as agar, Karaya or tragacanth. Alginic acid and its sodium salt are also useful as disintegrants.

[00264] Binders can be used to hold the therapeutic agent together to form a hard tablet and include materials from natural products such as acacia, tragacanth, starch and gelatin. Others include methyl cellulose (MC), ethyl cellulose (EC) and carboxymethyl cellulose (CMC). Polyvinyl pyrrolidone (PVP) and hydroxypropylmethyl cellulose (HPMC) could both be used in alcoholic solutions to granulate the therapeutic.

[00265] An antifrictional agent can be included in the formulation of the therapeutic to prevent sticking during the formulation process. Lubricants can be used as a layer between the therapeutic and the die wall, and these can include but are not limited to; stearic acid including its magnesium and calcium salts, polytetrafluoroethylene (PTFE), liquid paraffin, vegetable oils and waxes. Soluble lubricants can also be used such as sodium lauryl sulfate, magnesium lauryl sulfate, polyethylene glycol of various molecular weights, Carbowax^{*} 4000 and 6000.

[00266] Glidants that might improve the flow properties of the drug during formulation and to aid rearrangement during compression might be added. The glidants can include starch, talc, pyrogenic silica and hydrated silicoaluminate.

[00267] To aid dissolution of the compound of this invention into the aqueous environment a surfactant might be added as a wetting agent. Surfactants can include anionic detergents such as sodium lauryl sulfate, dioctyl sodium sulfosuccinate and dioctyl sodium sulfonate. Cationic detergents might be used and could include benzalkonium chloride or benzethonium chloride. The list of potential nonionic detergents that could be included in the

*Trademark

formulation as surfactants are lauromacrogol 400, polyoxyl 40 stearate, polyoxyethylene hydrogenated castor oil 10, 50 and 60, glycerol monostearate, polysorbate 40, 60, 65 and 80, sucrose fatty acid ester, methyl cellulose and carboxymethyl cellulose. These surfactants could be present in the formulation of the protein or derivative either alone or as a mixture in different ratios.

[00268] Oral dosage forms. Also useful are oral dosage forms of the inventive compositionss. If necessary, the composition can be chemically modified so that oral delivery is efficacious. Generally, the chemical modification contemplated is the attachment of at least one moiety to the molecule itself, where said moiety permits (a) inhibition of proteolysis; and (b) uptake into the blood stream from the stomach or intestine. Also desired is the increase in overall stability of the compound and increase in circulation time in the body. Moieties useful as covalently attached half-life extending moieties in this invention can also be used for this purpose. Examples of such moieties include: PEG, copolymers of ethylene glycol and propylene glycol, carboxymethyl cellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone and polyproline. See, for example, Abuchowski and Davis (1981), Soluble Polymer-Enzyme Adducts, Enzymes as Drugs (Hocenberg and Roberts, eds.), Wiley-Interscience, New York, NY, pp 367-83; Newmark, et al. (1982), J. Appl. Biochem. 4:185-9. Other polymers that could be used are poly-1,3-dioxolane and poly-1,3,6-tioxocane. Preferred for pharmaceutical usage, as indicated above, are PEG moieties.

[00269] For oral delivery dosage forms, it is also possible to use a salt of a modified aliphatic amino acid, such as sodium N-(8-[2-hydroxybenzoyl] amino) caprylate (SNAC), as a carrier to enhance absorption of the therapeutic compounds of this invention. The clinical efficacy of a heparin formulation using SNAC has been demonstrated in a Phase II trial conducted by Emisphere Technologies. See US Patent No. 5,792,451, "Oral drug delivery composition and methods."

[00270] In one embodiment, the pharmaceutically acceptable carrier can be a liquid and the pharmaceutical composition is prepared in the form of a solution, suspension, emulsion, syrup, elixir or pressurized composition. The active ingredient(s) (e.g., the inventive composition of matter) can be dissolved, diluted or suspended in a pharmaceutically acceptable liquid carrier such as water, an organic solvent, a mixture of both, or pharmaceutically acceptable oils or fats. The liquid carrier can contain other suitable pharmaceutical additives such as detergents and/or solubilizers (e.g., Tween 80, Polysorbate 80), emulsifiers, buffers at appropriate pH (e.g., Tris-HCl, acetate, phosphate), adjuvants, anti-oxidants (e.g., ascorbic acid,

sodium metabisulfite), preservatives (e.g., Thimersol, benzyl alcohol), sweeteners, flavoring agents, suspending agents, thickening agents, bulking substances (e.g., lactose, mannitol), colors, viscosity regulators, stabilizers, electrolytes, osmolutes or osmo-regulators. Additives can also be included in the formulation to enhance uptake of the inventive composition. Additives potentially having this property are for instance the fatty acids oleic acid, linoleic acid and linolenic acid.

[00271] Useful are oral solid dosage forms, which are described generally in Remington's Pharmaceutical Sciences (1990), supra, in Chapter 89. Solid dosage forms include tablets, capsules, pills, troches or lozenges, cachets or pellets. Also, liposomal or proteinoid encapsulation can be used to formulate the present compositions (as, for example, proteinoid microspheres reported in U.S. Patent No. 4,925,673). Liposomal encapsulation can be used and the liposomes can be derivatized with various polymers (e.g., U.S. Patent No. 5,013,556). A description of possible solid dosage forms for the therapeutic is given in Marshall, K., Modern Pharmaceutics (1979), edited by G. S. Banker and C.T. Rhodes, in Chapter 10. In general, the formulation will include the inventive compound, and inert ingredients that allow for protection against the stomach environment, and release of the biologically active material in the intestine.

[00272] The composition of this invention can be included in the formulation as fine multiparticulates in the form of granules or pellets of particle size about 1 mm. The formulation of the material for capsule administration could also be as a powder, lightly compressed plugs or even as tablets. The therapeutic could be prepared by compression.

[00273] Colorants and flavoring agents can all be included. For example, the protein (or derivative) can be formulated (such as by liposome or microsphere encapsulation) and then further contained within an edible product, such as a refrigerated beverage containing colorants and flavoring agents.

[00274] In tablet form, the active ingredient(s) are mixed with a pharmaceutically acceptable carrier having the necessary compression properties in suitable proportions and compacted in the shape and size desired.

[00275] The powders and tablets preferably contain up to 99% of the active ingredient(s). Suitable solid carriers include, for example, calcium phosphate, magnesium stearate, talc, sugars, lactose, dextrin, starch, gelatin, cellulose, polyvinylpyrrolidone, low melting waxes and ion exchange resins.

[00276] Controlled release formulation can be desirable. The composition of this invention can be incorporated into an inert matrix that permits release by either diffusion or leaching mechanisms e.g., gums. Slowly degenerating matrices can also be incorporated into the formulation, e.g., alginates, polysaccharides. Another form of a controlled release of the compositions of this invention is by a method based on the Oros™ therapeutic system (Alza Corp.), i.e., the drug is enclosed in a semipermeable membrane which allows water to enter and push drug out through a single small opening due to osmotic effects. Some enteric coatings also have a delayed release effect.

[00277] Other coatings can be used for the formulation. These include a variety of sugars that could be applied in a coating pan. The therapeutic agent could also be given in a film-coated tablet and the materials used in this instance are divided into 2 groups. The first are the nonenteric materials and include methylcellulose, ethyl cellulose, hydroxyethyl cellulose, methylhydroxy-ethyl cellulose, hydroxypropyl cellulose, hydroxypropyl-methyl cellulose, sodium carboxymethyl cellulose, providone and the polyethylene glycols. The second group consists of the enteric materials that are commonly esters of phthalic acid.

[00278] A mix of materials might be used to provide the optimum film coating. Film coating can be carried out in a pan coater or in a fluidized bed or by compression coating.

[00279] Pulmonary delivery forms.

[00280] Pulmonary delivery of the inventive compositions is also useful. The protein (or derivative) is delivered to the lungs of a mammal while inhaling and traverses across the lung epithelial lining to the blood stream. (Other reports of this include Adjei et al., Pharma. Res. (1990) 7: 565-9; Adjei et al. (1990), Internatl. J. Pharmaceutics 63: 135-44 (leuprolide acetate); Braquet et al. (1989), J. Cardiovasc. Pharmacol. 13 (suppl.5): s.143-146 (endothelin-1); Hubbard et al. (1989), Annals Int. Med. 3: 206-12 (α 1-antitrypsin); Smith et al. (1989), J. Clin. Invest. 84: 1145-6 (α 1-proteinase); Oswein et al. (March 1990), "Aerosolization of Proteins," Proc. Symp. Resp. Drug Delivery II, Keystone, Colorado (recombinant human growth hormone); Debs et al. (1988), J. Immunol. 140: 3482-8 (interferon- γ and tumor necrosis factor α) and Platz et al., U.S. Patent No. 5,284,656 (granulocyte colony stimulating factor).

Useful in the practice of this invention are a wide range of mechanical devices designed for pulmonary delivery of therapeutic products, including but not limited to nebulizers, metered dose inhalers, and powder inhalers, all of which are familiar to those skilled in the art. Some specific examples of commercially available devices suitable for the practice of this invention are the Ultravent nebulizer, manufactured by Mallinckrodt, Inc., St. Louis, Missouri; the Acorn II

nebulizer, manufactured by Marquest Medical Products, Englewood, Colorado; the Ventolin metered dose inhaler, manufactured by Glaxo Inc., Research Triangle Park, North Carolina; and the Spinhaler powder inhaler, manufactured by Fisons Corp., Bedford, Massachusetts. (See, e.g., Helgesson et al., Inhalation device, U.S. Patent No. 6,892,728; McDerment et al., Dry powder inhaler, WO 02/11801 A1; Ohki et al., Inhalant medicator, U.S. Patent No. 6,273,086).

[00281] All such devices require the use of formulations suitable for the dispensing of the inventive compound. Typically, each formulation is specific to the type of device employed and can involve the use of an appropriate propellant material, in addition to diluents, adjuvants and/or carriers useful in therapy.

[00282] The inventive compound should most advantageously be prepared in particulate form with an average particle size of less than 10 μm (or microns), most preferably 0.5 to 5 μm , for most effective delivery to the distal lung.

[00283] Pharmaceutically acceptable excipients include carbohydrates such as trehalose, mannitol, xylitol, sucrose, lactose, and sorbitol. Other ingredients for use in formulations can include DPPC, DOPE, DSPC and DOPC. Natural or synthetic surfactants can be used. PEG can be used (even apart from its use in derivatizing the protein or analog). Dextrans, such as cyclodextran, can be used. Bile salts and other related enhancers can be used. Cellulose and cellulose derivatives can be used. Amino acids can be used, such as use in a buffer formulation.

[00284] Also, the use of liposomes, microcapsules or microspheres, inclusion complexes, or other types of carriers is contemplated.

[00285] Formulations suitable for use with a nebulizer, either jet or ultrasonic, will typically comprise the inventive compound dissolved in water at a concentration of about 0.1 to 25 mg of biologically active protein per mL of solution. The formulation can also include a buffer and a simple sugar (e.g., for protein stabilization and regulation of osmotic pressure). The nebulizer formulation can also contain a surfactant, to reduce or prevent surface induced aggregation of the protein caused by atomization of the solution in forming the aerosol.

[00286] Formulations for use with a metered-dose inhaler device will generally comprise a finely divided powder containing the inventive compound suspended in a propellant with the aid of a surfactant. The propellant can be any conventional material employed for this purpose, such as a chlorofluorocarbon, a hydrochlorofluorocarbon, a hydrofluorocarbon, or a hydrocarbon, including trichlorofluoromethane, dichlorodifluoromethane, dichlorotetrafluoroethanol, and 1,1,1,2-tetrafluoroethane, or combinations thereof. Suitable surfactants include sorbitan trioleate and soya lecithin. Oleic acid can also be useful as a surfactant. (See, e.g., Bäckström et al.,

Aerosol drug formulations containing hydrofluoroalkanes and alkyl saccharides, U.S. Patent No. 6,932,962).

[00287] Formulations for dispensing from a powder inhaler device will comprise a finely divided dry powder containing the inventive compound and can also include a bulking agent, such as lactose, sorbitol, sucrose, mannitol, trehalose, or xylitol in amounts which facilitate dispersal of the powder from the device, e.g., 50 to 90% by weight of the formulation.

[00288] Nasal delivery forms. In accordance with the present invention, intranasal delivery of the inventive composition of matter and/or pharmaceutical compositions is also useful, which allows passage thereof to the blood stream directly after administration to the inside of the nose, without the necessity for deposition of the product in the lung. Formulations suitable for intranasal administration include those with dextran or cyclodextran, and intranasal delivery devices are known. (See, e.g., Freezer, Inhaler, U.S. Patent No. 4,083,368).

[00289] Transdermal and transmucosal (e.g., buccal) delivery forms). In some embodiments, the inventive composition is configured as a part of a pharmaceutically acceptable transdermal or transmucosal patch or a troche. Transdermal patch drug delivery systems, for example, matrix type transdermal patches, are known and useful for practicing some embodiments of the present pharmaceutical compositions. (E.g., Chien et al., Transdermal estrogen/progestin dosage unit, system and process, U.S. Patent Nos. 4,906,169 and 5,023,084; Cleary et al., Diffusion matrix for transdermal drug administration and transdermal drug delivery devices including same, U.S. Patent No. 4,911,916; Teillaud et al., EVA-based transdermal matrix system for the administration of an estrogen and/or a progestogen, U.S. Patent No. 5,605,702; Venkateshwaran et al., Transdermal drug delivery matrix for coadministering estradiol and another steroid, U.S. Patent No. 5,783,208; Ebert et al., Methods for providing testosterone and optionally estrogen replacement therapy to women, U.S. Patent No. 5,460,820). A variety of pharmaceutically acceptable systems for transmucosal delivery of therapeutic agents are also known in the art and are compatible with the practice of the present invention. (E.g., Heiber et al., Transmucosal delivery of macromolecular drugs, U.S. Patent Nos. 5,346,701 and 5,516,523; Longenecker et al., Transmembrane formulations for drug administration, U.S. Patent No. 4,994,439).

[00290] Buccal delivery of the inventive compositions is also useful. Buccal delivery formulations are known in the art for use with peptides. For example, known tablet or patch systems configured for drug delivery through the oral mucosa (e.g., sublingual mucosa), include some embodiments that comprise an inner layer containing the drug, a permeation enhancer, such

as a bile salt or fusidate, and a hydrophilic polymer, such as hydroxypropyl cellulose, hydroxypropyl methylcellulose, hydroxyethyl cellulose, dextran, pectin, polyvinyl pyrrolidone, starch, gelatin, or any number of other polymers known to be useful for this purpose. This inner layer can have one surface adapted to contact and adhere to the moist mucosal tissue of the oral cavity and can have an opposing surface adhering to an overlying non-adhesive inert layer. Optionally, such a transmucosal delivery system can be in the form of a bilayer tablet, in which the inner layer also contains additional binding agents, flavoring agents, or fillers. Some useful systems employ a non-ionic detergent along with a permeation enhancer. Transmucosal delivery devices may be in free form, such as a cream, gel, or ointment, or may comprise a determinate form such as a tablet, patch or troche. For example, delivery of the inventive composition can be via a transmucosal delivery system comprising a laminated composite of, for example, an adhesive layer, a backing layer, a permeable membrane defining a reservoir containing the inventive composition, a peel seal disc underlying the membrane, one or more heat seals, and a removable release liner. (E.g., Ebert et al., Transdermal delivery system with adhesive overlay and peel seal disc, U.S. Patent No. 5,662,925; Chang et al., Device for administering an active agent to the skin or mucosa, U.S. Patent Nos. 4,849,224 and 4,983,395). These examples are merely illustrative of available transmucosal drug delivery technology and are not limiting of the present invention.

[00291] Dosages. The dosage regimen involved in a method for treating the above-described conditions will be determined by the attending physician, considering various factors which modify the action of drugs, e.g. the age, condition, body weight, sex and diet of the patient, the severity of any infection, time of administration and other clinical factors. Generally, the daily regimen should be in the range of 0.1-1000 micrograms of the inventive compound per kilogram of body weight, preferably 0.1-150 micrograms per kilogram.

[00292] The following working examples are illustrative and not to be construed in any way as limiting the scope of the present invention.

[00293] EXAMPLES

[00294] Example 1. Expression and bioactivity of fusion proteins

[00295] Human protein domains were selected for small size, in order to aid in high level expression in prokaryotic hosts, and also to provide an advantage to the mass ratio of active peptide to inactive carrier. The small size of the fusion protein is expected to result in a short serum half-life for the native molecule, which may allow for modulation of the pharmacokinetic

profile of the molecule to fit the therapeutic need by attaching PEG moieties or other half-life extending moieties of various masses and configurations.

[00296] Selection of small pharmacologically inactive protein domains. Small protein domains from the following families were selected for further investigation: the CH2 domain of IgG1, the 10th fibronectin III domain, the villin headpiece domain, several SH3 domains, several PDZ domains, and several SH2 domains. The CH2 domain was chosen to represent the immunoglobulin fold superfamily, since it is the only domain in the ubiquitous IgG1 molecule that is not involved in dimerization. The 10th fibronectin III domain was also chosen to represent the immunoglobulin fold, since it is a stable domain and lacks the disulfide bonds found in most other members of this family. Fibronectins are extracellular proteins involved in cell adhesion, cell motility, opsonization, wound healing, and maintenance of cell shape. Three PDZ domains were chosen from divergent families of the 51 human PDZ domains for which structural coordinates were available at the Brookhaven Protein Databank (Figure 1). PDZ domains are intracellular peptide binding domains that prefer C-terminal peptides and often form signal transduction complexes. Three SH3 domains were chosen from divergent families of the 74 human SH3 domains for which structural coordinates were available at the Brookhaven Protein Databank (Figure 2). SH3 domains are intracellular proline motif (PxxP) recognition and binding domains. In addition, two SH2 domains were chosen from divergent families of the 22 human SH2 domains for which structural coordinates were available at the Brookhaven Protein Databank (Figure 3). SH2 domains are intracellular phosphotyrosine recognition and binding domains. Taken together, these domains represent a wide array of protein structures with diverse biochemical properties.

[00297] Construct Assembly. Two bacterial expression vectors were employed to express the fusion constructs (pAMG21 and pET30). The pAMG21(BamHI) vector encodes resistance to kanamycin ("Kanr") and contains an R100-derived origin of replication as well as multiple unique restriction sites suitable for cloning. Expression in the pAMG21 constructs is driven by the inducible promoter luxPR from Vibrio fischeri. The pET30 vector (Novagen/EMD Biosciences, San Diego, CA) encodes Kanr and contains a pBR322-derived origin of replication. Expression in pET30 is driven by the inducible T7 promoter.

[00298] For OsK1 and ShK fusions, optimization, reduction of mRNA secondary structure and subsequent gene synthesis was carried out. Genes encoded (i) an affinity purification tag, for convenience, comprising an initiator methionine (M), two glycines (G₂), six histidines (H₆), and two or three glycines (G₃) ("M-G₂-H₆-G₃"; SEQ ID NO:49); (ii) the small pharmacologically

inactive protein domain, (iii) a ten-residue linker composed of a repeat of four glycines and one serine (“(G₄S)₂” or “L10”; SEQ ID NO:22) and finally the bioactive peptide, examples of which were toxin peptides OSK1 and ShK. The following amino acid sequences are examples of the encoded fusion proteins:

CH2-OSK1:

GGHHHHHHGGGSPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKT
KPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISGGGGSGGGGSGVIINV
KCKISRQCLEPCKKAGMRFGKCMNGKCHCTPK// SEQ ID NO:80;

FnIII-OSK1:

GGHHHHHHGGGTVSDVPRDLEVVAATPTSLLISWDAPAVTVRYRYRITYGETGGNSPVQEFTVPG
SKSTATISGLKPGVDYITVYAVTGRGDSPASSKPISINYRTEGGGGSGGGGSGVIINVKCKISRQC
LEPCKKAGMRFGKCMNGKCHCTPK// SEQ ID NO:81;

1PHT-OSK1:

GGHHHHHHGGGSAEGYQYRALYDYKKEREEDIDLHLGDILTVNKGSLVALGFSDGQEARPEEIG
WLNQYNETTGERGDFPGTYVEYIGRKKISPGGGSGGGGSGVIINVKCKISRQCLEPCKKAGMRFG
GKCMNGKCHCTPK// SEQ ID NO:82;

1N7F-OSK1:

GGHHHHHHGGGSSGAIITYVELKRYGGPLGITISGTEEPFDPIISSLTKGGLAERTGAIHIGDRILAI
NSSLKKGKPLSEAIHLLQMAGETVTLKIKKQTDAQSASSPGGGSGGGGSGVIINVKCKISRQC
LEPCKKAGMRFGKCMNGKCHCTPK// SEQ ID NO:83;

1X2K-OSK1:

GGHHHHHHGGGKVFRALYTFEPRTPELYFEEGDIIYITDMSDTNWWKGTSKGRTGLIPSNYVA
EQGGGGSGGGGSGVIINVKCKISRQCLEPCKKAGMRFGKCMNGKCHCTPK// SEQ ID NO:84; and

1UEZ-OSK1:

GGHHHHHHGGGPGEVRLVSLRRAKAHEGLGFSIRGGSEHGVGIYVSLVEPGSLAEKEGL
RVGDQILRVNDKSLARVTHAEAVKALKGSKKLVLVSAGRIPGGGGSGGGGSGVIINV
KCKISRQCLEPCKKAGMRFGKCMNGKCHCTPK// SEQ ID NO:85.

