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(54) Title: SHORTENED CD95-FC VARIANTS

(57) Abrégé/Abstract:

The present invention relates to an isolated fusion protein comprising an extracellular CD95 domain or a functional fragment thereof and an Fc domain or functional fragment thereof, formulations providing such fusion protein in a stable form as well as a method for producing such a fusion protein.

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- 1 -

Shortened CD95-Fc variants**Description**

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The present invention relates to an isolated fusion protein comprising an extracellular CD95 domain or a functional fragment thereof and an Fc domain or functional fragment thereof, formulations providing such fusion protein in a stable form as well as a method for producing such a fusion protein.

10

Fusion proteins comprising the extracellular domain of the death receptor CD95 (Apo-1; Fas) fused to an immunoglobulin Fc domain are described in PCT/EP04/03239. However, it turned out difficult to provide such fusion proteins in sufficient amounts with a sufficient stability.

15

With the present invention it is possible for the first time to provide such compositions or methods.

20

According to a first aspect the present invention relates to a composition comprising a mixture of fusion protein isoforms, each fusion protein comprising at least an extracellular CD95 domain (APO-1; Fas) or a functional fragment thereof and at least a second domain being an Fc domain or a functional fragment thereof distributing within a pI range of about 4.0 to about 8.5. Accordingly, the extracellular CD95 domain as used herein may be also called "first domain", while the Fc domain may be called "second domain".

25

30

The first domain protein is an extracellular CD95 domain, preferably a mammalian extracellular domain, in particular a human protein, i.e. a human extracellular CD95 domain. The first domain, i.e. the extracellular CD95 domain, of the fusion protein preferably comprises the amino acid sequence up to amino acid 170, 171, 172 or 173 of human CD95 (SEQ ID NO. 1). A

- 2 -

signal peptide (e.g. position 1-25 of SEQ ID NO: 1) may be present or not.

Particularly for therapeutic purposes the use of a human protein is preferred.

- 5 The fusion protein can comprise one or more first domains which may be the same or different. However, one first domain, i.e. a fusion protein comprising one extracellular CD95 domain is preferred.

According to a preferred embodiment, the Fc domain or functional fragment
10 thereof, i.e. the second domain of the fusion protein according to the invention, comprises the CH2 and/or CH3 domain, and optionally at least a part of the hinge region. domain or a modified immunoglobulin domain derived therefrom. The immunoglobulin domain may be an IgG, IgM, IgD, or IgE immunoglobulin domain or a modified immunoglobulin domain derived,
15 therefrom. Preferably, the second domain comprises at least a portion of a constant IgG immunoglobulin domain. The IgG immunoglobulin domain may be selected from IgG1, IgG2, IgG3 or IgG4 domains or from modified domains therefrom. Preferably, the second domain is a human Fc domain, such as a IgG Fc domain, e.g. a human IgG1 Fc domain.

20

The fusion protein can comprise one or more second domains which may be the same or different. However, one second domain, i.e. a fusion protein comprising one Fc domain is preferred.

- 25 Further, both the first and second domains are preferably from the same species.

The first domain, i.e. the extracellular CD95 domain or the functional fragment thereof may be located at the N- or C-terminus. The second
30 domain, i.e. the Fc domain or functional fragment may also be located at the C- or N-terminus of the fusion protein. However, the extracellular CD95 domain at the N-terminus of the fusion protein is preferred.

- 3 -

According to a further preferred embodiment, the fusion protein is APG101 (CD95-Fc, position 26-400 in SEQ ID NO: 1). As defined by SEQ ID NO: 1 APG101 can be a fusion protein comprising a human extracellular CD95 domain (amino acids 26-172) and a human IgG1 Fc domain (amino acids 172-400), further optionally comprising an N-terminal signal sequence (e.g. amino acids 1-25 of SEQ ID NO: 1). The presence of the signal peptide indicates the immature form of APG101. During maturation, the signal peptide is cleaved off. According to an especially preferred embodiment the signal sequence is cleaved off. APG101 with the signal sequence is also comprised by the term "unmodified APG101". In a further embodiment the fusion protein is a polypeptide having at least 70% identity, more preferably 75% identity, 80% identity, 85% identity, 90% identity, 95% identity, 96% identity, 97% identity, 98% identity, 99% identity with APG101. According to the present application the term "identity" relates to the extent to which two amino acid sequences being compared are invariant, in other words share the same amino acids in the same position.