[00299] Additional nucleotides were added to the 5' and 3' ends incorporating NdeI and EcoRI restriction sites. The final six nucleotides of the 10 residue linker, GAATTC, were

designed to encode glycine and serine as well as providing a BamHI restriction site. Full nucleotide sequences of the genes are exemplified by the following.

M-G₂-H₆-G₃-10thF_n3-(G₄S)₂-OsK1 (coding region underlined)

catatgggtggtcatcatcatcatcatcatggtggtggtaccgtaagcgatgtaccacgcgatctggaagtagtagctgccacaccaacctctt
tgctgatctcttgggacgcacctgcagttacagtcgcttattatcgtattacgtatggagaaaccggtggcaacagtccagtacaagaatttac
cgtgcctggttccaaaagtaccgcaacaatttcaggcctcaaacagggtgttgattatagattacagtttatgcggttaccggtcgtggcgatt
cacccgcatcaagtaaaccaatttctattaactatcgtacagaaggcgggggaggtagcggcggaggaggatccggagtcattatcaatgtt
aatgtaaaatcagccgtcagtggttagaaccatgtaaaaagccggaatgcgctttggaaaatgtatgaatggtaaatgtcattgcaccccgga
aataatgaattc// SEQ ID NO:62;

M-G₂-H₆-G₃-PDZ(1N7F)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtggtcatcatcatcatcatcatggtggtggtccagcgggtgcaattatctatacggtagaacttaaacgttacggtggtcctctgggt
attacaatcagcggcacagaagaaccctttgatccaattattatttcacgcttactaaagggtggtcttgctgaacgcacaggcgccattcatatt
ggagatcgtattttagctatcaactcatcatcattaaaaggcaaaccgttatcagaagctattcacttattacaaatggcgggcgaaacagttac
ccttaaatcaaaaaacaaccgacgcacaatctgcaagtagtcgggggggaggcggctcaggaggaggaggatccggtgttattatcaa
tgtcaaatgtaaaatttctcgtcagtggttggaaacctgtaaaaagccggtatgcgctttggaaaatgtatgaacggaaaatgtcactgtacc
caaaataatgaattc// SEQ ID NO:63;

M-G₂-H₆-G₃-PDZ(1UEZ)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtggtcatcatcatcatcatcatggtggtggtccgggcgaagttcgtcttgttagtttacgtcgcgcaaaagcacatgaaggcttag
gtttcicaattcgtggcggcagcgaacatggtgttgaatttatgtatccttagtagaacctggtagtttagccgaaaaagaaggcctgcgtgtc
ggcgatcaaatcttacgcgtcaacgataaatcttagcccgcgttactcatgccgaagccgttaaagcgttgaaaggtagcaaaaaattagttc
tgtctgtttattccgcaggtcgtattcctggtggtggaggaaagtgggtggtggatccggagtaattattaacgttaaatgtaaaatcagtcgtc
aatgtttggaacctgtaaaaaagctggaatgcggtttggaaaatgtatgaatggtaaatgtcactgtaccctaaataatgaattc// SEQ
ID NO:64;

M-G₂-H₆-G₃-PDZ(1WFV)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtggtcatcatcatcatcatcatggtggtggtcctcaagacttcgattactttactgttgatatggaaaaagggtgcaaaagggttttggtt
tctctattcgtggcggtcgtgaatataaaatggacttatatgtgttacgcttagctgaagacggaccgcgaattcgtaacggacgtatgcgtgtt
ggcgatcaaatattgaaattaatggcgaatcaactcgtgatatgacctatgcacgtgcgattgaacttattaatctggaggacgtcgtgtac
gcttactcttaaaacgtggtacaggtcaggttcccgggtggcggcgagtggtggtggtggatccggagtattatcaatgttaaatgtaaaat
tagtcgtcaatgcttagaaccttgtaaaaaagctggaatgcgctttggaaaatgcatgaacgggaaatgtcactgcacacctaaataatgaatt
c// SEQ ID NO:65;

M-G₂-H₆-G₃-SH2(1AB2)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtggtcatcatcatcatcatcatggtggtggttaattctttagaaaaacattcatggtatcatggtcctgtatcacgtaacgcagccgaa
tatctcttatcttctggcattaacggtagtttttagtccgcgaatccgaatcttctcctggccaacgcagtatcagtciccggtatgaaggctcgtgt

gtatcattatcgcatcaataccgcttcagatggtaaattatatgtttcctcggaaagtcgtttcaatacccttcggaactcgttcacatcattcta
ctgtggcagatggctcattacaacgttacattatcctgcacccggcggtgggtgctctgggtggcggaatccggtgttattattaatgttaa
gtaaaattagtcgccaatgtcttgaaccttgtaaaaaagctggcatgcgctttgtaaatgtatgaacggaaaatgtcattgtaccccgaaataa
 tgaattc// SEQ ID NO:66;

M-G₂-H₆-G₃-SH2(1JYQ)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtgggtcatcatcatcatcatcatgggtgggtggtccttgggttttggtaaaatcccacgtgcgaaagctgaagaaatgctctcaaaaca
acgtcatgacgggtgcatcttaattcgtgaaagtgaatctgctccaggtgatttagtttaagtgttaaatttgtaaatgatgtccaacattttaagt
ccttcgtgatgggtgcgggtaaaatatttttatgggtagtcaaatcaatagcttaacgaacttgctgattatcatcgttcaccagtgttagccgta
atcaacaaatttttctccgcgataattgaacaagggtgggtgggtcaggagggggcggaatccggcgtaaatcatcaatgtaaaatgtaaaatctc
tcgtcaatgtttagaacctgtaaaaaagcaggaatgcgttcggtaaatgtatgaatgtaaatgtcattgtaccccaaaataatgaattc//
 SEQ ID NO:67;

M-G₂-H₆-G₃-SH3(1PHT)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtgggtcatcatcatcatcatcatgggtgggtggtcagcagaagggttatcaatatcgtgcattatatgattataaaaaagaacgtgaaga
agatatcgacttacatctgggagacattttaactgttaataaaggaagcttagtcgttttaggatttagtgatgggcaagaggcacgccctgaa
gaaattggatgggtgaatgggtataatgaaacaaccggcgaacgtggtgactttccgggtacctatgtagaatatcggtcgtaaaaaaatta
gccctggaggaggggggtctggaggtgggtgatccggtgtaattatcaatgtaaaatgtaaaattagtcgtcaatgtttagaaccttgtaaaaa
agcaggcatgcgctttgaaaatgtatgaacggtaaatgccattgcaccccaaaataatgaattc// SEQ ID NO:68;

M-G₂-H₆-G₃-SH3(1WA7)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtgggtcatcatcatcatcatcatgggtgggtggtccagaagaacaagggtgatattgtagttgctttatatccttatgatggattcatccag
acgatttaagttttaaaaaagggtgaaaaatgaaagtgttagaagaacatggagaatgggtggaaggcaaaaagtttattaacgaaaaaagaa
ggttttattccgtctaattatgtggcaaaattaaatacaggaggtgggggtgtagtggggggggaggatccggtgtaattattaatgtaaaat
gtaaaattagtcgtcaatgtttggaacctgtaaaaaagcaggatgcgctttgtaaatgtatgaatgtaaatgtcattgcactccaaaataat
 gaattc// SEQ ID NO:69;

M-G₂-H₆-G₃-SH3(1X2K)-(G₄S)₂-OsK1 (coding region underlined)

catatgggtgggtcatcatcatcatcatcatgggtgggtggttaaagttttcgcgcactttatacctttgaacccgtacccagatgaattatatttga
agaaggcgacattatttatattacggacatgtcagataactaattgggtggaaggaacaagcaaaggccgtactggactgatcccaagtaatta
cgtagcagaacaaggaggaggtgggtcaggaggaggtggatccggtgtaattatcaatgtaaaatgtaaaatctctcgtcaatgcctggaac
cctgtaaaaaagctggatgcgctttgtaaatgtatgaatgtaaatgtcattgcacccctaaataatgaattc// SEQ ID NO:70;

M-G₂-H₆-G₃-10thFn3-(G₄S)₂-ShK (coding region underlined)

catatgggtgggtcatcatcatcatcatcatgggtgggtgtaccgtaagcgatgttccccgtgacctggaagtgggtgcagcgaccctacctcat
tattaatcagttgggtatgcacctgcagttacagttcgggtattatcgtattacgtatggagagacaggcggaactcaccagttcaagaatttacc
gtccccgggtcttaaatcaacagcaacaatttcaggcttaaaaccaggagtagattacacaattacagtatacgcagtaacagggtcgcggcga
ctccccagctagctcaaaacctatctctattaattatcgacccgaagggtggcgagggttccgggtgggtggatcctgcatcgatacaatccct

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- 86 -

aagtcgctgtactgcctttcaatgcaaacactcaatgaaataccgtctcagtttctgtcgtaaaacctgtggcacctgttaatgaattc//

SEQ ID NO:71;

M-G₂-H₆-G₃-PDZ(1N7F)-(G₄S)₂-ShK (coding region underlined)

catatgggtggcatcatcatcatcatcatggtgggtggtccagcggtgcaattatctatacggtagaacttaaacgttacggtggctcctctgggt
attacaatcagcggcacagaagaaccctttgatccaattattttcatcgcttactaaaggtggtcttctgaacgcacagcgccattcatatt
ggagatcgtattttagctatcaactcatcatcattaaaaggcaaaccgttatcagaagctattcacttattacaaatggcgggcgaaacagttac
ccttaaaatcaaaaaacaaaccgacgcacaatctgcaagtagtccggggggaggcggctcaggaggaggaggatcctgcacgatacaa
tcctaagtcccgtgtactgcctttcaatgcaaacactcaatgaaataccgtctcagtttctgtcgtaaaacctgtggcacctgttaatgaattc/

/ SEQ ID NO:72;

M-G₂-H₆-G₃-PDZ(1UEZ)-(G₄S)₂- ShK (coding region underlined)

catatgggtggcatcatcatcatcatcatggtgggtggtccggcggaagttcgtcttgtagtttacgtcgcgcaaaagcacatgaaggcttag
gtttctcaattcgtggcggcagcgaacatggtgttggaatttatgtatccttagtagaacctggttagtttagccgaaaaagaaggcctgcgtgtc
ggcgatcaaatcttacgcgtcaacgataaatcttagcccggttactcatgccgaagccgttaaagcgttgaaaggtagcaaaaaattagttc
tgtctgtttattccgcaggtcgtattcctggtgggtggaggaaagtggtgggtggatcctgcacgatacaatccctaagtcccgtgtactgcc
ttcaatgcaaacactcaatgaaataccgtctcagtttctgtcgtaaaacctgtggcacctgttaatgaattc// SEQ ID NO:73;

M-G₂-H₆-G₃-PDZ(1WV)-(G₄S)₂- ShK (coding region underlined)

catatgggtggcatcatcatcatcatcatggtgggtggtcctcaagacttcgattactttactgttgatggaaaaagggtgcaaaagggttttggtt
tctctattcgtggcggcgtgaatataaaatggacttatatgtgttacgcttagctgaagacggaccgcaattcgtaacggacgtatgcgtgtt
ggcgatcaaatattgaaattaatggcgaatcaactcgtgatatgacccatgcacgtgcgattgaactattaaatctggaggacgtcgtgtac
gcttactcttaaaacgtggtacaggtcaggttcccgggtggcggcgccagtggtgggtggatcctgcacgatacaatccctaagtcccgt
gtactgcctttcaatgcaaacactcaatgaaataccgtctcagtttctgtcgtaaaacctgtggcacctgttaatgaattc// SEQ ID

NO:74;

M-G₂-H₆-G₃-SH2(1AB2)-(G₄S)₂- ShK (coding region underlined)

catatgggtggcatcatcatcatcatcatggtgggtggttaattcttagaaaaacattcatggtatcatggtcctgtatcacgtaacgcagccgaa
tatctcttattcttggcattaacggtagtttttagtccgcgaatccgaatcttctcctggccaacgcagtatcagttcctggtatgaaggctgtgt
gtatcattatcgcatcaataccgcttcagatggtaaattatatgttccctcgaaagtcgtttcaatacccttgcggaactcgttcacatcattcta
ctgtggcagatggtctcattacaacgttacattatcctgcacccggcggtgggtggctctggtgggtggcggatcctgcacgatacaatccctaa
gtcccgtgtactgcctttcaatgcaaacactcaatgaaataccgtctcagtttctgtcgtaaaacctgtggcacctgttaatgaattc// SEQ

ID NO:75;

M-G₂-H₆-G₃-SH2(1JYQ)-(G₄S)₂- ShK (coding region underlined)

catatgggtggcatcatcatcatcatcatggtgggtggtccttggttttttgtaaaatcccacgtgcgaaagctgaagaaatgctctcaaaaca
acgtcatgacgggtgattcttaattcgtgaaagtgaatctgctccaggtgattttagtttaagtgttaaatttggtaatgatgtccaacattttaagt

ccttcgtgatggtgcgggtaaataatTTTTATGGGTAGTCAAATCAATAGTCTTAACGAACCTGTCGATTATCATCGTTCCACCAGTGTTAGCCGTA
ATCAACAAATTTTCTCCGCGATATTGAACAAGGTGGTGGTGGTTCAGGAGGGGGCGGATCCTGCATCGATACAATCCCTAAGTCCCGCTGTA
CTGCCTTCAATGCAACACTCAATGAAATACCGTCTCAGTTTCTGTCGTAACCTGTGGCACCTGTTAATGAATC// SEQ ID NO:76;

M-G₂-H₆-G₃-SH3(1PHT)-(G₄S)₂- ShK (coding region underlined)

CATATGGGTGGTCATCATCATCATCATGGTGGTGGTTCAGCAGAAGGTATCAATATCGTGCATTATATGATTATAAAAAAGAACGTGAAGA
AGATATCGACTTACATCTGGGAGACATTTAACTGTTAATAAAGGAAGCTTAGTCGCTTAGGATTAGTGATGGGCAAGAGGCACGCCCTGAA
GAAATTGGATGGTTGAATGGTTAATGAAACAACCGGCGAACGTGGTGACTTCCGGGTACCTATGTAGAATATATCGGTCGTAACAAAAATTA
GCCCTGGAGGAGGGGGGTCTGGAGGTGGTGGATCCTGCATCGATACAATCCCTAAGTCCCGCTGTACTGCCTTCAATGCAACACTCAATG
AAATACCGTCTCAGTTTCTGTCGTAACCTGTGGCACCTGTTAATGAATC// SEQ ID NO:77;

M-G₂-H₆-G₃-SH3(1WA7)-(G₄S)₂- ShK (coding region underlined)

CATATGGGTGGTCATCATCATCATCATGGTGGTGGTCCAGAAGAACAAGGTGATATTGTAGTTGCTTTATATCCTTATGATGGTATTCATCCAG
ACGATTTAAGTTTAAAAAGGTGAAAAATGAAAGTGTAGAAGAACATGGAGAATGGTGAAGGCAAAAAGTTTATAACGAAAAAGAA
GGTTTATTCCGTCTAATTATGTGGCAAAATTAATACAGGAGGTGGGGGTGGTAGTGGGGGGGGAGGATCCTGCATCGATACAATCCCTAAG
TCCCGCTGTACTGCCTTCAATGCAACACTCAATGAAATACCGTCTCAGTTTCTGTCGTAACCTGTGGCACCTGTTAATGAATC// SEQ

ID NO:78; and

M-G₂-H₆-G₃-SH3(1X2K)-(G₄S)₂- ShK (coding region underlined)

CATATGGGTGGTCATCATCATCATCATGGTGGTGGTAAAGTTTTCCGCGCACTTTATACCTTGAACCCGTACCCAGATGAATTATTTTGA
AGAAGGCGACATTATTATATTACGGACATGTCAGATACTAATTGGTGGAAAGGAACAAGCAAAGGCCGTACTGGACTGATCCCAAGTAATTA
CGTAGCAGAACAAGGAGGAGGTGGCTCAGGAGGAGGTGGATCCTGCATCGATACAATCCCTAAGTCCCGCTGTACTGCCTTCAATGCAAA
CACTCAATGAAATACCGTCTCAGTTTCTGTCGTAACCTGTGGCACCTGTTAATGAATC// SEQ ID NO:79.

[00300] The synthesized DNA was initially digested with NdeI and EcoRI, and then ligated into likewise treated pAMG21(BamHI^r; Table 3).

Table 3. Nucleotide sequence of pAMG21(BamHI^r).

GATCAGCAGTCCCCGGAACATCGTAGCTGACGCCTTCGCGTTGCTCAGTTGTCCAACCCCGGAAACGGGAAAAAGCAAGTTTCCCCGCTCC
CGGCGTTCAATAACTGAAACCATACTATTTACAGTTTAAATCACATAACGACAGTAATCCCCGTTGATTGTGCGCAACACAGATCTTCG
TCACAATTCTCAAGTCGCTGATTCAAAAACTGTAGTATCCTCTGCGAAACGATCCCTGTTGAGTATTGAGGAGGCGAGATGTCGCAGACAG
AAAATGCAGTGACTTCTCATTGAGTCAAAAGCGGTTGTGCGCAGAGGTAAGCCTATGACTGACTCTGAGAAACAAATGGCCGTTGTTGCAA
GAAAACGCTTACACACAAAGAGATAAAAGTTTTGTCAAAAATCCTCTGAAGGATCTCATGGTTGAGTACTGCGAGAGAGAGGGGATAACAC
AGGCTCAGTTGTTGAGAAAATCATCAAAGATGAAGTCAAAGACTGGATATACTAAAGTAAAGACTTTACTTTGTGGCGTAGCATGCTAGATTA
CTGATCGTTAAGGAATTTGTGGCTGGCCACGCCGTAAGGTGGCAAGGAAGTGGTCTGATGTGGATTACAGGAGCCAGAAAAGCAAAAA
CCCCGATAATCTTCTCAACTTTTGCAGTACGAAAAGATTACCGGGGCCACTTAAACCGTATAGCCAACAATCAGCTATCGGGGGAGTATA
GTTATATGCCCCGAAAAGTTCAAGACTTCTTCTGTGCTCGCTCCTTCTGCGCATTGTAAGTGCAGGATGGTGTGACTGATCTTACCAAACGTATT
ACCGCCAGGTAAGAACCCGAATCCGGTGTTTACACCCCGTGAAGGTGCAGGAACGCTGAAGTCTGCGAAAACTGATGGAAAAGGCG
GTGGGCTTCACTTCCCGTTTGATTTCGCCATTCATGTGGCGCACGCCGTTGCGTGATCTGCGTCGCCGTATGCCACCAGTGCTGCGTCGTCG
GGCTATTGATGCGCTCTGCAGGGGCTGTGTTCCACTATGACCCGCTGGCCAACCGCGTCCAGTGCTCCATCACCACGCTGGCCATTGAGTG