The term "APG101" describes a fusion protein of position 26-400 of SEQ ID NO: 1, with and without a signal peptide. The term "APG101" also includes fusion proteins containing N-terminally truncated forms of the CD95 extracellular domain.

In another preferred embodiment the fusion protein according to the invention is a functional fragment of APG101. As used herein, the term "fragment" generally designates a "functional fragment", i.e. a fragment or portion of a wild-type or full-length protein which has essentially the same biological activity and/or properties as the corresponding wild-type or full-length protein has.

A person skilled in the art is aware of methods to design and produce fusion proteins according to the present invention. The mixture of fusion protein isoforms, in particular APG101 isoforms, however, is obtained by the method described hereinbelow. Such methods are described, e.g., in

- 4 -

PCT/EP04/03239. According to a preferred embodiment designing a fusion protein of the present invention comprises a selection of the terminal amino acid(s) of the first domain and of the second domain in order to create at least one amino acid overlap between both domains. The overlap between
5 the first and the second domain or between the two first domains has a length of preferably 1, 2 or 3 amino acids. More preferably, the overlap has a length of one amino acid. Examples for overlapping amino acids are S, E, K, H, T, P, and D.

10 The composition according to the invention comprises a mixture of protein isoforms. The term "isoform" as used herein designates different forms of the same protein, such as different forms of APG101, in particular APG101 without signal sequence. Such isoforms can differ, for example, by protein length, by amino acid, i.e. substitution and/or deletion, and/or post-
15 translational modification when compared to the corresponding unmodified protein, i.e. the protein which is translated and expressed from a given coding sequence without any modification. Different isoforms can be distinguished, for example, by electrophoresis, such as SDS-electrophoresis, and/or isoelectric focussing which is preferred according to the present
20 invention.

Isoforms differing in protein length can be, for example, N- terminally and/or C-terminally extended and/or shortened when compared with the corresponding unmodified protein. For example, a mixture of APG101
25 isoforms according to the invention can comprise APG101 in unmodified form as well as N- terminally and/or C-terminally extended and/or shortened variants thereof.

Thus, according to a preferred embodiment, the mixture according to the
30 invention comprises N-terminally and/or C-terminally shortened variants of APG101.

- 5 -

Thus, according to a preferred embodiment, the mixture according to the invention comprises N-terminally and/or C-terminally shortened variants of APG101.

5

In particular preferred is a mixture of fusion protein isoforms comprising N-terminally shortened fusion proteins.

10 The shortened fusion proteins can comprise a sequence SEQ ID NO: 1 N-terminally truncated by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 35, 40, 45 and/or 50 amino acids. Preferred shortened fusion proteins have SEQ ID NO: 1 N-terminally truncated by 16, 20, or 25 amino acids.

15 Such N-terminally shortened fusion proteins may in terms of the present invention also be named and comprise -1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -13, -14, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -25, -26, -27, -28, -29, -30, -35, -40, -45 and/or -50 N-terminally shortened variants of unmodified APG101. Particularly preferred are -17, -21 and/or -26 N-terminally shortened variants. The numbering refers to the APG101 protein including signal sequence according to SEQ ID NO: 1, wherein the number refers to the first amino acid in the N-terminally truncated APG101.

25 This means a shortened fusion protein having SEQ ID NO:1 N-terminally truncated by 16 amino acids corresponds to a APG101 variant designated -17 in results in a protein having amino acids 17-400 of SEQ ID NO:1, N-terminally truncated by 20 amino acids (amino acids 21 – 400 of SEQ ID NO:1) corresponds to -21 and N-terminally truncated by 25 amino acids corresponds to -26 (amino acids 26 – 400 of SEQ ID NO:1).

30

An example for a C-terminal shortening of APG101 isoforms is C-terminal Lys-clipping.

- 6 -

According to a preferred embodiment of the present invention the mixture of fusion proteins of the composition according to the present invention preferably comprises 50 mol-% unmodified APG101 in relation to modified isoforms, more preferably 40 mol-% unmodified APG101, more preferably 30 mol-% unmodified APG101, more preferably 20, more preferably 10 mol-% unmodified APG101, more preferably 5 mol-% unmodified APG101 and even more preferably 3 mol-% unmodified APG101 and most preferably 1 mol-% and/or less unmodified APG101. Most preferred is an embodiment comprising a mixture of fusion protein isoforms that does not comprise any unmodified APG101.

As outlined above, isoforms can also differ by amino acid substitution, amino acid deletion and/or addition of amino acids. Such a substitution and/or deletion may comprise one or more amino acids. However, the substitution of a single amino acid is preferred according to this embodiment.

Isoforms according to the invention can also differ with regard to post-translational modification. Post-translational modification according to the present invention may involve, without being limited thereto, the addition of hydrophobic groups, in particular for membrane localisation such as myristoylation, palmitoylation, isoprenylation or glypiation, the addition of cofactors for enhanced enzymatic activity such as lipoylation, the addition of smaller chemical groups such as acylation, formylation, alkylation, methylation, amidation at the C-terminus, amino acid addition, γ -carboxylation, glycosylation, hydroxylation, oxidation, glycation, biotinylation and/or pegylation.

According to the present invention the addition of sialic acids, Fc-based glycosylation, in particular Fc-based N-terminal glycosylation, and/or pyro-Glu-modification are preferred embodiments of post-translational modification.

According to a preferred embodiment the fusion proteins comprised by the

- 7 -

composition of the invention comprise high amounts of sialic acids. According to the present invention the content of sialic acid is preferably from about 4.0 to 7.0 mol NeuAc/mol APG101, more preferably from 4.5 to 6.0 mol NeuAc/mol APG101 and most preferably about 5.0 mol NeuAc/mol APG101. As used herein, sialic acids refer N- or O-substituted derivatives of neuraminic acid. A preferred sialic acid is N-acetylneuraminic acid (NeuAc). The amino group generally bears either an acetyl or glycolyl group but other modifications have been described. The hydroxyl substituents may vary considerably. Preferred hydroxyl substituents are acetyl, lactyl, methyl, sulfate and/or phosphate groups. The addition of sialic acid results generally in more anionic proteins. The resulting negative charge gives this modification the ability to change a protein's surface charge and binding ability. High amounts of sialic acid lead to better serum stability and thus, improved pharmacokinetics and lower immunogenicity. The high degree of sialylation of APG101 isoforms of the present invention could be explained by the high amount of diantennary structure. It has to be regarded as highly surprising that the APG101 isoforms in the composition of the invention obtained by the inventive method show such a high grade of sialic acid addition.

According to the present invention, glycosylation designates a reaction in which a carbohydrate is attached to a functional group of a fusion protein, functional fragment thereof as defined herein. In particular, it relates to the addition of a carbohydrate to APG101 or an isoform thereof. The carbohydrate may be added, for example, by N-linkage or O-linkage. N-linked carbohydrates are attached to a nitrogen of asparagine or arginine side chains. O-linked carbohydrates are attached to the hydroxy oxygen of serine, threonine, tyrosine, hydroxylysine or hydroxyproline side chains. According to the present invention, N-linkage, in particular Fc-based N-terminal glycosylation is preferred. Particularly preferred N-linked glycosylation sites are located at positions N118, N136 and/or N250 of APG101 (SEQ ID NO: 1).

- 8 -

Fucosylation according to the present invention relates to the adding of fucose sugar units to a molecule. With regard to the present invention such an addition of a fucose sugar unit to the fusion protein, and in particular to APG101, represents an especially preferred type of glycosylation. A high
5 portion of fucosylated forms leads to a reduced antibody-dependent cellular cytotoxicity (ADCC). Thus, the mixture of fusion protein isoforms is characterised by reduced ADCC, which is beneficial for pharmaceutical and diagnostic applications.

10 Of course, beside the first and second domain as defined herein, the fusion proteins according to the invention may comprise further domains such as further targeting domains, e.g. single chain antibodies or fragments thereof and/or signal domains. According to a further embodiment, the fusion protein used according to the invention may comprise an N-terminal signal
15 sequence, which allows secretion from a host cell after recombinant expression. The signal sequence may be a signal sequence which is homologous to the first domain of the fusion protein. Alternatively, the signal sequence may also be a heterologous signal sequence. In a different embodiment the fusion protein is free from an additional N-terminal
20 sequence, such as a signal peptide.

The composition according to the present invention may comprise N-terminally blocked fusion proteins, which provide a higher stability with regard to N-terminal degradation by proteases, as well as fusion proteins
25 having a free N-terminus, which provides a higher stability with regard to N-terminal degradation by proteases.