cggactggcgacggagctctgctgccggaaaactctccatcaccctgccaccctgccctgacgttctgtcagagctgggactgattacct
accagacggaatatgaccgcttatcggtgtctacattccgaccgatatcacgttcacatctgcactgtttgctgccctcgatgtatcagagga
ggcagtgggcgccgcgcgcgcgcagccgtgtggtatgggaaaacaacaacgcaaaaagcaggggctggataccctgggcatggatga
actgatagcgaaagcctggcggtttgtcgtgagcgttttcgcagttatcagacagagcttaagtcctgggaataaagcgtgcccggtgcgcg
tcgtgatgcggacaggggaacgtcaggatattgtaccctgggtgaaacggcagctgacgcgcgaaatcgcggaagggcgcttcaactgcca
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tccccctgaaagtgacctctctgaataatccggcctgcgcgcggaggcttccgcacgtctgaagcccgacagcgcacaaaaaatcagcac
cacatacaaaaaacaacctcatcatccagcttctgggtcatccggccccctgttttcgatacaaaacacgcctcacagacggggaattttg
cttatccacattaaactgcaagggaacttcccataagggttacaaccgttcatgtcataaagcgccatccgccagcgttacagggtgcaatgtat
cttttaaacacctgtttatctctctttaaactacttaattacattcatttaaaaagaaaacctattcactgcctgtccttggacagacagatatgcac
ctcccaccgcaagcggcgggccccctaccggagcgcgttttagttacaacactcagacacaaccaccagaaaaacccccggctccagcgcaga
actgaaaccacaaagccccctccctcataactgaaaagcggccccggccgggtccgaaggcgccggaacagagtcgctttaaattatgaatgt
tgtaactacttcatcatcgtgtcagcttctcgtctggaagttctcagtacacgctcgtgaagcggccctgacggccccgtaacgcggagatac
gccccgacttccgggtaaacctcgtcgggaccactccgaccgcgcacagaagctctctcatggctgaaagcgggtatggctggcagggc
tggggatgggtaagggtgaaatctatcaatcagtagccggcttacgcccgggcttcggcggttttactcctgtttcatatatgaaacaacagggtcac
cgcttccatgccgctgatgcggcatatcctggtaacgatatctgaattgttatacatgtgtatatacgtggtaatgacaaaaataggacaagtt
aaaaattacaggcgatgcaatgattcaaacacgtaataatcgggggtgggcgaagaactccagcatgagatccccgcgctggaggat
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cgctcgttggtcggctcattcgaaccccagagtcggcgtcagaagaactcgtcaagaaggcgatagaaggcgatgcgctgcgaatcggga
gcggcgataccgtaaagcacgaggaagcggtcagccattcggcgccaagctcttcagcaataacacgggtagccaacgctatgtcctgat
agcggctccggcacacccagccggccacagtcgatgaatccagaaaagcggccatttccaccatgatattcggcaagcaggcatcgccat
gagtcacgacgagatcctcggcgtcgggcatgcgcgccttgagcctggcgaacagttcggctggcgcgagccccgatgctcttcgtcca
gatcatcctgatcgacaagaccggcttccatccgagtagctgtcgtcgtcgtatgcgatgttctcgttgggtggaatgggcaggttagccggat
caagcgtatgcagccggcgattgcatcagccatgatggatacttctcggcaggagcaaggtgagatgacaggagatcctgccccggca
cttcgccccaatagcagccagtccttcccgcttcagtgacaacgtcagacacagctgcgcaagggaacggccgtcgtggccagccacgata
gcccgcgtgccctcgtcctgcaattcattcaggacaccggacaggtcggctcttgacaaaaagaaccggcgccccctgcgtgacagccgga
acacggcggtcatcagagcagccgattgtctgttgcagcagtcagccgaatagcctctccaccaagcggccgggagaacctgcgtgca
atccatcttgttcaatcatgcgaaacgatcctcatcctgtctcttgatctgatcttgatccccctgcgccatcagatccttggcggcaagaaagcca
tccagtttactttgcagggttcccaaccttaccagagggcgccccagctggcaattccgggttcgcttgcgtgtccataaaaccgcccagcttag
ctatcgccatgtaageccactgcaagctacctgcttctcttgcgttgcgttttcccttgcagatagcccagtagctgacattcatccgggg
tcagcaccgttctgcggactggcttctacgtgttccgcttcccttagcagcccttgcgcctgagtgcttgcggcagcgtgaagctacatata
tgtgatccgggcaaatcgtgaatattcctttgtctccgaccatcaggcacctgagtcgctgtcttttctgtacattcagttcgtcgtcac
ggctctggcagtgatgggggttaattggcactacaggcgccctttatggattcatgcaaggaaactaccataatacaagaaaagcccgtca
cgggcttctcaggggcgttttatggcggtctgctatgtgtgctatctgacttttgcgttcagcagttcctgccctctgatttccagctgacca
cttcggattatcccgtgacagggtcattcagactggctaattgacccagtaaggcagcggatcatcaacagggttacccttcttactgtcgaa
gacgtgcgtaacgtatgatgtgtcctccatgcgagagtagggaactgccaggcatcaataaaacgaaaggctcagtcgaaagactggg
ccttctgtttatctgttgttgcgggtgaacgctctcctgagtaggacaaatccgcccgggagcggattgaacgttgcgaagcaacggccccg
aggggtggcgggcaggacggccgataaactgccaggcatcaataaagcagaaggccatcctgacggatggccttttgcgttctacaa
actcttttgtttatttttctaaatacattcaaatatggacgtcgtacttaacttttaaagtatgggcaatcaattgctcctgttaaaattgctttagaaata
ctttggcagcgggttgttattgagtttatttgcgcatgtttaaattgaaagtaccgtgcgttactacagcctaataattttgaaatatcca
agagcttttctcgtatgcccacgctaaacattcttttcttttggtaaactcgttgttgattattttgctatatttttgcataattatcaact
agagaagggaacaattaatggatgttcatacacgcagtaaaaaataaactatctatagttgtcttctgaatgtgcaaaactaagcattccg
aagccattattagcagtatgaatagggaactaaacccagtgataagacctgatgattcgttctttaaattacatttggagattttttattacagc
attgttttcaaatatattccaattaatcggtgaatgattggagttagaataatctactataggtatcatattttattaaattagcgtcatcataatattgcc
tccatttttagggtaattatccagaattgaaatatcagatttaaccatagaatgaggataaatgatcgcgagtaataatattcacaatgtaccatt
ttagtcatacagataagcattgattaatacattattgcttctacaggctttaaattttattatttctgtgaagtgtcgtcggcatttatgtcttctacac
ccatctctttatccttacctattgttgcgcaagtttgcgtgttatatacattaaaacggtaatatgattgacatttgatttcaataaattggattttgt
cacactattatcgttgaatacaattgtttaaataagtagctgttaggagctgtacaggtttacgcaagaaaatgggttgttatagtcgattaatc
gatttgattctagatttgttttaactaattaaaggaggaataacatatgtttaaaccggttggaaattcgagctcactagtgtcgacctgcagggtac
catggaagcttactcgaagatccgcggaaagaagaagaagaagaagaagccgaaaggagctgagttggctgctgccaccgctgag

caataactagcataaccccttggggcctctaaacgggtcttgaggggtttttgctgaaaggaggaaccgctcttcacgctcttcacgcggata
aataagtaacgatccgggtccagtaatgacctcagaactccatctggattgttcagAACGCTCGGTTGCCCGGGCGTTTTATTGGTGAGAA
tcgcagcaactgtcgcgccaatcgagccatgtcgtcgtcaacgacccccattcaagaacagcaagcagcattgagaactttggaatcca
gtccctcttcacctgctgaccg// SEQ ID NO:57

[00301] This created the nine OSK1 fusions, as well as the first ShK fusion; to make the remaining ShK fusions (actually [desArg1]ShK fusions), the toxin DNA was first excised with BamHI and EcoRI digestion. Then the ShK (actually [desArg1]ShK peptide analog) coding sequence was ligated downstream of the small domain fusion partners. In addition, several of the ShK (actually [desArg1]ShK) fusions were excised with NdeI/EcoRI digestion and ligated to likewise digested pET30 DNA (Table 4).

Table 4. Nucleotide sequence of pET30.

atccggatagttcctccttcagcaaaaaacccctcaagaccggttagaggccccaaggggttatgctagttattgctcagcgggtggcag
cagccaactcagcttccttcgggctttgttagcagccggatctcagtggtggtggtggtggtgctcagtgccggccgaagctgtcgacg
gagctcgaattcggatccgatatcagccatggccttgtcgtcgtcgtcgggtaccagatctgggctgtccatgtgctggcgttcgaatttagca
gcagcgggtttcttcataaccagaaccgcgtggcaccagaccagaagaatgatgatgatggtgcatatgtatatctccttcttaaagttaaac
aaaattatttctagaggggaattgtatccgctcacaattcccctatagtgagtcgtattaatttcgcgggatcgagatcgatctcgatcctctacg
ccggacgcacgtggccggcatcaccggcgccacaggtgcgggtgctggcgccctatatcgccgacatcaccgatggggaagatcgggct
cgccacttcgggctcatgagcgttgttcggcgtgggtatggtggcaggccccgtggccgggggactgttggcgccatctccttgcag
caccattccttgcggcgggcgtgctcaacggcctcaacctactactgggctgcttcctaatgcaggagtcgcataaggagagcgtcgaga
tcccggaacacatcgaatggcgcaaaaccttgcgggtatggcatgatagcggcggaagagagtcgaattcagggtggtgaatgtgaaacc
agtaacgttatacgtatgtcgcagagtatgccggtgtctcttatcagaccgttcccgcgtggtgaaccaggccagccacgttctgcgaaaac
gcgggaaaaagtggaaagcggcgatggcgagctgaattacattcccaaccgcgtggcacaacaactggcgggcaaacagtcgttgcgtga
ttggcgttggccactccagcttggccctgcacgcgccgtcgcaaatgtcgcggcgattaaatctcgcgccgatcaactgggtgccagcgtg
gtggtgtcgtatgtagaacgaagcggcgctcgaagcctgtaaagcggcggtgcacaatctctcgcgcaacgcgtcagtggtggtgatcatta
actatccgctggatgaccaggatgccattgctgtggaagctgcctgcactaatgtccggcggtatttcttgatgtctctgaccagacaccatc
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cgactggagtgccatgtccggtttcaacaaacctgcaaatgctgaatgagggcatcgttcccactgcgatgctggttgccaacgatcagat
ggcgttggcgcaatgcgcgccattaccgagtcgggctgcgcgttgggtgcggacatctcggtagtgggatacgacgataccgaagaca
gctcatgttatatcccgccgttaaccacatcaaacaggatttgcctgctggggcaaaccagcgtggaccgcttgcgaactctctcagg
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gcgcgttggccgattcattaatgcagctggcacgacaggttcccactggaaagcgggcagtgagcgcgaacgaattaatgtaagttagct
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gcgagaagcaggccattatcgccggcatggcgggccccacgggtgcgcatgatcgtgctcctgtcgttgaggaccgggctaggctggcgg
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ccagttgtttaccctcacaacgttccagtaaccgggcatgttcatcatcagtaaccggtatcgtgagcatcctctctcgttcatcggtatcattac
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gacattaacgcttctggagaaactcaacgagctggacgcggatgaacaggcagacatctgtgaatcgcttcacgaccacgctgatgagctt
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tgccgggagcagacaagcccgctcagggcgcgctcagcgggtgttggcgggtgtcggggcgagccatgacccagtcacgtagcgatagc
ggagtgtatactggcttaactatgcggcatcagagcagattgtactgagagtgcaccatatatgcgggtgtgaaataccgcacagatgcgtaa
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cgcctttctcccttcgggaagcgtggcgcttttctcatagctcacgctgtaggtatctcagttcggtgtaggtcgttcgctccaagctgggctgtg
tgcacgaaccccccggtcagcccgaccgctgcgccttaccggtaactatcgtcttgagtccaacccggtaagacacgacttatcgccactg
gcagcagccactggtaacaggattagcagagcgaggtatgtaggcggtgctacagagttcttgaagtgggtggcctaactacggctacacta
gaaggacagtatttggatctgcgctctgctgaagccagttaccttcgaaaaagagttggtagctcttgatccggcaaaacaaccaccgctg
gtagcgggtgggtttttgttgaagcagcagattacgcgcagaaaaaaaggatctcaagaagatcctttgatctttctacggggtctgacgct
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cagatgagatggtcagactaaactggctgacggaatttatgcctcttccgaccatcaagcattttatccgtactcctgatgatgcattgttactca
ccactgcgatccccgggaaaacagcattccaggtattagaagaatatcctgattcaggtgaaaatattgttgatgcgctggcagtggtcctgcg
ccggttgcattcgattcctgtttgtaattgtccttttaacagcgcgctatttcgtctcgcctcagggcgcaatcacgaatgaataacgggttggt
gatgcgagtgttttgatgacgagcgtaatggctggcctgttgaacaagtctggaaagaaatgcataaacttttgccattctcaccggattcagt
cgtcactcatggtgatttctcattgataacctattttgacgaggggaaataataggttgattgatgttgacgagtcggaatcgagaccg
ataccaggatcttgccatcctatggaactgcctcgggtgagttttctccttcattacagaaacggctttttcaaaaataggtattgataatcctgata
tgaataaattgcagtttcatttgatgctcgatgagttttctaagaattaattcatgagcggatacatatttgatgtatttagaaaaataaacaata
gggggtccgcgcacattccccgaaaagtgccacctgaaattgtaaactgtaaatattttgttaaaattcgcggttaaattttgttaaatcagctcattt
tttaaccaataggccgaaatcggaacaaatcccttataaatcaaaagaatagaccgagatagggttgagtggttccagtttgaacaagagtc
cactattaaagaacgtggactccaacgtcaaagggcgaaaaaccgtctatcagggcgatggccactacgtgaaccatcacctaatcaag
tttttggggtcgaggtgccgtaaagcactaaatcggaaccctaaagggagcccccgatttagagcttgacgggggaaagccggcgaaacgtg
gcgagaaaggaagggaagaaagcgaaaggagcgggcgctagggcgctggcaagtgtagcggtcacgctgcgcgtaaccaccacacc
cgccgcgcttaatgcgccgctacagggcgcgctccattcgcca// SEQ ID NO:58

[00302] The MK6H-G2-SH3-G5-2X(TMP22-7Q) fusion construct (Table 4A) was made as follows. A PCR fragment was amplified from strain 14066 harboring a plasmid encoding SH3 and MP22-7Q using the following two primers: GAG GAA TAA CAT ATG AAA CAT CAT CAT CAT CAT CAT GGT GGT AAA GTT TTT CGC GCA CTT TAT ACC TTT (SEQ ID NO:51), which encodes lysine, the 6 histidine tag, the glycine-glycine linker, the first 9 amino acids of SH3 plus a 15 nucleotides 5' extension including an NdeI site and GTT ATT GCT CAG CGG TGG CA (SEQ ID NO:52), which encodes a 20 nucleotides universal reverse primer for the pAMG21 vector. The PCR product was cloned in pAMG21 vector using NdeI and EcoRI sites, and the sequenced was confirmed.

Table 4A. Amino acid sequence of MK6H-G2-SH3-G5-2X(TMP22-7Q).

MKHHHHHHGGKVFRALYTFEP RTPDELYFEEGDIIYITDMSDTNWWKGT SKGRGLIPSNYVAEQ
GGSGGQGCSSGGPTLREWQQCRRMQHSGGGGGGGGQGCSSGGPTLREWQQCRRMQHSGG//
SEQ ID NO:86

[00303] The MK6H-G2-PDZ-G5-2X(TMP22-7Q) fusion construct (Table 4B) was made as follows. A PCR fragment was amplified from strain 14175 harboring a plasmid encoding PDZ and TMP22-7Q using the following two primers: AG GAA TAA CAT ATG AAA CAT CAT CAT CAT CAT GGT GGT CCG GGC GAA GTT CGT CTT GTT AGT (SEQ ID NO:53), which encodes lysine, the 6 histidine tag, the glycine-glycine linker, the first 8 amino acids of PDZ plus a 15 nucleotides 5' extension including an NdeI site and GTT ATT GCT CAG CGG TGG CA (SEQ ID NO:54), which encodes a 20 nucleotides universal reverse primer for the pAMG21 vector. The PCR product was cloned in pAMG21 vector using NdeI and EcoRI sites, and the sequenced was confirmed.

Table 4B. Amino acid sequence of MK6H-G2-PDZ-G5-2X(TMP22-7Q).

MKHHHHHHGGPGEVRLVSLRRAKAHEGLGFSIRGGSEHGVGIYVSLVEPGSLAEKEGLRVGDQI
LRVNDKSLARVTHAEAVKALKGSKKLVLSVYSAGRIPGGSGGQGCSSGGPTLREWQQCRRMQH
SGGGGGGGGQGCSSGGPTLREWQQCRRMQHSGG// SEQ ID NO:87

[00304] The MK6H-G2-Fn3-G5-2X(TMP22-7Q) fusion construct (Table 4C) was made as follows. A PCR fragment was amplified from strain 14176 harboring a plasmid encoding Fn3 and TMP22-7Q using the following two primers: GAG GAA TAA CAT ATG AAA CAT CAT CAT CAT CAT GGT GGT ACC GTA AGC GAT GTA CCA CGC GAT (SEQ ID NO:55), which encodes lysine, the 6 histidine tag, the glycine-glycine linker, the first 8 amino acids of Fn3 plus a 15 nucleotides 5' extension including an NdeI site and GTT ATT GCT CAG CGG TGG CA (SEQ ID NO:56), which encodes a 20 nucleotides universal reverse primer for the pAMG21 vector. The PCR product was cloned in pAMG21 vector using NdeI and EcoRI sites, and the sequenced was confirmed.

Table 4C. Amino acid sequence of MK6H-G2-Fn3-G5-2X(TMP22-7Q).

MKHHHHHHGGTVSDVPRDLEVVAATPTSLLISWDAPAVTVRYRITYGETGGNSPVQE
FTVPGSKSTATISGLKPGVDYTITVYAVTGRGDSPASSKPISINYRTEGGSGGQGCSSGGP
TLREWQQCRRMQHSGGGGGGGGQGCSSGGPTLREWQQCRRMQHSGG// SEQ ID NO:88

[00305] Protein Expression. All the pAMG21 constructs were transformed into competent E. coli GM221 cells for expression (GM221 was derived from the K12 strain). Transformants were grown overnight (o/n) in TB media (1.2% Tryptone, 2.4% yeast extract, 0.4% glycerol, 72

mM K₂HPO₄, and 17 mM KH₂PO₄) supplemented with 40 µg/mL kanamycin. This o/n culture was diluted 1:100 into fresh media the following morning. The cells were then grown to an optical density (OD) at 600 nm of 0.4 - 0.6. Expression commenced upon addition of N-(3-oxo-hexanoyl) homoserine lactone (HSL) at a final concentration of 50 µg/mL. Harvesting by centrifugation was done 3 to 4 hours later. Expression levels were visualized and evaluated by Coomassie gel (see Figure 4A-B and Table 5).

[00306] All the expression testing of the TMP fusion constructs was done with 5 ml test tubes using terrific broth. Cells were induced at 37°C with N-(3-oxo-hexanoyl) homoserine lactone(HSL) for 6 hours. Whole cell extracts, soluble and insoluble fractions were analyzed using a 4-20% Tris-Glycine gel. The MK6H-G2-SH3-G5-2X(TMP22-7Q) construct showed good expression with about 25% of the recombinant protein insoluble and most of the soluble fraction is in the lower band (Figure 5A-B). The MK6H-G2-PDZ-G5-2X(TMP22-7Q) construct showed very good expression with approximately 50% of the recombinant protein in the insoluble fraction and 50% of the recombinant protein in the soluble fraction. The MK6H-G2-Fn3-G5-2X(TMP22-7Q) also expressed well with about 15% of the recombinant protein in the insoluble fraction and the remainder in the soluble fraction.

Table 5. Relative expression levels of various ShK (actually [desArg1]ShK) fusion and OSK1 fusion constructs: “+/-“ means a faint band was observed; “+” represents a weak band indicating definite low level expression of the recombinant fusion protein; “++” represents a moderately strong band indicating strong expression of the recombinant fusion protein; “+++” represents a strong band indicating high level expression of the recombinant fusion protein. The word “clipped” in the table refers to bands that ran significantly below their calculated mass; in some cases, two bands were apparent – one expected to be the full-length and another smaller product, for which protease-mediated clipping of the recombinant fusion protein is the most likely explanation.

	<u>pAMG21</u>	<u>pET30</u>
M-G ₂ -H ₆ -G ₃ -10 th Fn3-(G ₄ S) ₂ -OsK1	+++	NA
M-G ₂ -H ₆ -G ₃ -PDZ(1N7F)-(G ₄ S) ₂ -OsK1	++	NA
M-G ₂ -H ₆ -G ₃ -PDZ(1UEZ)-(G ₄ S) ₂ -OsK1	+++	NA
M-G ₂ -H ₆ -G ₃ -PDZ(1WFFV)-(G ₄ S) ₂ -OsK1	+	NA
M-G ₂ -H ₆ -G ₃ -SH2(1AB2)-(G ₄ S) ₂ -OsK1	++	NA
M-G ₂ -H ₆ -G ₃ -SH2(1JYQ)-(G ₄ S) ₂ -OsK1	+/-	NA
M-G ₂ -H ₆ -G ₃ -SH3(1PHT)-(G ₄ S) ₂ -OsK1	++	NA

M-G ₂ -H ₆ -G ₃ -SH3(1WA7)-(G ₄ S) ₂ -OsK1 ^b	++ clipped	NA
M-G ₂ -H ₆ -G ₃ -SH3(1X2K)-(G ₄ S) ₂ -OsK1	+++	NA
M-G ₂ -H ₆ -G ₃ -CH2-(G ₄ S) ₂ -OsK1	+++	NA
M-G ₂ -H ₆ -G ₃ -10 th Fn3-(G ₄ S) ₂ -ShK	+/-	NA
M-G ₂ -H ₆ -G ₃ -PDZ(1N7F)-(G ₄ S) ₂ -ShK	+	++
M-G ₂ -H ₆ -G ₃ -PDZ(1UEZ)-(G ₄ S) ₂ -ShK	+/-	++
M-G ₂ -H ₆ -G ₃ -PDZ(1WfV)-(G ₄ S) ₂ -ShK	+/-	NA
M-G ₂ -H ₆ -G ₃ -SH2(1AB2)-(G ₄ S) ₂ -ShK	+/-	NA
M-G ₂ -H ₆ -G ₃ -SH2(1JYQ)-(G ₄ S) ₂ -ShK	+/-	NA
M-G ₂ -H ₆ -G ₃ -SH3(1PHT)-(G ₄ S) ₂ -ShK	+/-	NA
M-G ₂ -H ₆ -G ₃ -SH3(1WA7)-(G ₄ S) ₂ -ShK	+/- clipped	+ clipped
M-G ₂ -H ₆ -G ₃ -SH3(1X2K)-(G ₄ S) ₂ -ShK	+/-	++
M-G ₂ -H ₆ -G ₃ -CH2-(G ₄ S) ₂ -ShK	++	NA

[00307] Protein Purification. Inclusion bodies were prepared by thawing frozen cell paste in 5 times the pellet mass (defined as 1 volume assuming 1 g = 1 mL) of room temperature 50 mM tris HCl pH 8.0, 5 mM EDTA with approximately 0.1 mg/ml hen egg white lysozyme using a tissue grinder. The suspension was then passed through a microfluidizer twice at about 12,000 PSI to disrupt the cells. The homogenized suspension was then centrifuged at 11,300 g for 50 min at 4 °C and the supernatant was discarded. The pellet was resuspended in ½ volume of 1% deoxycholic acid using a tissue grinder and centrifuged at 15,300 g for 40 min at 4 °C discarding the supernatant. The pellet was then resuspended in ½ volume of water using a tissue grinder and centrifuged at 15,300 g for 40 min at 4 °C discarding the supernatant. The lysate and wash fractions were evaluated by SDS-PAGE (Figure 6A-E).

[00308] The insoluble proteins were then subjected to protein refolding by first dissolving the washed inclusion bodies at a ratio of 9 ml of 8 M guanidine HCl with 50 mM tris pH 8.0 per gram of pellet mass using a tissue grinder followed by reduction using 10 mM DTT with gentle agitation for 30 min at room temperature. The refolding was then initiated by slowly adding 1 part by volume of the reduced denatured protein solution to 100 parts by volume of the refolding buffer cocktail (1 M urea, 50 mM ethanolamine, 160 mM arginine HCl, 5 mM EDTA, 0.02%

NaN₃, pH 9.8, 4 mM cysteine, and 1.2 mM cystamine HCl) at 4 °C. The refolding mixture was then incubated at 4 °C with gentle stirring typically from 2 to 4 days.

[00309] Purification of the refolding cocktail was then conducted by first filtering the refold mixture through a 0.45 µm cellulose acetate filter. The filtered solution was then concentrated and buffer exchanged using a Pall Omega 3 kDa UF/DF membrane and Ni-Buffer A (50 mM NaH₂PO₄, 300 mM NaCl, pH 7.5). After removing the retentate, the apparatus was flushed with Ni-Buffer A and combined this with the retentate, which was then filtered through a 0.45 µm cellulose acetate filter. The 1PHT and 1AB2 constructs were refolded in the absence of EDTA, hence, the diafiltration step was bypassed for these constructs. To the buffer exchanged material, 1/100 of a volume of 500 mM imidazole was added, then the protein was applied to a Qiagen Ni-NTA Superflow^{*} column in Ni-Buffer A at about 13 °C. The column was washed with several column volumes of Ni-Buffer A followed by 8% Ni-Buffer B (250 mM Imidazole, 50 mM NaH₂PO₄, 300 mM NaCl, pH 7.5). The protein was eluted with 60% Ni-Buffer B. The eluted protein was then dialyzed against 10 mM NaH₂PO₄, pH 7.1 over night at 7 °C using a Pierce Slide-A-Lyzer with a 3.5 kDa membrane. The protein was further purified by loading on to a GE HiTrap SP-HP column in S-Buffer A (10 mM NaH₂PO₄, pH 7.1) at about 13 °C. The column was washed with several column volumes of S-Buffer A, then eluted with a linear gradient to 60% S-Buffer B (1 M NaCl, 10 mM NaH₂PO₄, pH 7.1). The fractions were pooled based on SDS-PAGE analysis and concentrated to 2.47 to 5.44 mg/ml using a Pall Macrosep with a 3 kDa membrane at 4 °C. The final product was then filtered through a 0.22 µm cellulose acetate filter.

[00310] The concentration of the products was then analyzed by conducting a spectral scan from 250 to 340 nm, and concentrations were calculated using the molecular masses and extinction coefficients at 280 nm listed in Table 6 below. The pyrogen content was then determined using the Charles River Laboratories cartridge (0.05 – 5 EU/ml sensitivity) pyrogen assay diluting the samples to read between 1 and 100 EU/mg. The aggregation state was determined by injecting the protein solution on to a Phenomenex SEC 3000 column (7.8 x 300 mm) in SEC-Buffer (50 mM NaH₂PO₄ pH 6.9, 250 mM NaCl) at 1 ml/min observing the absorbance at 280 nm (Figure 7A-F). The purity of the proteins was assessed using a 1.0 mm 4-12% BisTris NuPAGE gel developing at 200V for 30 min in MES SDS running buffer and non-reducing NuPAGE loading buffer. The gels were stained with Boston Biologicals QuickBlue stain (Figure 8A-C). The molecular mass of the products was verified using mass spectroscopy (Figure 9A-E).

*Trademark

Table 6. Product concentrations of OSK1 fusion proteins.

Construct	ϵ ($M^{-1} cm^{-1}$)	MW (Daltons)	Concentration (mg/ml)
CH2 SEQ ID NO:80	17,460	17,373	3.35
FnIII SEQ ID NO:81	14,090	16,099	2.47
1X2K SEQ ID NO:84	17,220	12,382	5.44
1UEZ SEQ ID NO:85	3,280	15,574	2.70
1N7F SEQ ID NO:83	3,280	16,148	4.01
1PHT SEQ ID NO:82	15,390	15,324	3.90

[00311] Bioactivity Assay. To determine the activity of the purified OsK1 fusions, test samples were serially diluted 1:3 eight times in 0.3% bovine serum albumin in PBS, with Ca^{2+} and Mg^{2+} . CHO cells stably expressing the voltage-activated K^+ channel, Kv1.3, were plated in T-175 tissue culture flasks (at a density of 5×10^6) 2 days before experimentation and allowed to grow to around 95% confluence. Immediately prior to the experiment, the cells were washed with

PBS and then detached with a mixture (2 ml) of trypsin (0.25%) and Versene^{*} (1:5000) (1:1 volume ratio) at 37 °C (for 3 minutes). Subsequently, the cells were re-suspended in the flask in 10 ml of tissue culture medium (HAM's F-12 with Glutamax, InVitrogen, #31765) with 10% FBS, 1x NEAA and 750 µg/ml of G418) and centrifuged at 1000 rpm for 1.5 minutes. The resultant cell pellet was re-suspended in PBS at $3-5 \times 10^6$ cells/ml. The ability of the peptides to inhibit K^+ currents in the CHO-K_v1.3 cells was investigated using the automated electrophysiology system IonWorks Quattro. Re-suspended cells, the assay plate, a population patch clamp (PPC) patch plate as well as appropriate intracellular (90mM K-Gluconate, 20mM KF, 2 mM NaCl, 1mM MgCl₂, 10mM EGTA, 10mM HEPES, pH 7.35) and extracellular (PBS, with Ca^{2+} and Mg^{2+}) buffers and were positioned on the IonWorks Quattro. Electrophysiology recordings were made from the CHO-K_v1.3 cells using an amphotericin-based perforated patch-clamp method. Using the voltage-clamp circuitry of the IonWorks Quattro, cells were held at a membrane potential of -80 mV and voltage-activated K^+ currents were evoked by stepping the membrane potential to +30 mV for 400 ms. K^+ currents were evoked under control conditions (i.e. in the absence of inhibitor at the beginning of the experiment) and after a 10-15 minute incubation in the presence of the test solution. The mean K^+ current amplitude was measured between 430 and 440 ms. The amplitude of the K^+ current in the presence of each concentration of the test samples was expressed as a percentage of the K^+ current in control conditions in the same well. The data were then plotted as a function of peptide concentration in the test solution and the IC₅₀ value was estimated using the following logistic equation: $(Y=A+((B-A)/(1+((X/C)^D)))$, where A is min, B is max, C is IC₅₀, D is slope, X is concn range, Y is POC range.

[00312] Example 2. PEGylation of fusion proteins

[00313] Six different OSK1 fusion proteins (SEQ ID NOS:80-85) were PEGylated with 20 kDa methoxy-PEG-aldehyde by reductive alkylation of their reactive amino groups similar to methods previously described in Kinstler et al., N-terminally chemically modified protein compositions and methods, U.S. Patent No. 5,824,784. Briefly, the purified fusion proteins were diluted to 2 mg/ml in 50 mM NaOAc, pH 5.0 to which 20 kDa methoxy-PEG-propionaldehyde (Nektar, Huntsville, AL) was added in a 2-fold molar excess, followed by a sufficient volume of 1 M sodium cyanoborohydride to result in a final concentration of 10 mM. The reaction was sealed and mixed gently overnight at 4 °C. Upon completion of the reaction period, the reactions were quenched by 4-fold dilution with 20 mM NaOAc, pH 4.0.

*Trademark

[00314] The mono-substituted PEG conjugates were purified from the poly-substituted conjugates and un-reacted fusion proteins by preparative FPLC (Akta, GE Healthcare, Piscataway, NJ) using 5 ml SP Sepharose HP HiTrap columns in a 10 mM NaOAc, pH 4 buffer and eluted with a linear 0-0.5 M NaCl gradient over 25 column volumes. Figure 10 shows a chromatogram from the purification of 20 kDa mPEG-1UEZ-OSK1 and is representative of the other purifications. Eluted peak fractions were evaluated by SDS-PAGE to identify fractions containing mono-substituted PEG-conjugates. These were pooled, concentrated and dialyzed into PBS. The final purified pools were characterized by SDS-PAGE (Figure 11A-B) and submitted for further analyses.

[00315] Whole Blood Activity Assay. For the in vitro whole blood activity assay of the compounds after PEGylation, the compounds were serially diluted 1:3 in DMSO (Sigma #D2650) and then diluted into Assay Medium (Iscoves DMEM (Gibco #2440-053) + 0.1% Human Albumin (Human Serum Albumin 25% USP, Gemini #800-120) + 1x Pen/Strep/Glu (Gibco #10378-016) + 55 μ M 2-mercaptoethanol (Gibco #21985-023)) to 4 times the working concentration in polypropylene 96 well plates (Corning #3365 or #3957). Samples were serially diluted 1:3 into Assay Medium to 4 times the working concentration.

[00316] Fifty microliters of samples were added to each well of 96 well flat bottom tissue culture plates (Falcon* #35-3072). One hundred μ l of heparinized human whole blood from healthy, non-medicated donors was then added. The plates were incubated for 1 hour at 37 °C. After incubation, 50 μ l per well of either 40 μ M thapsigargin (Alomone Labs #T-650) for a final concentration of 10 μ M or assay media (negative control) was added and plates were incubated at 37 °C for 48 hours. One hundred μ l of the supernatant was then collected into round bottom polypropylene 96 well plates (Corning #3355) and either analyzed immediately or stored at -80 °C.

[00317] Cytokines (human IL-2 and human IFN- γ) were measured on MSD MS6000 4 Spot Plates (#N411B-1) per the manufacturer's recommendation. In brief, 20 μ l of supernatant was added per well to MSD plates followed by 130 μ l per well of detection antibody cocktail. The plate was then sealed and shaken in the dark at room temperature overnight. Plates were read the following morning on an MSD Sector HTS instrument (Meso Scale Discoveries, Gaithersburg, MD). Data were then analyzed and IC₅₀ values generated using ActivityBase and Xlfit programs (IDBS, Guildford, UK). (Table 7 below).

Table 7. Bioactivity of PEGylated OSK1 fusion proteins.

PEGylated Construct	IL-2 IC50	IL-2 IC50	IFN- γ IC50	IFN- γ IC50
	Donor 1	Donor 2	Donor 1	Donor 2
	(μ M)	(μ M)	(μ M)	(μ M)
CH2 SEQ ID NO:80	0.007429	0.00922	0.088987	0.0113
FnIII SEQ ID NO:81	0.018726	0.03476	0.037399	0.003634
1X2K SEQ ID NO:84	0.007057	0.020087	0.011178	0.013763
1UEZ SEQ ID NO:85	0.00533	>0.100000	0.004107	0.014324
1N7F SEQ ID NO:83	0.033277	0.079462	>0.100000	>0.033333
1PHT SEQ ID NO:82	0.017752	>0.100000	>0.100000	>0.100000

[00318] Pharmacokinetics of fusion proteins. The Swiss Webster mice used to determine the pharmacokinetic properties of the fusions were obtained from Taconic Inc. (nomenclature: Tac:SW). The mice were 8-10 weeks of age at the time of dosing and the average weight was 31 grams. The mice were maintained in groups of 5 in static filter top cages on Sani-Chip (Harlan-Teklad, Inc.) bedding. The mice were provided with irradiated rodent chow (Harlan-Teklad rodent diet 2919) and reverse osmosis water, *ad libitum*. The mice were maintained in a facility that is AAALAC accredited. Environmental conditions and sanitation practices meet or exceed

standards set by the Guide for the Care and Use of Laboratory animals. The mice were exposed to a 12 hour light, 12 hour dark light cycle (6:30 AM-6:30 PM). The total volume injected per mouse was 150 µl at 2mg/kg, intravenous. The animals were euthanized (CO₂ gas inhalation) 24 hours after injection with the test compounds, and blood was collected by cardiac puncture. The blood was placed in serum separator tubes (B.D.). The levels of the fusion proteins was determined by the whole blood activity assay described above (Figure 12).

[00319] Example 3. Villin Headpiece Protein Fusions and PEGylation.

[00320] In another embodiment of the present invention a small protein domain was selected that is an autonomously folding protein fragment from villin, which has an unusually thermostable structure and contains no cysteine. Several internal sites suitable for mutation to cysteine have been identified that allow PEGylation while not interfering with peptide fusions at either the N- or C-terminus of the small pharmacologically inactive protein domain. Provided herein is an example that the villin headpiece fusion platform permits recombinant expression of small, therapeutic peptides while allowing, optionally, facile PEGylation for enhanced pharmacokinetic properties.

[00321] Villin is a large (92.5 kDa) actin-binding protein involved in the maintenance and organization of actin filaments and implicated in the formation of microvilli in absorptive tissues. The protein is broadly expressed in a variety of tissues and the human sequence has been determined. (Arpin, M., et al., *Sequence of human villin: A large duplicated domain homologous with other actin-severing proteins and a unique small carboxy-terminal domain related to villin specificity*. J. Cell Biol., (1988). 107: p. 1759-1766). Villin activity is shared between two domains, a large core domain (84 kDa) and a much smaller, C-terminal domain (8 kDa) called the "headpiece". Both domains contain independent actin binding sites. An NMR structure of the villin headpiece domain has been determined and the actin-binding site and unique structural features mapped by cysteine scanning mutagenesis. (Vardar, D., et al., *NMR structure of an F-actin-binding "headpiece" motif from villin*. J. Mol. Biol., (1999). 294: p. 1299-1310; Doering, D.S. and P.T. Matsudaira, *Cysteine scanning mutagenesis at 40 of 76 positions in villin headpiece maps the F-actin binding site and structural features of the domain*. Biochemistry, (1996). 35: p. 12677-12685). These studies of the villin headpiece have lead to the identification of a headpiece subdomain called "HP-35" and consisting of the last 35 amino acids of the headpiece. The HP-35 polypeptide contains no cysteine and was readily expressed in *E. coli* independent of the remaining headpiece sequence. This fragment was found to fold

autonomously into a stable, monomeric and well-organized structure. (McKnight, C.J., et al., A thermostable 35-residue subdomain within villin headpiece, J. Mol. Biol., (1996). 260: p. 126-134). HP-35 appears to be unique as the smallest known polypeptide with no disulphide bonds, which demonstrates reversible unfolding with unusually high thermostability ($T_m = 70^\circ\text{C}$) and resistance to guanidine-HCl denaturation ($>4\text{ M GuHCl}$). Although the HP-35 subdomain contains some of the actin-binding site found in the headpiece domain, HP-35 does not bind actin. (See, Luna, E.J., et al., Actin-binding polypeptides and nucleic acids encoding the same., US 5,985,608, (1999)). There has also been an NMR structure determined for HP-35 which indicates a very stable, well packed three-helix structure nearly identical to the equivalent sequence in the intact headpiece structure. (McKnight, J.C., P.T. Matsudaira, and P.S. Kim, *NMR structure of the 35-residue villin headpiece subdomain*. Nature Structural Biology, (1997). 4: p. 180-184). These studies conclude that most of the structural stability of the headpiece domain is derived from the HP-35 subdomain. Similarly, the larger extended villin headpiece domain consisting of the last 76 amino acids called HP-76 was also characterized as a fusion partner.

[00322] In order to facilitate subsequent PEGylation of the HP35-, or HP76-peptide fusion proteins three different positions for single cysteine substitutions were tested: T48C, A56C or N68C. These mutation sites are located on the solvent exposed surface of each of the three helices and are sufficiently distal to the polypeptide termini to minimize interference with the therapeutic peptide fusion partner once PEGylated. Each of these cysteine mutations has been shown to be well-tolerated and solvent exposed in expressed headpiece mutants. (Doering, D.S. and P.T. Matsudaira, *Cysteine scanning mutagenesis at 40 of 76 positions in villin headpiece maps the F-actin binding site and structural features of the domain*. Biochemistry, (1996). 35: p. 12677-12685). In fact, cysteine at position 68 was found to be stabilizing and increased the thermal stability of headpiece by 8°C . Although most of the HP-35 studies have been done with the chicken sequence, there is substantial homology with the equivalent human sequence (Figure 13). The suggested cysteine mutation sites for the human sequence are conserved if not identical between the two species.

[00323] PTH-HP76 fusion protein. In one embodiment of the inventive recombinant fusion protein, parathyroid hormone (PTH) was fused to the villin headpiece domain HP76 using conventional molecular biology techniques resulting in a polypeptide of the following sequence:

SVSEIQLMHN LGKHLNSMER VEWLRKKLQD VHNFGGGGGV FNANSNLSSG
 PLPIFPLEQL VNKPVEELPE GVDPSRKEEH LSIEDFTQAF GMTPAAFSAL
 PRWKQQCLKK EKGLFH~~HHHH~~ H// SEQ ID NO:59.

[00324] In this construct, the therapeutic peptide PTH represents the first 34 amino acids, the next 5 glycine residues represent a linker, followed by the 76 amino acids of the HP76 domain which includes the N68C mutation (underlined cysteine residue in SEQ ID NO:59) for conjugation to PEG and a six- histidine extension to facilitate IMAC purification.

[00325] Expressed in E. coli, the PTH-HP76 fusion was detected by western blot in both the soluble and insoluble fractions of the cell lysate. However, some degradation of the PTH-HP76 molecule was observed when the fusion protein was isolated from the soluble fraction. In contrast, PTH-HP76 isolated from the insoluble fraction appeared largely intact. Briefly, the cells were lysed, centrifuged and the insoluble pellet dissolved in 8 M urea, 10 mM NaHPO₄, 50 mM NaCl, 10 mM DTT, pH7.5 by stirring 30 min. at 4 degrees C.

[00326] The solubilized PTH-HP76 was clarified by centrifugation and the supernatant diluted 1:4 with 6 M urea, 10 mM NaHPO₄, 50 mM NaCl, 5 mM 2-mercaptoethanol, 5 mM imidazole, pH7. The diluted fusion protein was then loaded to a Ni-NTA column (Qiagen, Germany) and eluted with a linear 5-245 mM imidazole gradient (Figure 14). Peak fractions were analyzed by SDS-PAGE gels (Figure 15) and those containing PTH-HP76 pooled, concentrated and buffer exchanged into 50 mM NaHPO₄, 5 mM EDTA, pH6.5.

[00327] The isolated PTH-HP76 fusion protein was then PEGylated by addition of 30k mPEG-maleimide (Nektar, Huntsville, AL) in a 1.5-fold molar excess and allowed to react overnight at 4 degrees C. The conjugate was then purified by cation exchange chromatography (Figure 16), analyzed by SDS-PAGE (Figure 17), concentrated and dialyzed into PBS.