Modifications blocking the N-terminus of protein are known to a person skilled in the art. However, a preferred post-translational modification
30 according to the present invention blocking the N-terminus is the pyro-Glu-modification. Pyro-Glu is also termed pyrrolidone carboxylic acid. Pyro-Glu-modification according to the present invention relates to the modification of an N-terminal glutamine by cyclisation of the glutamine via condensation of

- 9 -

the α -amino group with a side chain carboxyl group. Modified proteins show an increased half-life. Such a modification can also occur at a glutamate residue. Particularly preferred is a pyro-Glu-modification, i.e. a pyrrolidone carboxylic acid, with regard to the N-terminally shortened fusion protein -26.

5

In a preferred embodiment of the present application the composition according to the present invention comprises 80-99 mol-% N-terminally blocked fusion proteins and/or 1-20 mol-% fusion proteins having a free N-terminus.

10

According to a further preferred embodiment the composition comprises 0.0 to 5.0 mol-%, more preferably 0.0 to 3.0 mol-% and even more preferably 0.0 to 1.0 mol-%, of fusion protein high molecular weight forms such as aggregates. In a preferred embodiment the composition according to the present invention does not comprise any aggregates of fusion protein isoforms, in particular no dimers or aggregates of APG101. Dimers or aggregates are generally undesired because they have a negative effect on solubility.

15

20

The functional form of APG101 comprises two fusion proteins, as described herein, coupled by disulfide bridges at the hinge region at positions 179 or/and 182 with reference SEQ ID NO:1 of the two molecules (see Figure 7). The disulfide bridge may also be formed at position 173 with reference to SEQ ID NO:1 of the two molecules, resulting in an improved stability. If the disulfide bridge at position 173 with reference to SEQ ID NO:1 is not required, the Cys residue at this position can be replaced by another amino acid, or can be deleted.

25

30

In a preferred embodiment the mixture according to the present invention is provided by the method according to the present invention described herein.

According to the invention, the mixture of fusion protein isoforms distributes within a pI range of about 4.0 to about 8.5. In a further embodiment the pI

- 10 -

range of the mixture of fusion protein isoforms comprised by the composition according to the invention is about 4.5 to about 7.8, more preferably about 5.0 to about 7.5.

5 The isoelectric point (pI) is defined by the pH-value at which a particular molecule or surface carries no electrical charge. Depending on the pH range of the surrounding medium the amino acids of a protein may carry different positive or negative charges. The sum of all charges of a protein is zero at a specific pH range, its isoelectric point, i.e. the pI value. If a protein molecule
10 in an electric field reaches a point of the medium having this pH value, its electrophoretic mobility diminishes and it remains at this site. A person skilled in the art is familiar with methods for determining the pI value of a given protein, such as isoelectric focussing. The technique is capable of extremely high resolution. Proteins differing by a single charge can be
15 separated and/or fractionated.

The composition according to the present invention described herein may be used for pharmaceutical, diagnostic and/or research applications. It may be applied in human medicine as well as veterinary medicine.

20

Another aspect of the present invention relates to a formulation comprising a composition according to the invention.

According to a preferred embodiment the formulation comprises

- 25 (a) phosphate, preferably about 20 mM to about 100 mM phosphate, more preferably about 30 mM to about 70 mM phosphate, even more preferably about 40 mM to about 60 mM phosphate, most preferred about 50 mM phosphate,
- (b) a viscosity enhancing agent, preferably about 0.1-10 weight-%
30 viscosity enhancing agent, more preferably 1 to 8 weight-% viscosity enhancing agent, more preferably about 3 weight-% to about 7 weight-% viscosity enhancing agent, even more preferred about 6 weight-% to about 7 weight-% viscosity enhancing agent, and most

- 11 -

preferred about 5 weight-% viscosity enhancing agent, and
(c) has a pH value in the range of 4-8.

5 Viscosity enhancing or increasing agents are well-known to a person skilled in the art and comprise alginic acid, carboxymethyl cellulose, dextrin, gelatin, guar gum, hydroxyethyl cellulose, magnesium aluminum silicate, polyvinyl alcohol, polyethylene oxide, silicon dioxide, starch, xanthan gum, etc. However, a viscosity enhancing agent which is especially preferred according to the present invention is sorbitol.