[00328] The PEG-PTH-HP76 was tested in a murine *in vivo* study measuring PTH induced hypercalcemia comparing a PEGylated synthetic PTH conjugate (designated "c33") and the E. coli derived PTH-HP76 and PEG-PTH-HP76 (Figure 18). In this study, groups of 5 BDF 1 mice (4 weeks old, male) were given a single subcutaneous dose of either 200 nmoles synthetic PEG-PTH, 58.6 nmoles E. coli-derived PTH-HP76 or 58.6 nmoles E. coli-derived PEG-PTH-HP76 and ionized calcium measurements were taken at 0, 2, 6, 24, 48 and 72 hrs.

[00329] The data demonstrate that HP76 fusions with PTH enable expression of therapeutic peptides in a prokaryotic microbial host cell and incorporation of cysteine at position 68 allows facile site-directed PEGylation. The resultant conjugate was active and potent *in vivo*.

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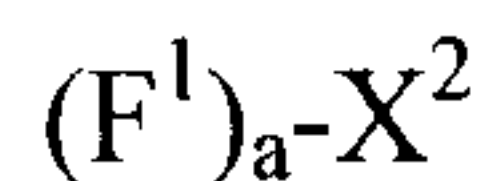
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The data presented in this Example further demonstrate that pharmacologically active peptides expressed as recombinant fusion proteins of the present invention can be optionally PEGylated and demonstrate prolonged efficacious half-lives.

[00330] The foregoing being illustrative but not an exhaustive description of the embodiments of the present invention, the following claims are presented.

CLAIMS

1. A composition of matter of the formula



and multimers thereof, wherein:

F^1 is a half-life extending moiety, and a is 0 or 1;

X^2 is $D-(L)_c-(P^5)_d-(X^3)_e$, $(X^4)_f-(P^5)_d-(L)_c-D$, or $(X^4)_f-(P^5)_d-(L)_c-D-(L)_g-(P^6)_h-(X^3)_i$, wherein c and g are each independently 0 or 1, d and h are 1, and e , f , and i are each independently 0, 1, 2, 3, or 4;

X^3 is $-(L)_j-(P^7)$, j is 0 or 1;

X^4 is $(P^8)-(L)_k$, k is 0 or 1;

D is a pharmacologically inactive protein domain of human origin, wherein said pharmacologically inactive protein domain is a SH3 domain, and

(i) has a mass of 3 kDa to 20 kDa, and

(ii) characteristically forms protein aggregates of less than 10 percent of total mass of protein when suspended without other proteins in a pharmaceutically acceptable formulation buffer of interest not comprising a detergent or chaotropic agent;

P^5 , P^6 , P^7 and P^8 are each independently a selected pharmacologically active protein of interest 5 to 80 amino acid residues in length; and

L is in each instance a peptidyl linker.

2. The composition of matter of Claim 1, wherein the pharmacologically inactive protein domain comprises an amino acid sequence selected from SEQ ID NOS: 4, 94, 105 and 106.

3. The composition of matter of Claim 1, wherein the pharmacologically active protein is a toxin peptide, a CGRP peptide antagonist, a bradykinin B1 receptor peptide antagonist, a PTH agonist peptide, a PTH antagonist peptide, an ang-2 binding peptide, a myostatin binding peptide, an EPO-mimetic peptide, a TPO-mimetic peptide, a NGF binding peptide, a BAFF antagonist peptide, a GLP-1 or peptide mimetic thereof, or a GLP-2 or peptide mimetic thereof.

4. The composition of matter of Claim 3, wherein the toxin peptide is selected from ShK, a ShK peptide analog, OSK1 and an OSK1 peptide analog.
5. The composition of matter of Claim 1, wherein a is 1, and F¹ is a polyethylene glycol, a copolymer of ethylene glycol, a polypropylene glycol, a copolymer of propylene glycol, a carboxymethylcellulose, a polyvinyl pyrrolidone, a poly-1,3-dioxolane, a poly-1,3,6-trioxane, an ethylene maleic anhydride copolymer, a polyaminoacid, a dextran n-vinyl pyrrolidone, a poly n-vinyl pyrrolidone, a propylene glycol homopolymer, a propylene oxide polymer, an ethylene oxide polymer, a polyoxyethylated polyol, a polyvinyl alcohol, a linear or branched glycosylated chain, a polyacetal, a long chain fatty acid, a long chain hydrophobic aliphatic group; or a combination of any of these members.
6. The composition of matter of Claim 1, wherein a is 1, and F¹ is a polyethylene glycol.
7. The composition of matter of Claim 1, wherein a is 1, and F¹ is selected from peptide ligands and small molecule ligands that have binding affinity for a long half-life plasma protein under physiological conditions of temperature, pH, and ionic strength.
8. A pharmaceutical composition, comprising the composition of matter of Claim 1, and a pharmaceutically acceptable carrier.
9. A nucleic acid comprising a polynucleotide sequence encoding a recombinant fusion protein that comprises:
 - (i) the composition of matter of Claim 1, wherein a is 0, or
 - (ii) the composition of matter of Claim 7, wherein a is 1, and F¹ is a peptide ligand that has binding affinity for a long half-life plasma protein under physiological conditions of temperature, pH, and ionic strength.
10. The nucleic acid of Claim 9, wherein the encoded pharmacologically inactive protein domain comprises an amino acid sequence selected from SEQ ID NOS: 4, 94, 105 and 106.
11. The nucleic acid of Claim 9, wherein the nucleic acid is a DNA.
12. An expression vector comprising the nucleic acid of Claim 11.

13. The expression vector of Claim 12, further comprising a coding sequence encoding a secretory signal peptide operably linked to the polynucleotide sequence encoding the recombinant fusion protein.
14. A cultured recombinant host cell comprising the expression vector of Claim 12.
15. The recombinant host cell of Claim 14, wherein the host cell is a prokaryotic host cell.
16. The recombinant host cell of Claim 15, wherein the prokaryotic host cell is an Escherichia coli.
17. A method of producing a pharmacologically active recombinant fusion protein, comprising:
 - (a) placing the recombinant host cell of Claim 14 in a growth medium, such that the recombinant fusion protein is expressed; and
 - (b) isolating the fusion protein from the cell or growth medium.

Application number / Numéro de demande: 2840407

Figures: 4A, 4B, 5A, 5B, 6A TO 6E
8ABC, 11A, ~~11~~-11B

Pages: 4/20, 5/20, 6/20, 9/20, 15/20

03 Feb 2014

Drawings

Unscannable items received with this application
(Request original documents in File Prep. Section on the 10th floor)

Jon

Documents reçu avec cette demande ne pouvant être balayés
(Commander les documents originaux dans la section de la préparation
des dossiers au 10^{ième} étage)

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FIG. 1

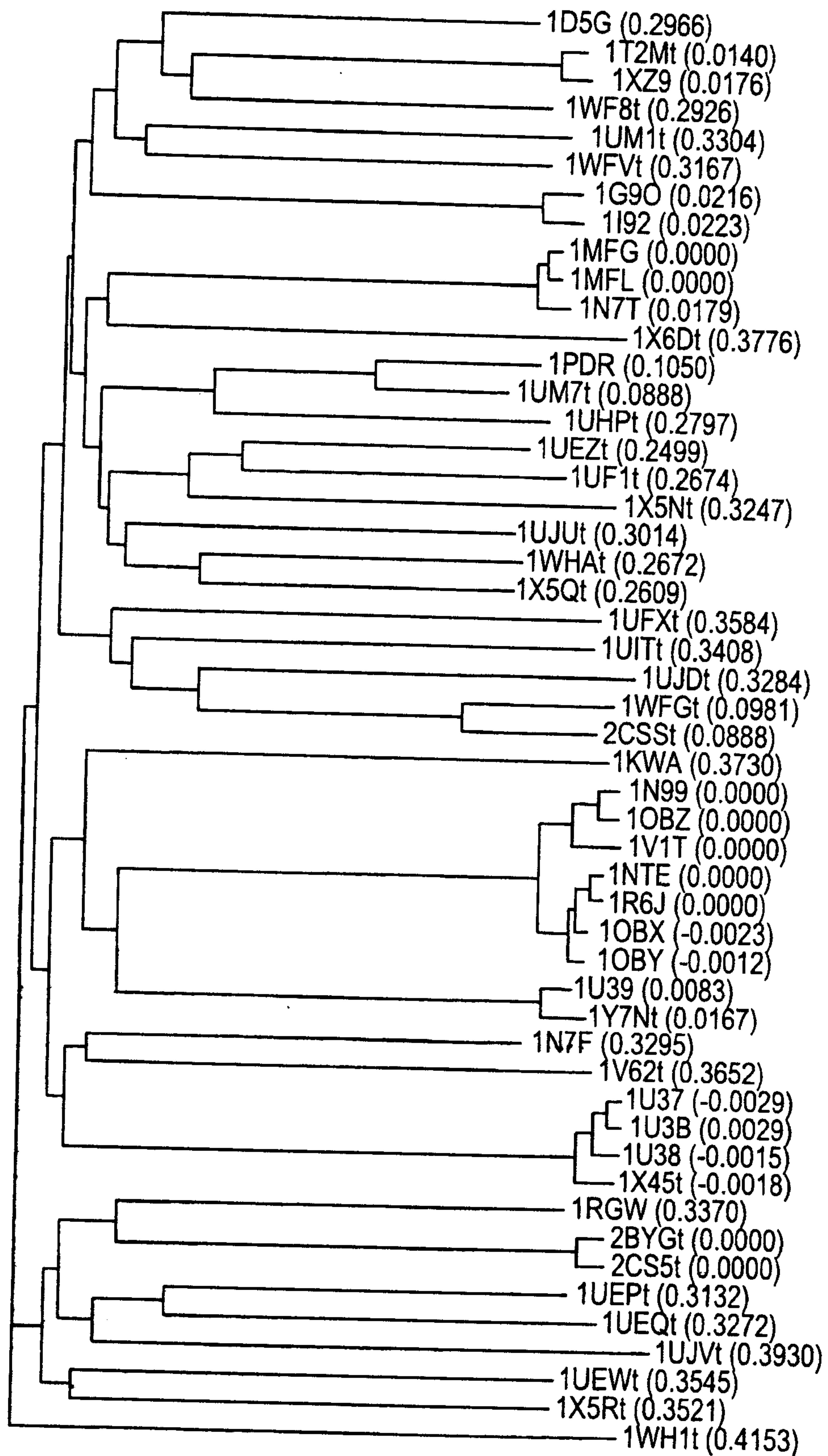
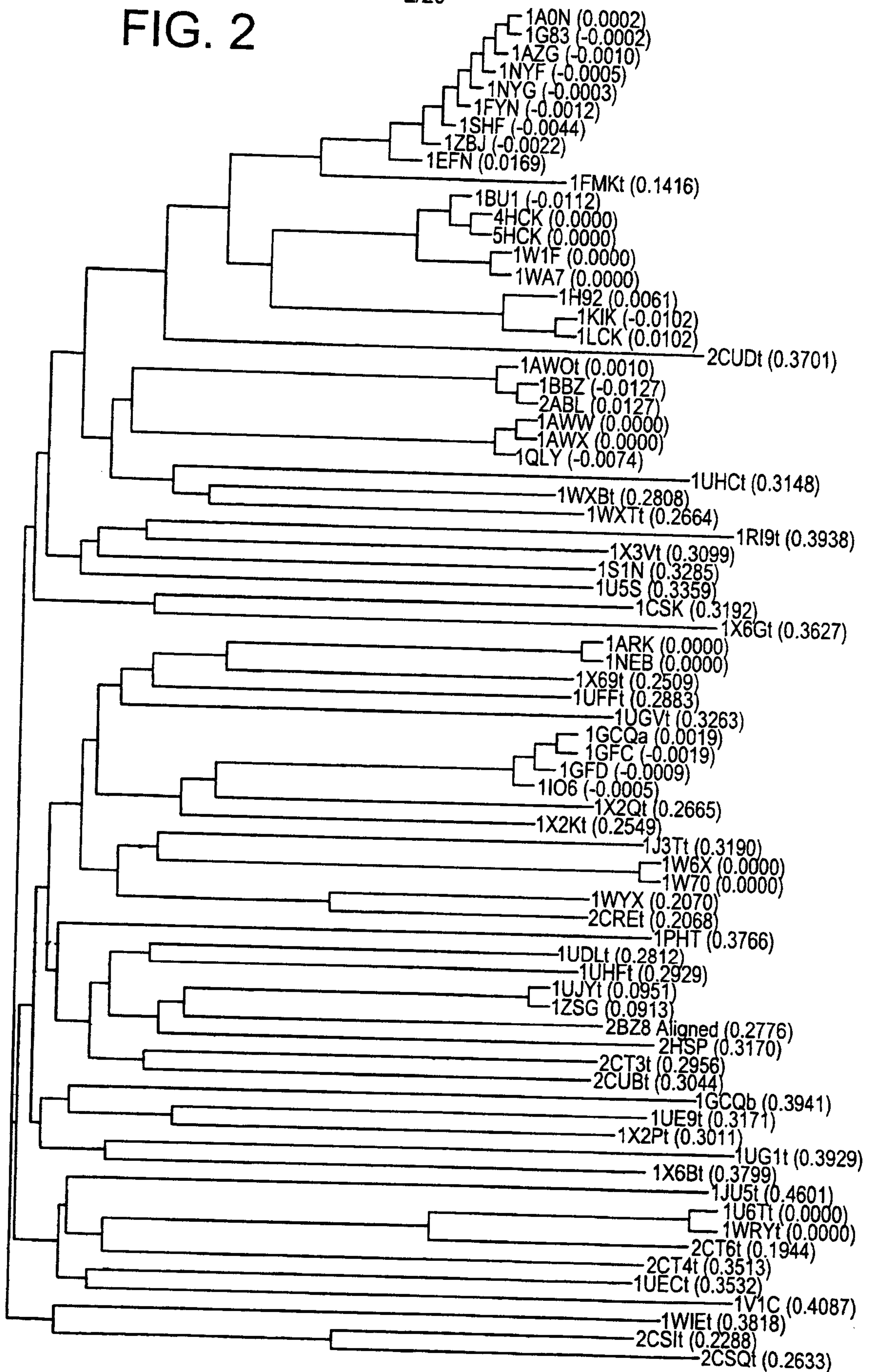


FIG. 2

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FIG. 3

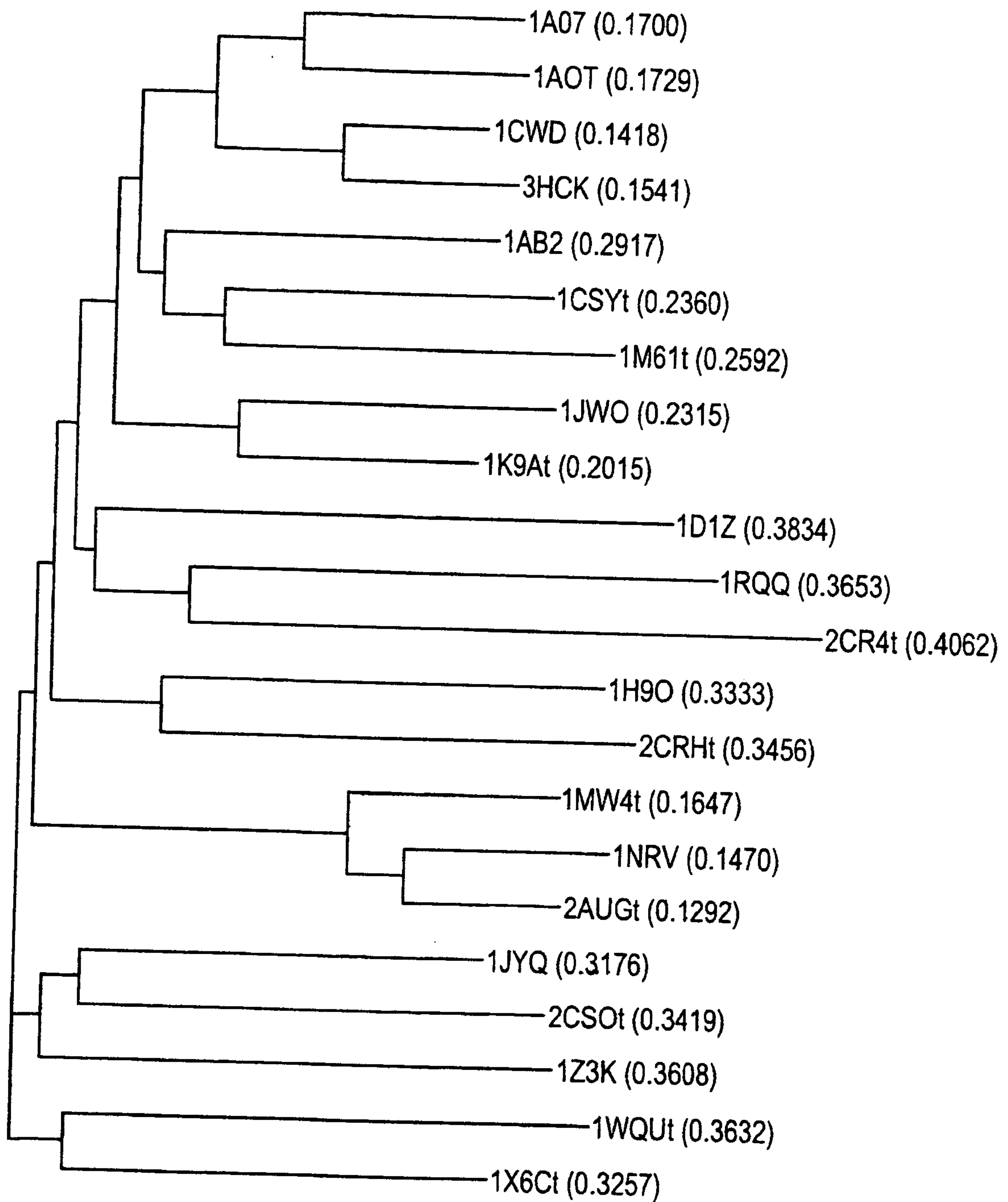


FIG. 7A

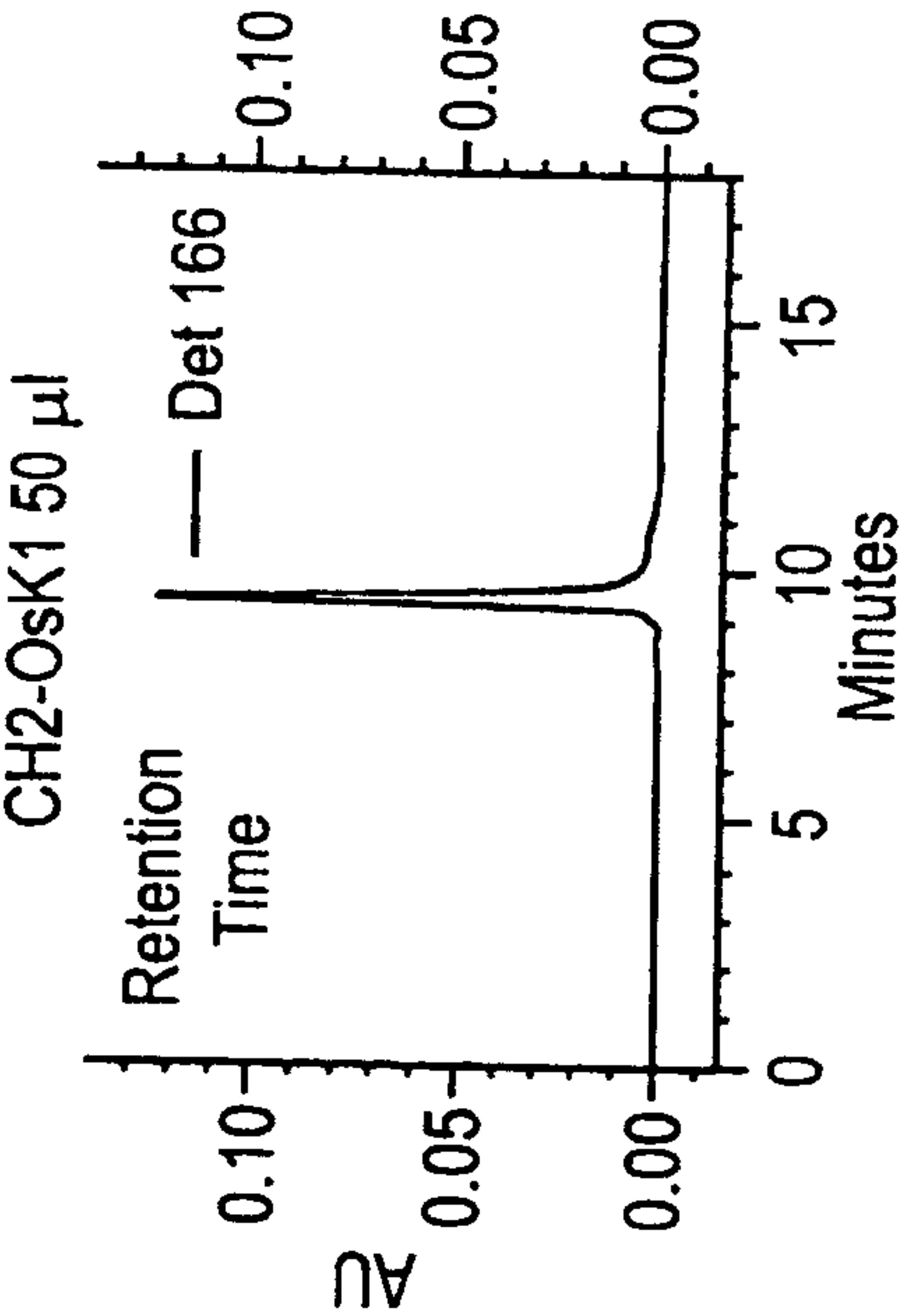


FIG. 7B

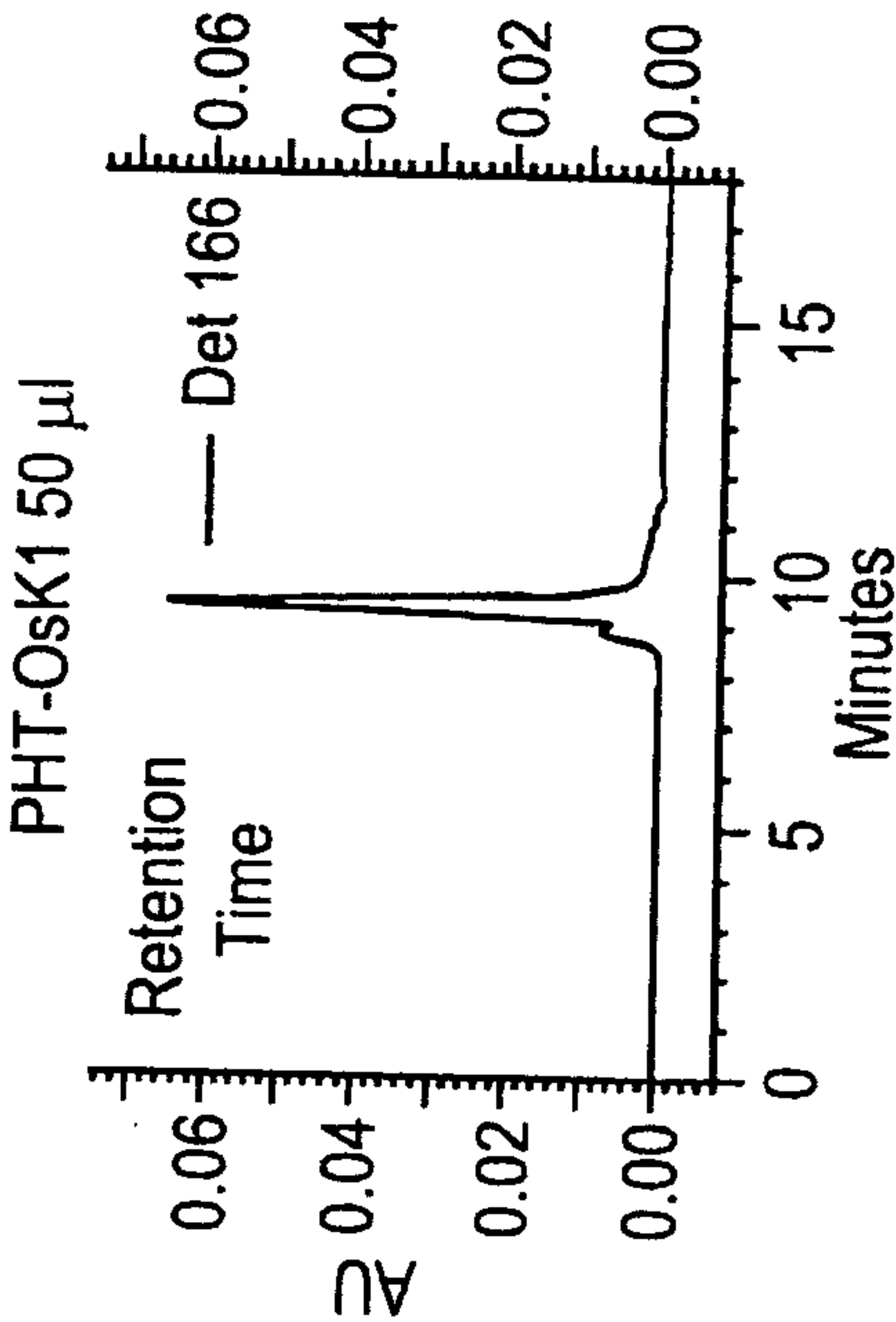


FIG. 7C

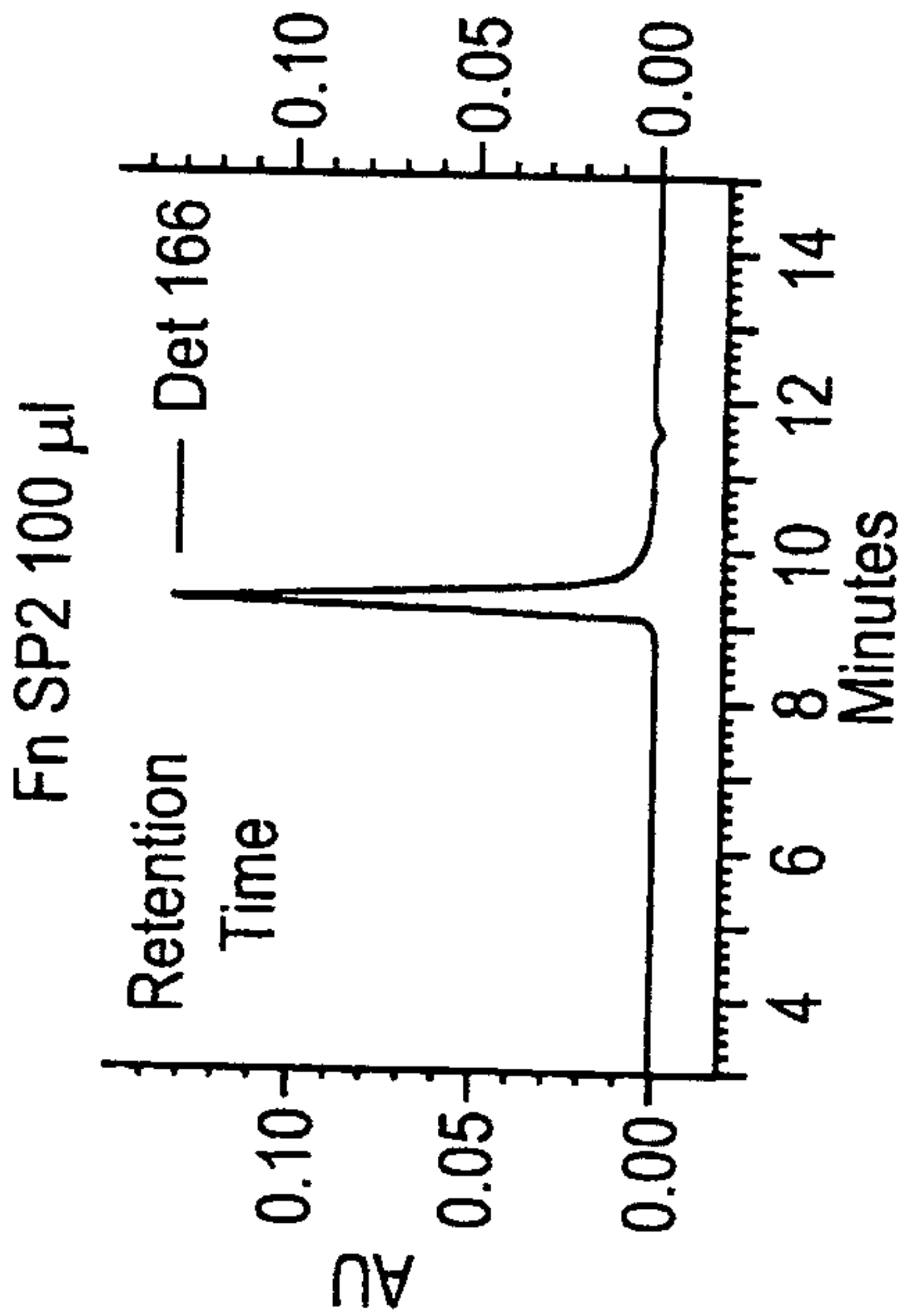


FIG. 7E

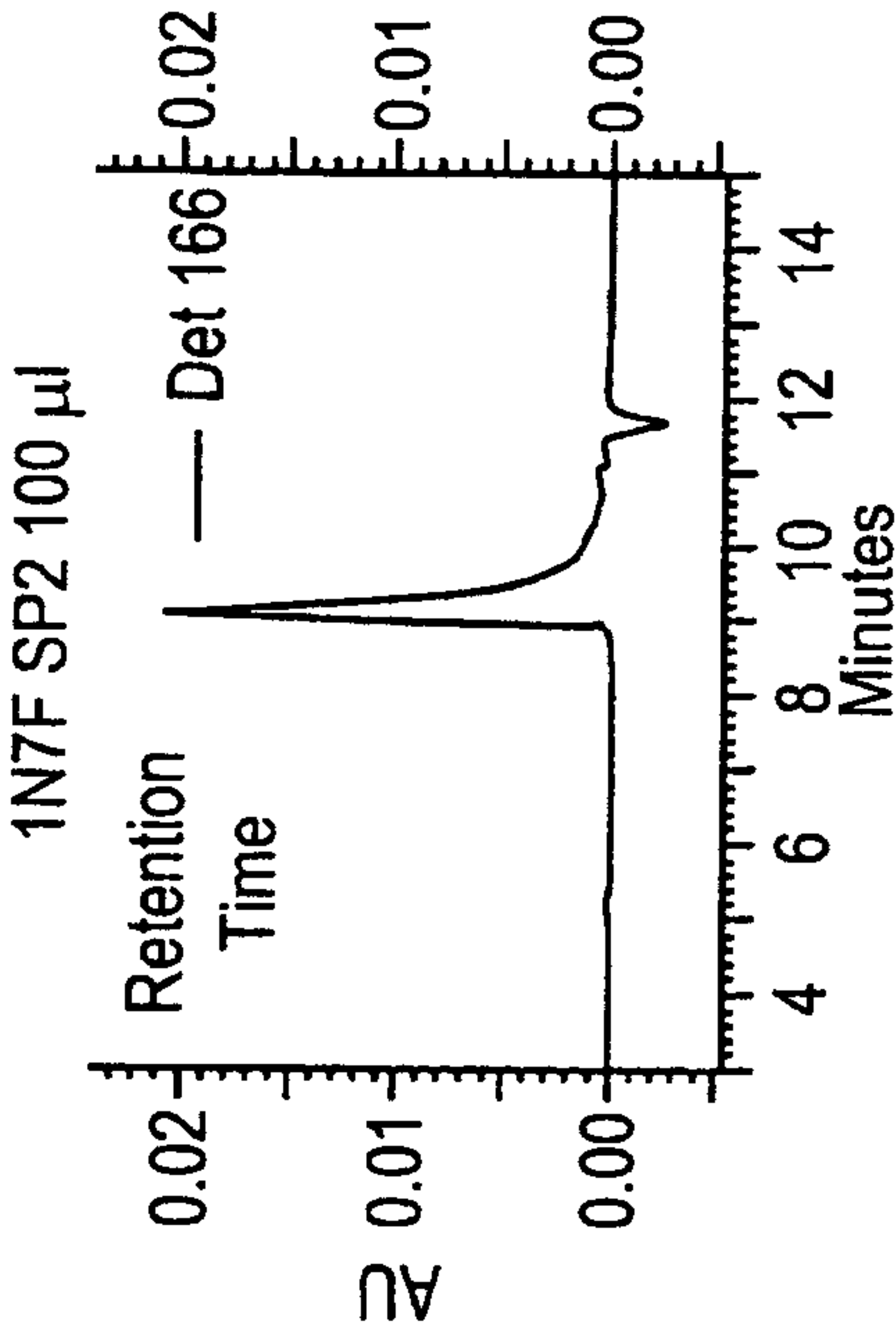


FIG. 7D

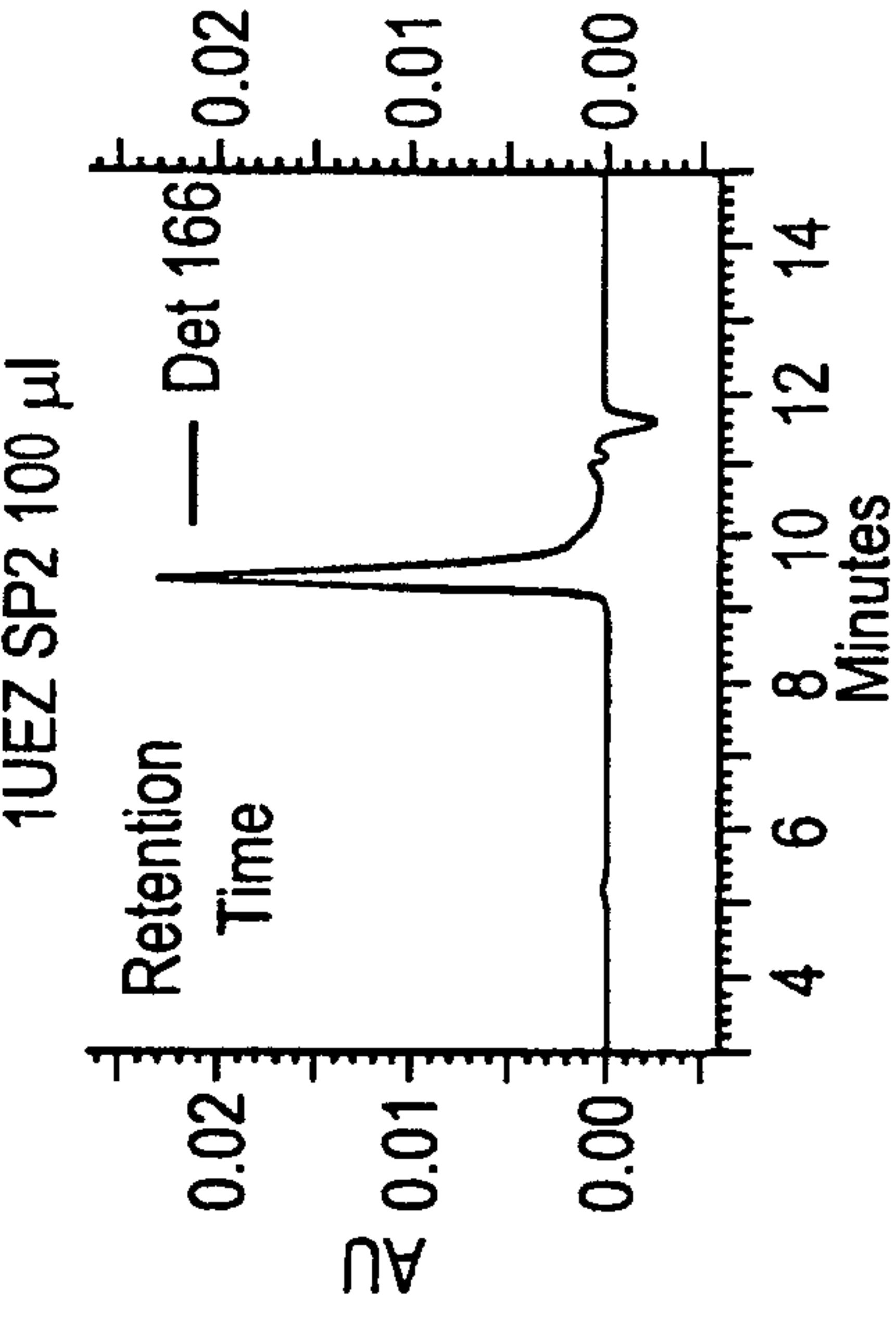
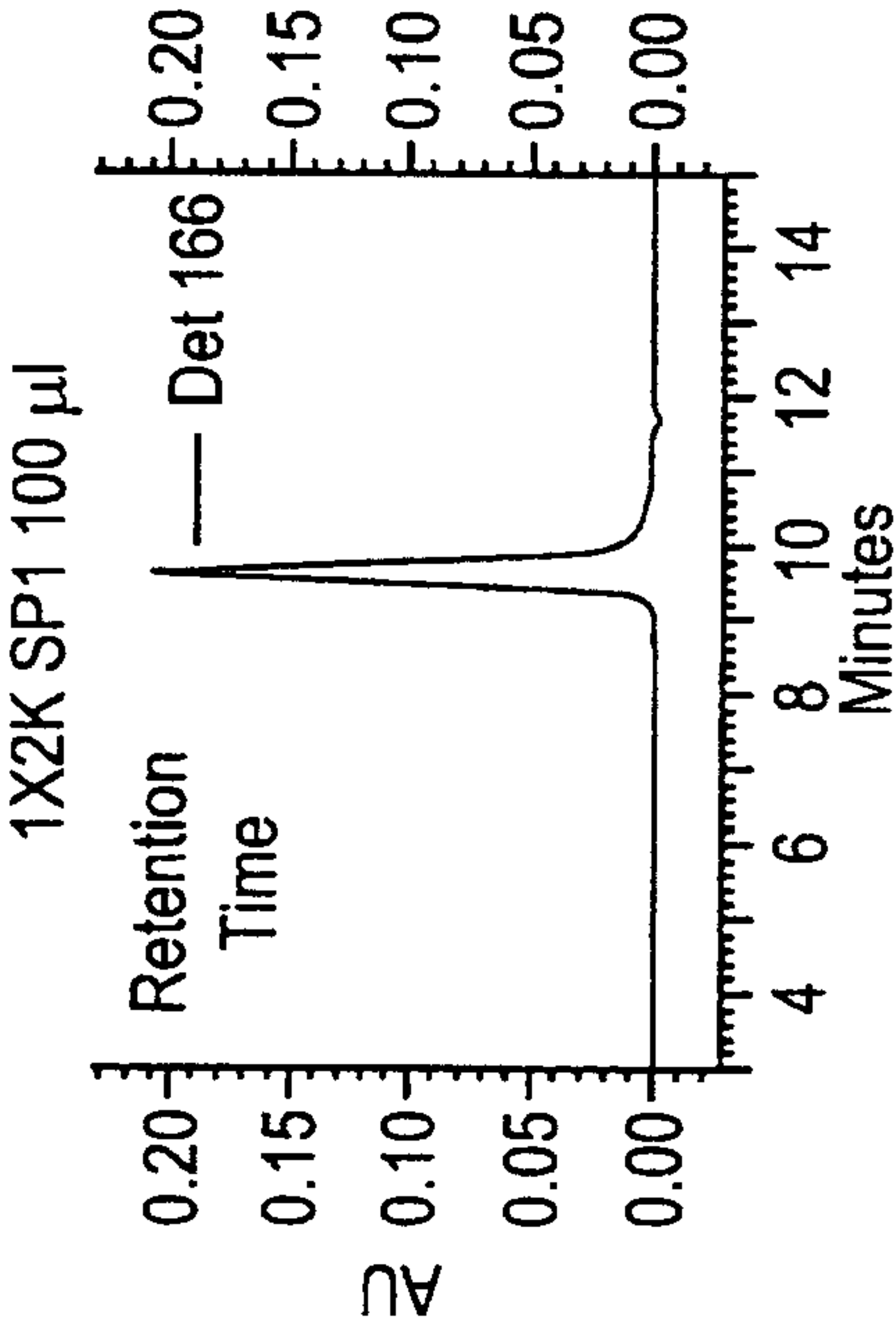
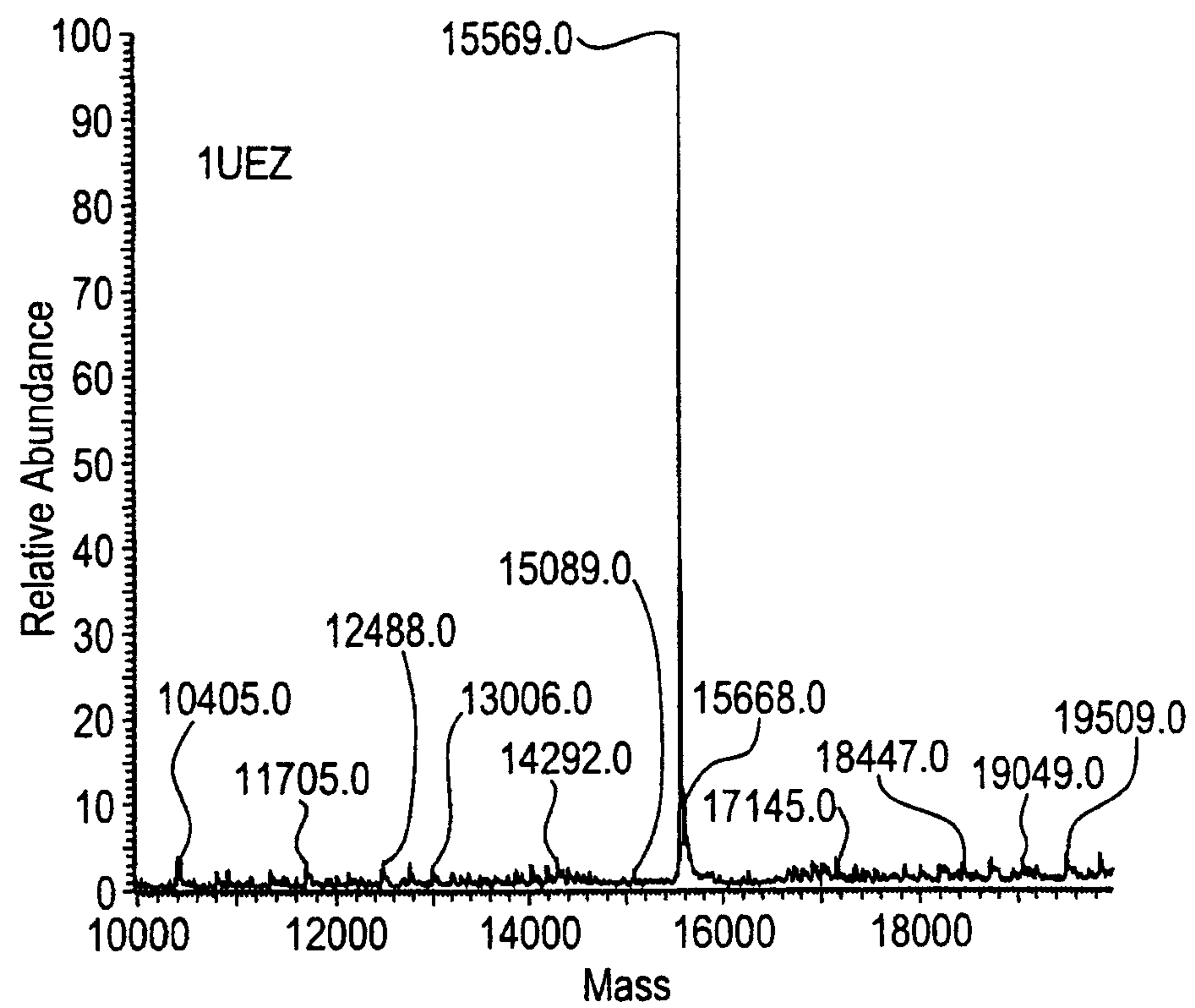


FIG. 7F



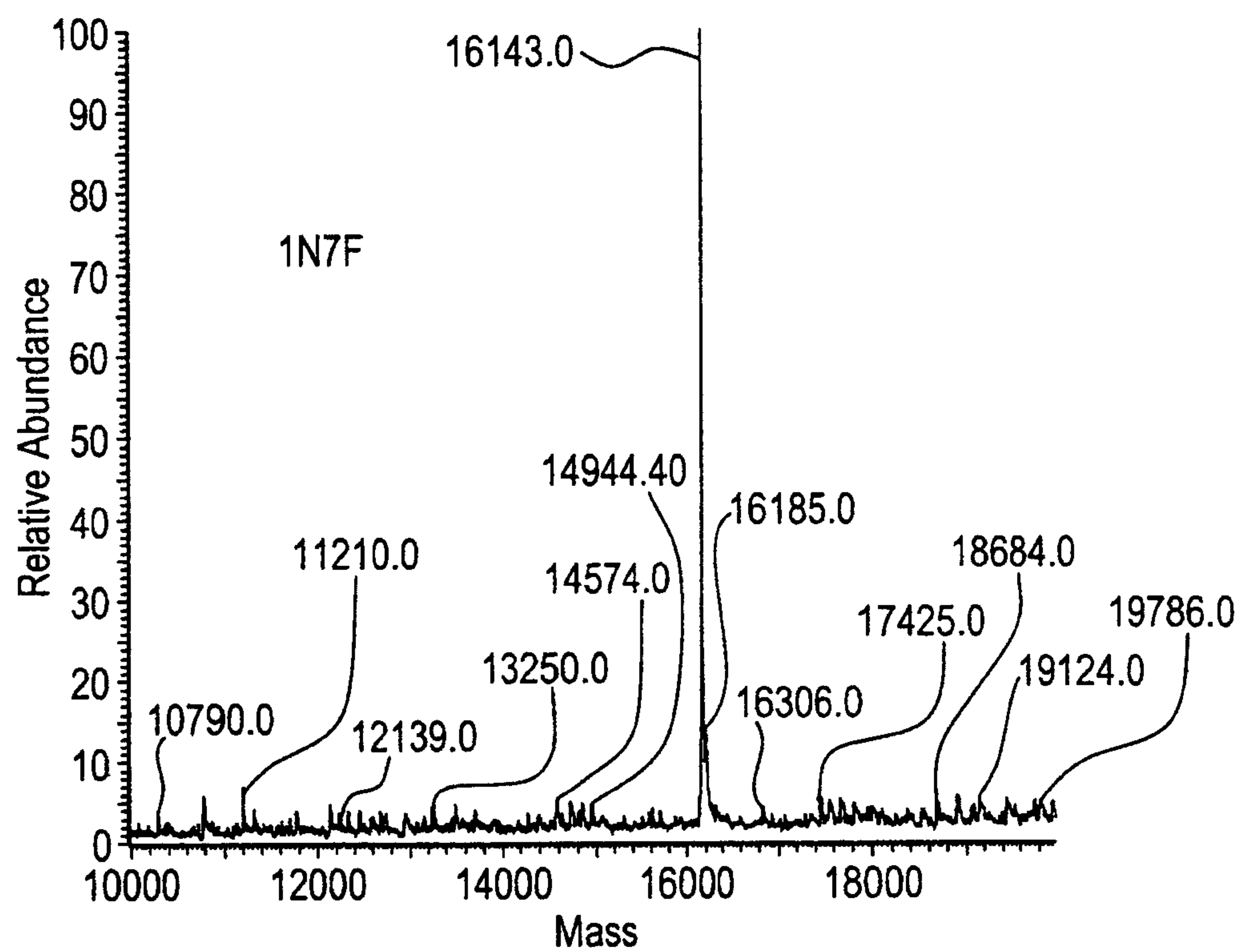
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FIG. 9A



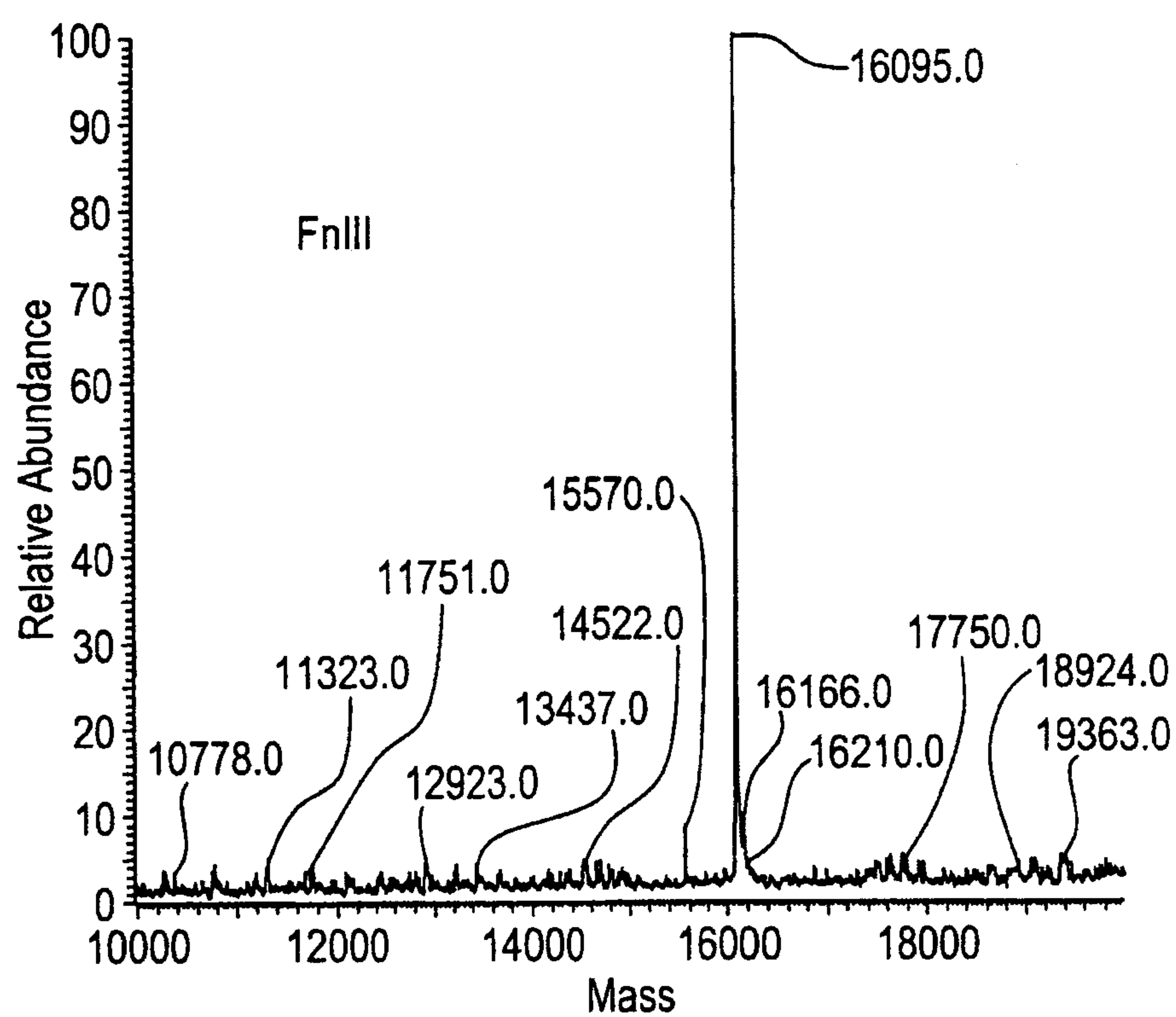
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FIG. 9B



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FIG. 9C



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FIG. 9D

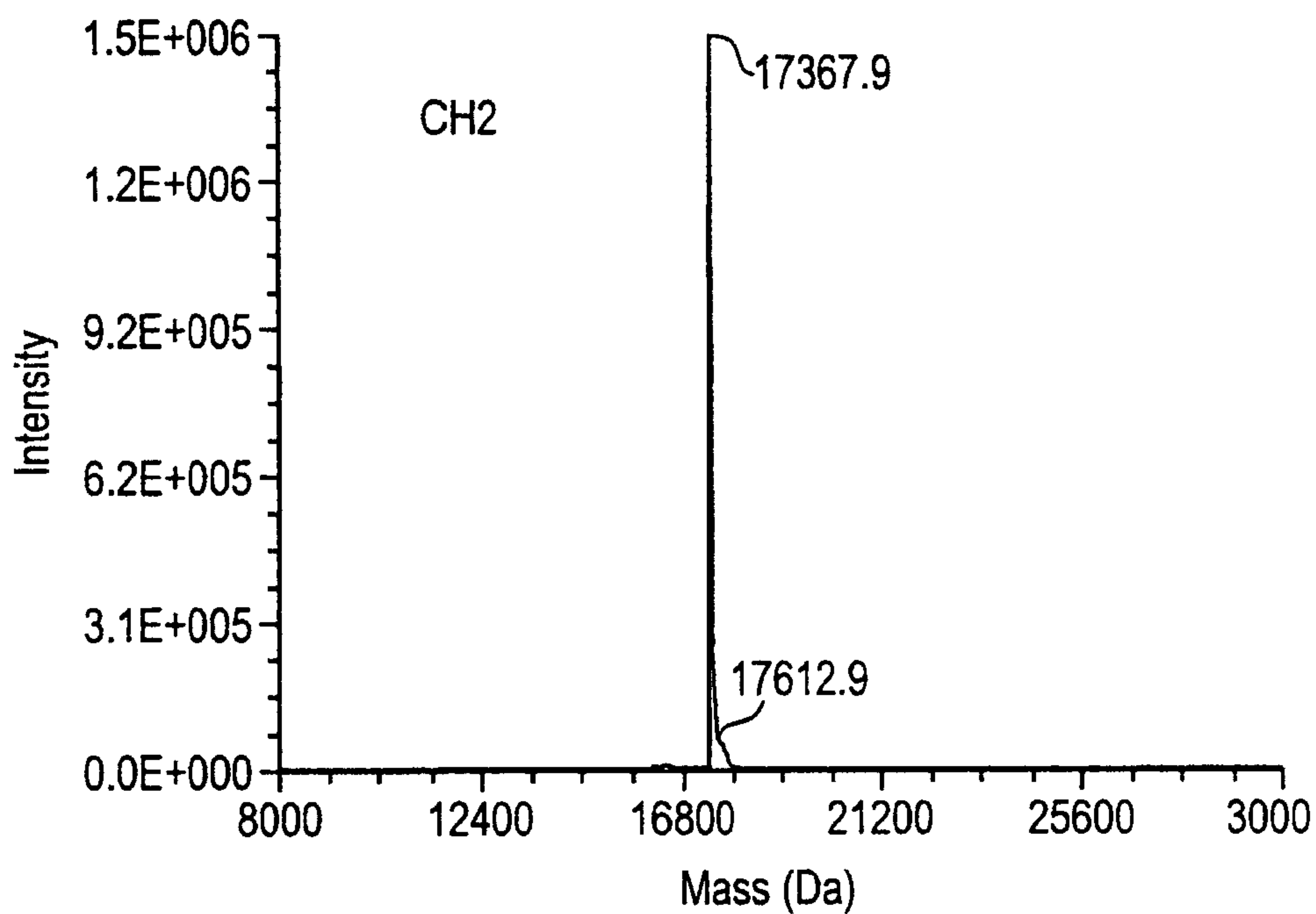
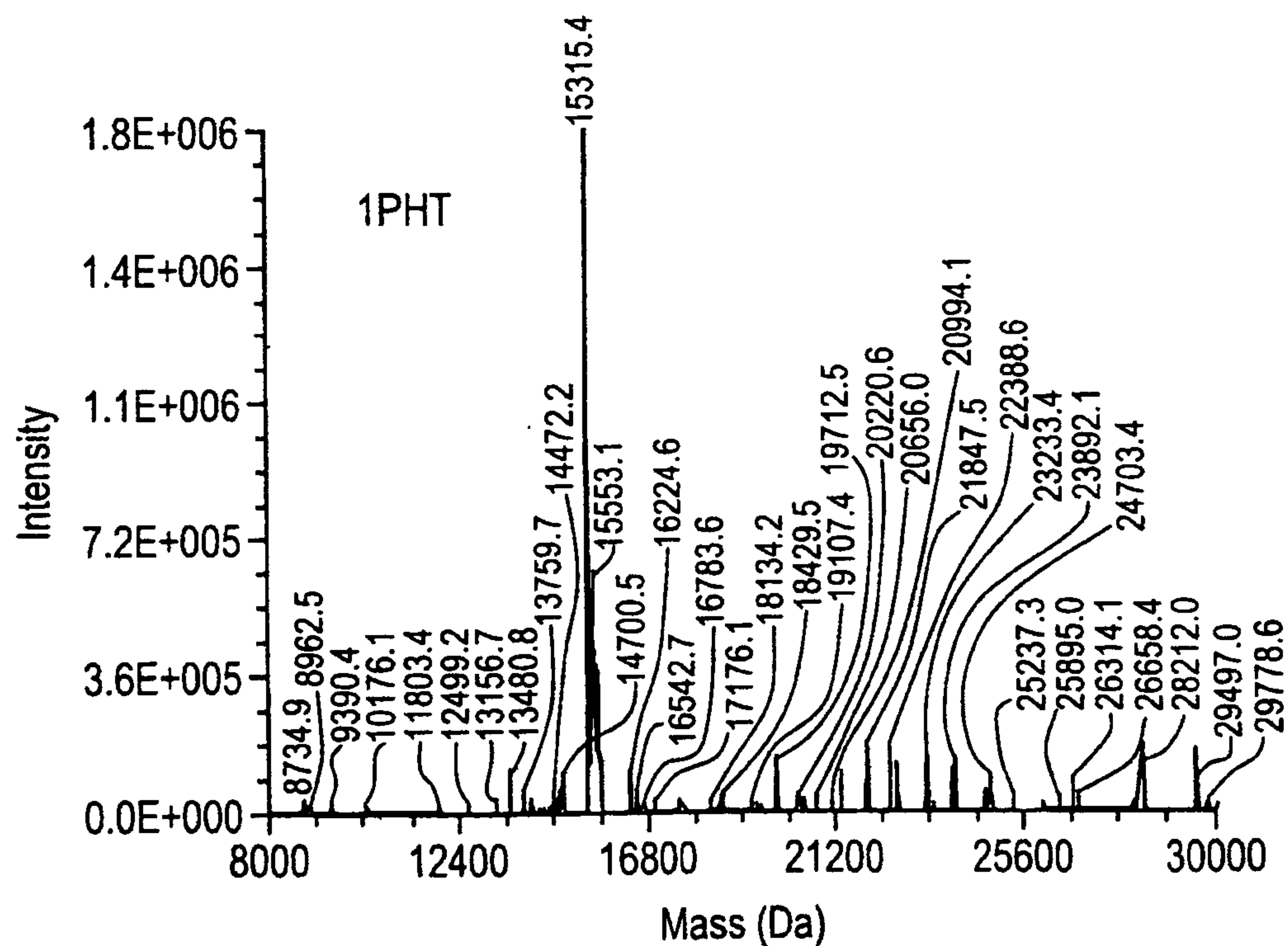
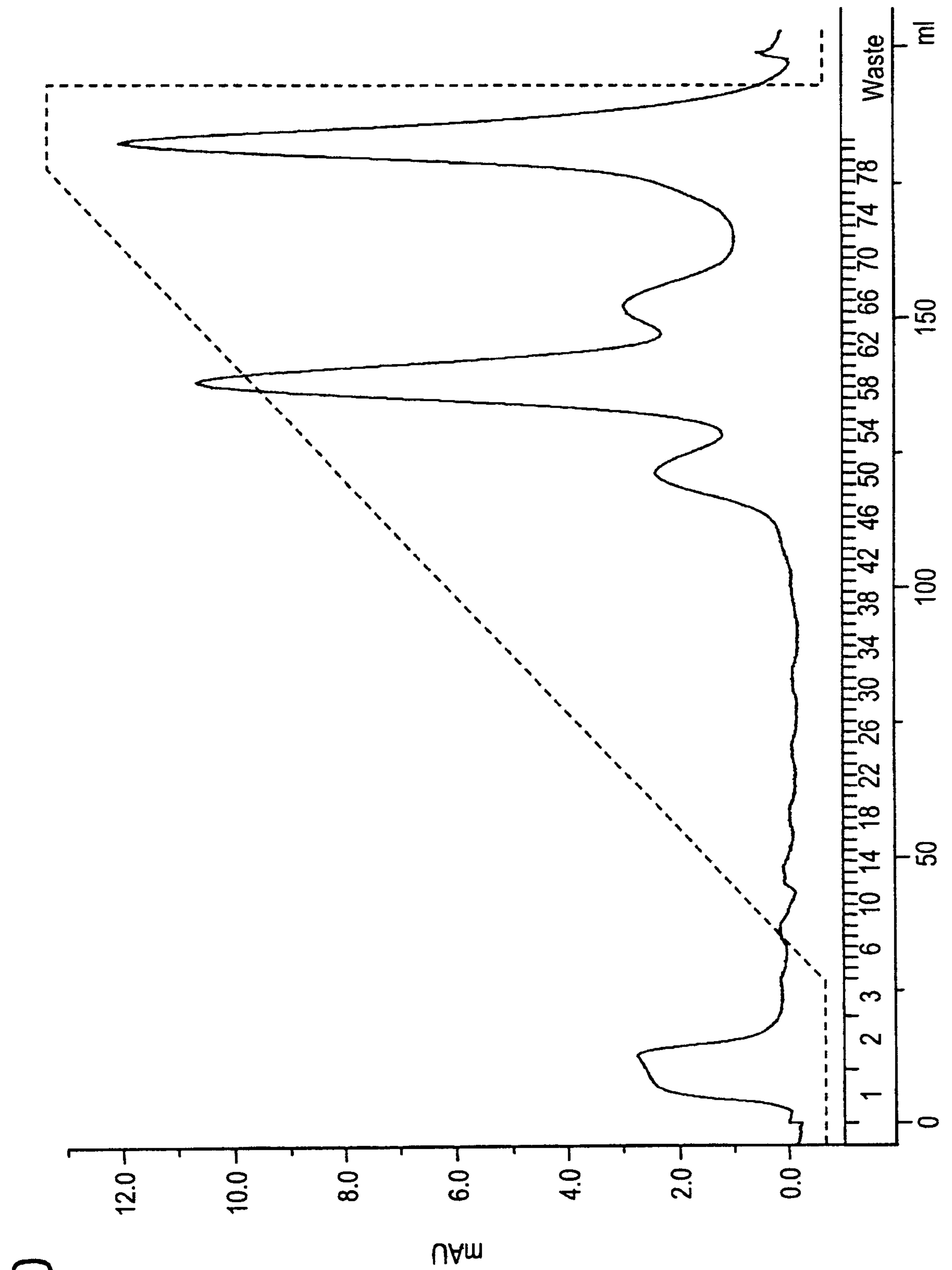


FIG. 9E



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FIG. 12

Serum Concentration of Novel OSK Fusions
in Mice at 24hr Polyclonal Rabbit anti-OSK
Sandwich EIA

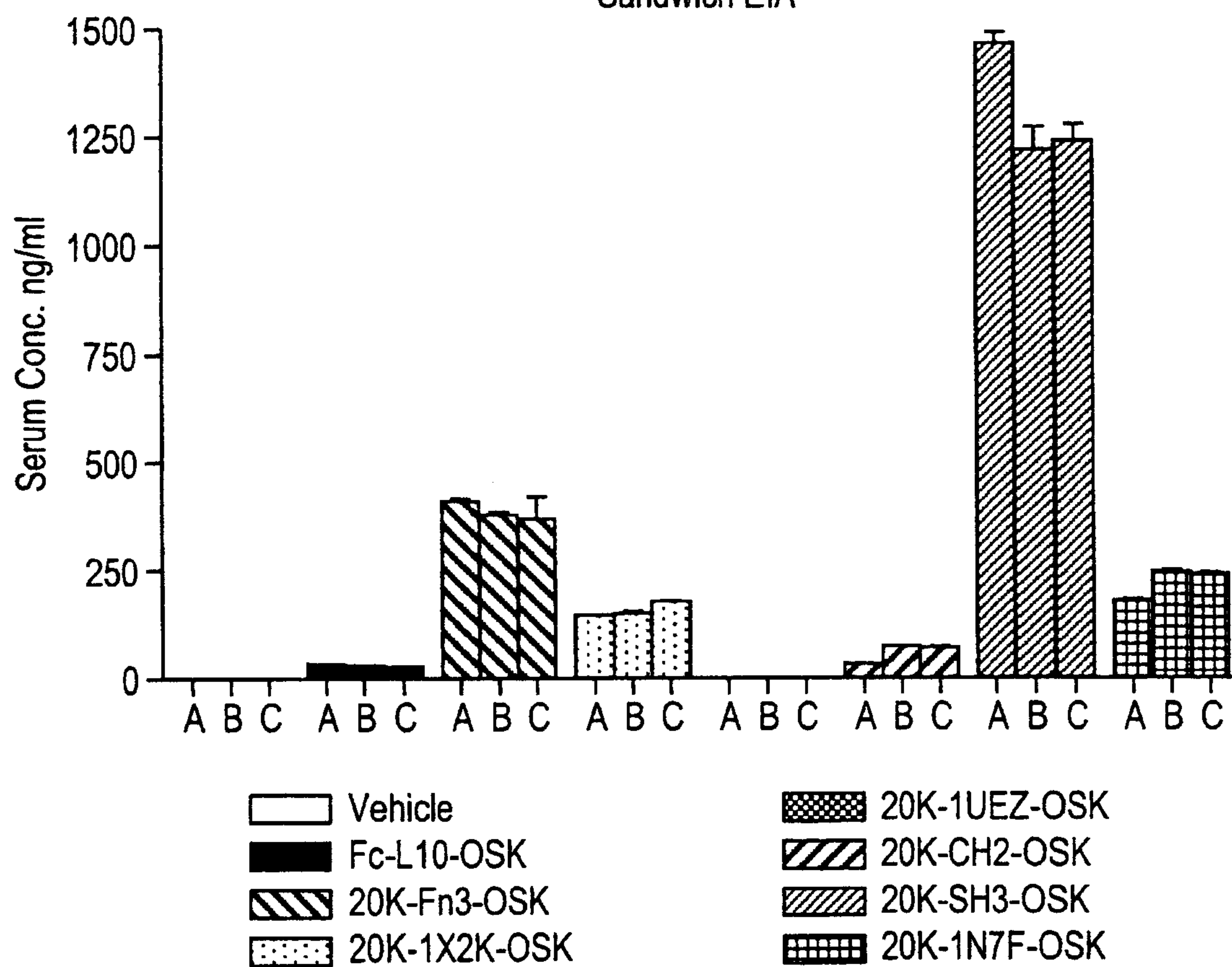
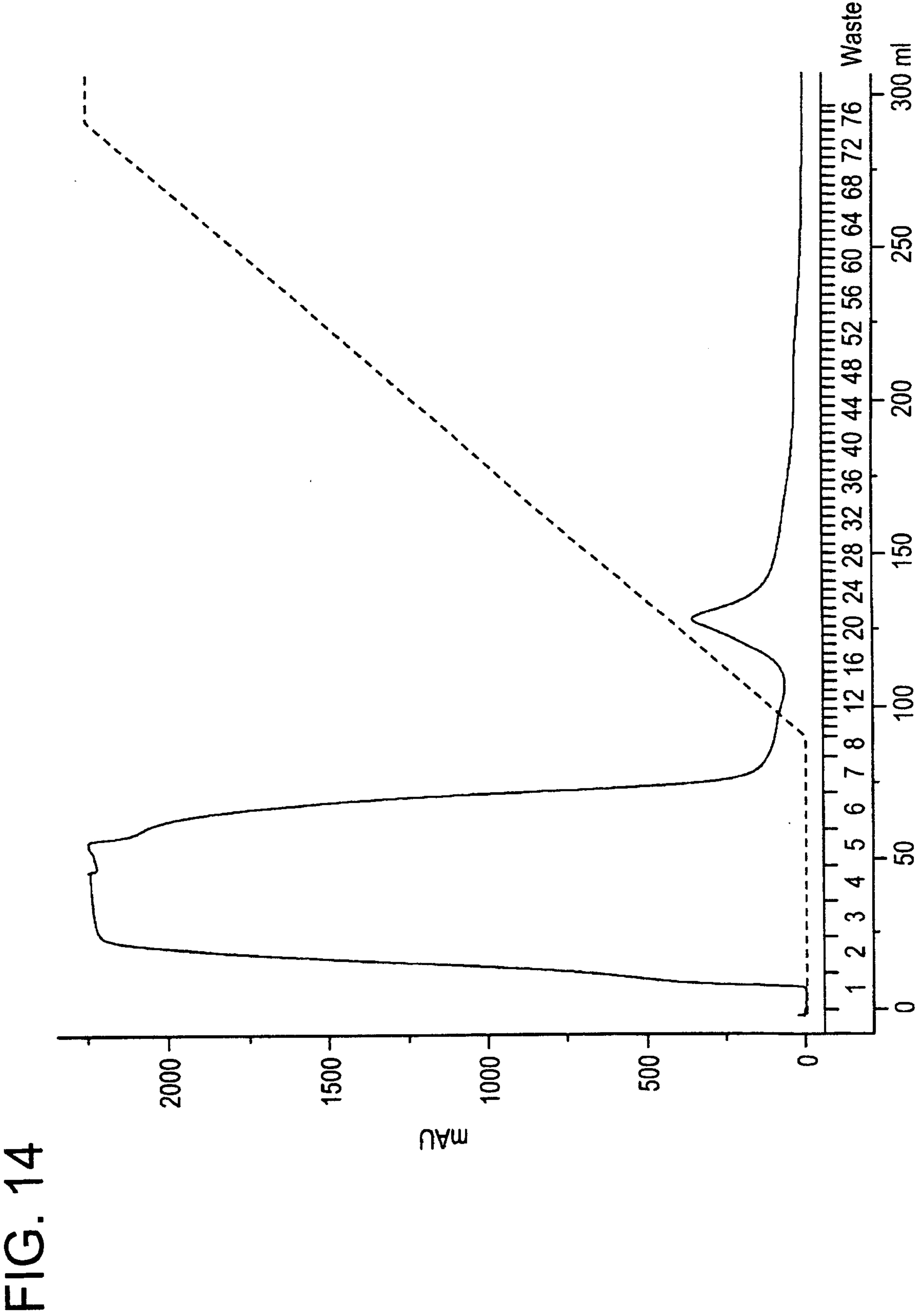


FIG. 13

Ch: LSDED FKAVF GMTRS AFANL PLWKQ QNLKK EKGLF
 Hu: LSIED FTQAF GMTPA AFSAL PRWKQ QNLKK EKGLF

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FIG. 15

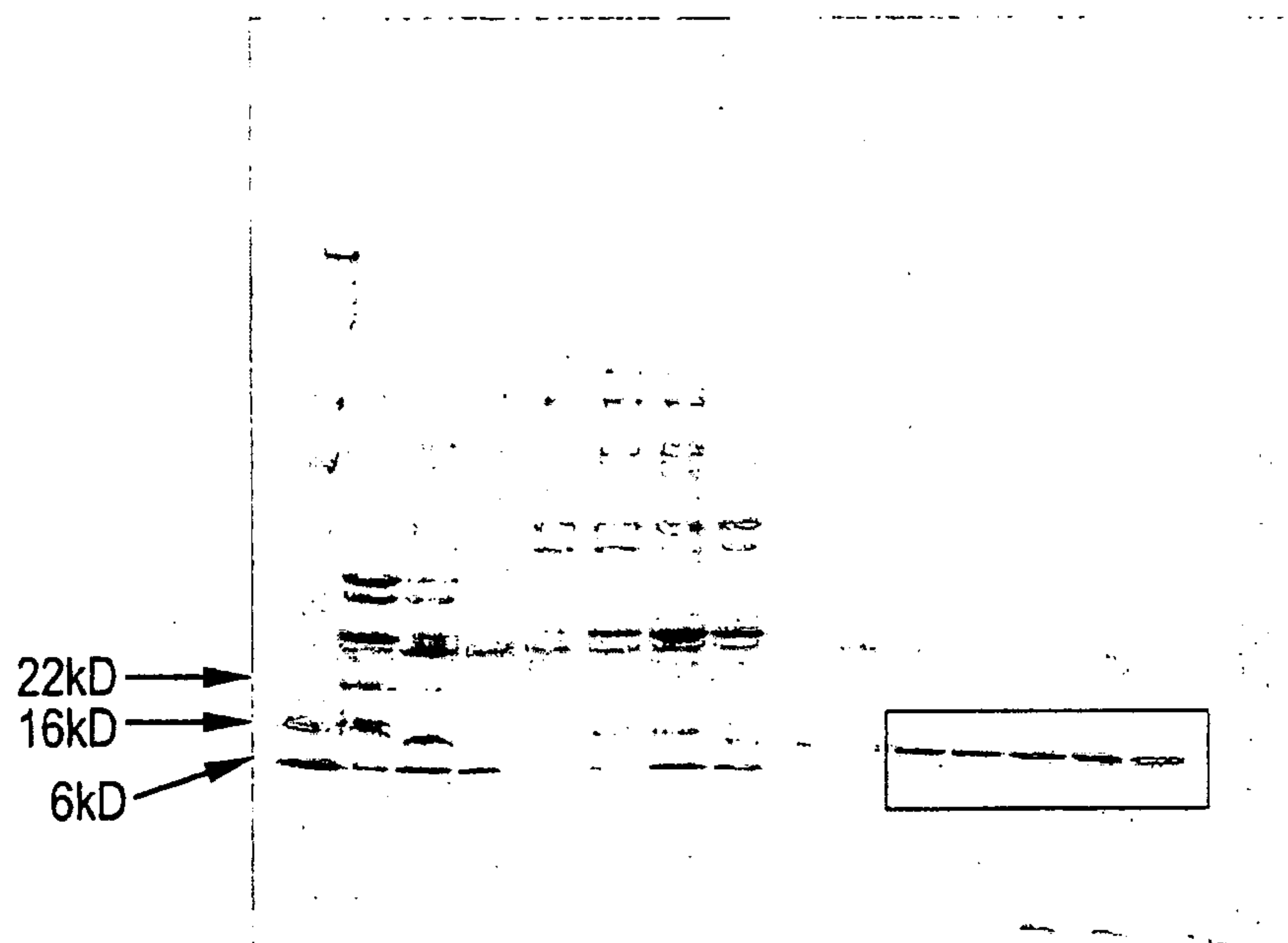
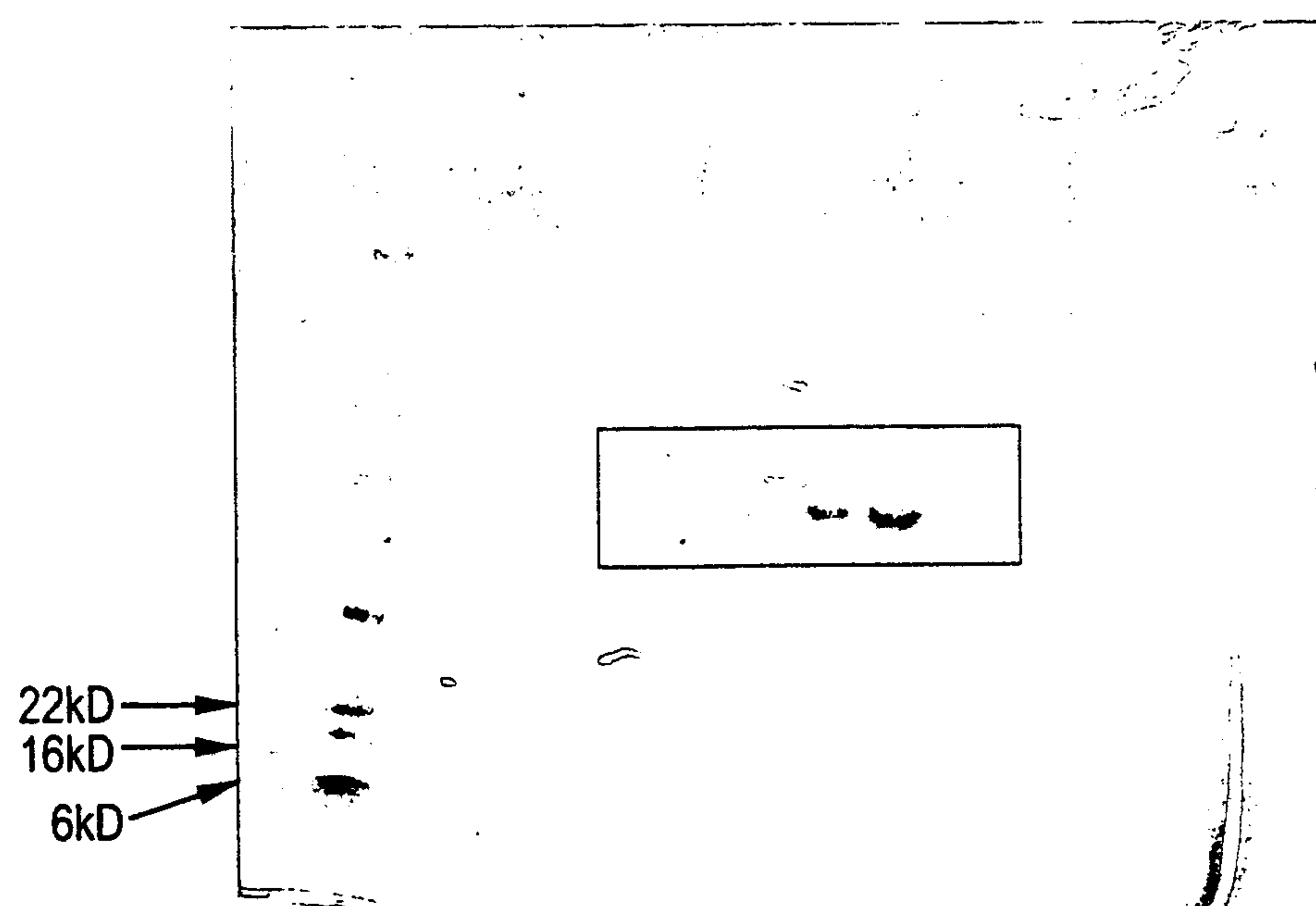
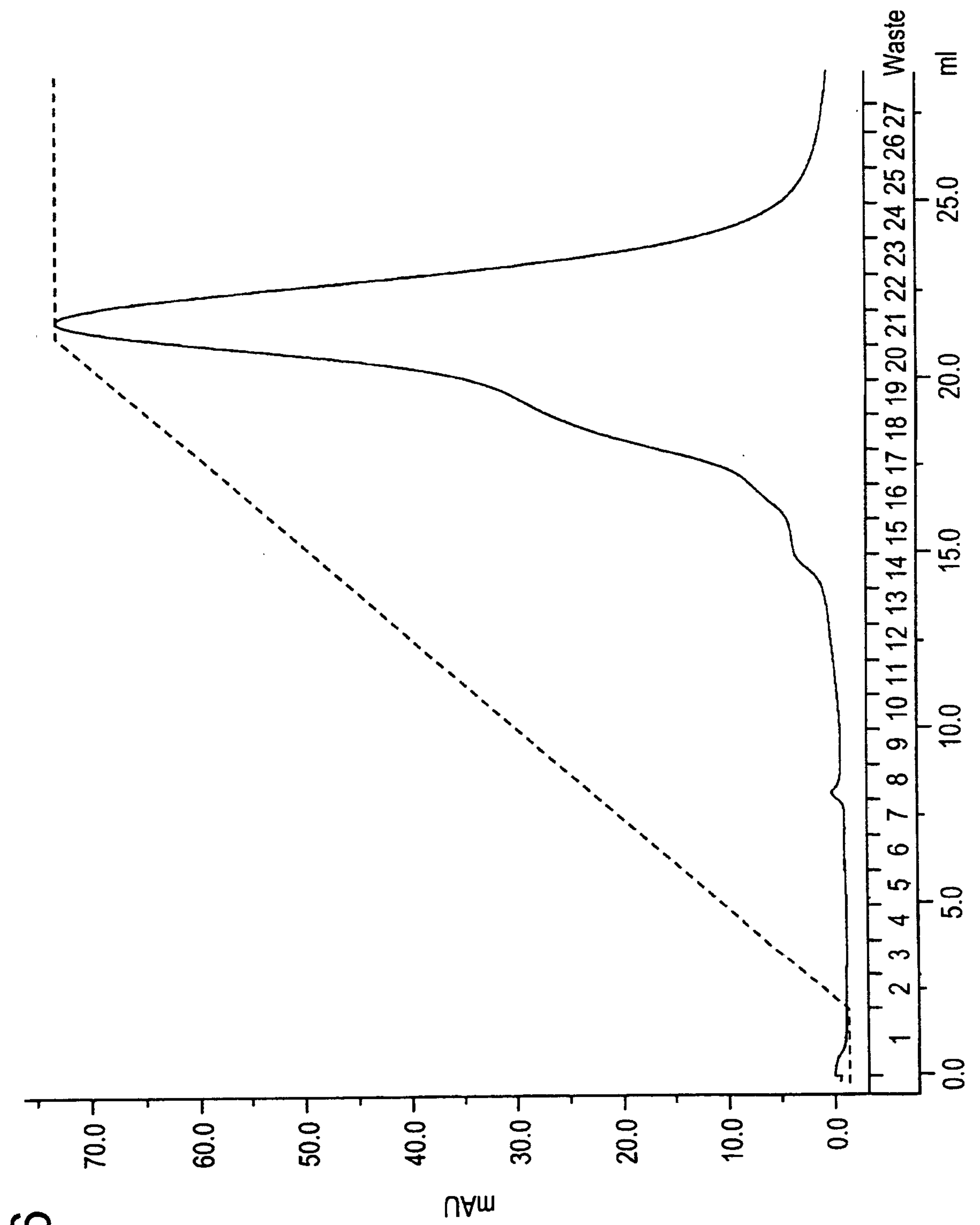


FIG. 17



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FIG. 18