10

Surprisingly, the composition of the invention provided in that type of formulation is very stable and does not tend to form aggregates. Moreover, it was possible to provide high protein concentrations, e.g. about 20 mg/ml in stable form.

15

The composition and/or formulation according to the invention can be administered to a subject in need thereof, particularly a human patient, in a sufficient dose for the treatment of the specific conditions by suitable means. For example, the composition and/or formulation according to the invention
20 may be formulated as a pharmaceutical composition together with pharmaceutically acceptable carriers, diluents and/or adjuvants. Therapeutic efficiency and toxicity may be determined according to standard protocols. The pharmaceutical composition may be administered systemically, e.g. intraperitoneally, intramuscularly, or intravenously or locally such as
25 intranasally, subcutaneously or intrathecally. The dose of the composition and/or formulation administered will, of course, be dependent on the subject to be treated and on the condition of the subject such as the subject's weight, the subject's age and the type and severity of the disease or injury to be treated, the manner of administration and the judgement of the prescribing
30 physician. For example, a daily dose of 0.001 to 100 mg/kg is suitable.

Another aspect of the present invention relates to a pharmaceutical composition or formulation comprising the composition or formulation

- 12 -

according to the invention, which contains at least one further active agent. Which further active agent is used depends on the indication to be treated. For example, cytotoxic agents such as doxorubicin, cisplatin or carboplatin, cytokines or other anti-neoplastic agents may be used in the treatment of
5 cancer.

The formulation and/or composition according to the invention may further comprise pharmaceutically acceptable carriers, diluents, and/or adjuvants. The term "carrier" when used herein includes carriers, excipients and/or
10 stabilisers that are non-toxic to the cell or mammal being exposed thereto at the dosages and concentrations employed. Often the physiologically acceptable carriers are aqueous pH buffered solutions or liposomes. Examples of physiologically acceptable carriers include buffers such as phosphate, citrate and other organic acids (however, with regard to the
15 formulation of the present invention, a phosphate buffer is preferred); anti-oxidants including ascorbic acid, low molecular weight (less than about 10 residues) polypeptides; proteins such as serum albumin, gelatine or immunoglobulins; hydrophilic polymers such as polyvinyl pyrrolidone; amino acids such as glycine, glutamine, asparagine, arginine or lysine;
20 monosaccharides, disaccharides, and other carbohydrates including glucose, mannose or dextrans, gelating agents such as EDTA, sugar, alcohols such as mannitol or sorbitol; salt-forming counterions such as sodium; and/or non-ionic surfactants such as TWEEN, polyethylene or polyethylene glycol.

25 According to a preferred embodiment the composition and/or formulation according to the invention can be used to inhibit the CD95 signalling pathway, in particular the extrinsic apoptotic pathway triggered by CD95L, i.e. the CD95 receptor ligand. In particular, the composition can be used in
30 the prophylaxis and/or treatment of disorders selected from autoimmune disorders, AIDS, heart disorders, e.g. myocardial infarction, graft-versus-host disorders, transplant rejection, brain damage, e.g. stroke, spinal cord injuries, sepsis, hepatitis, disorders associated with inflammation, ischemic

- 13 -

reperfusion injury and renal disorders. Of course, the composition and/or formulation described herein may be used for the treatment of cancers, preferably solid cancers, e.g., brain cancers, e.g., glioblastomas. Alternatively, the cancer to be treated may be a cancer of lymphoid or myeloid origin.

Another aspect of the present invention relates to a method for producing a composition according to the invention. According to a preferred embodiment the method comprises the steps

- (a) production of a composition as provided by the present invention by a feed batch production process, providing a cell harvest and
- (b) isolation of the composition of the present invention from the cell harvest.

One advantage of the method of the present invention compared to the methods known from the prior art is its high yield.

Step (a), i.e. the "method for producing a composition according to the present invention by a feed-batch production process providing a cell harvest" will also be designated as "upstream process (USP)" in the following. The method according to step (a) of the present invention is also referred to as "inventive USP". Figure 1 shows a comparison of the upstream process according to the prior art and a preferred embodiment of the upstream process of the present invention.

Step (b), i.e. "isolation of the composition of the present invention from the cell harvest" will also be designated as "downstream process (DSP)" in the following.

Preferably, step (a) comprises a series of cultivation steps of a given master cell batch until relevant harvest parameters are reached followed by sedimentation and filtration of fusion protein, preferably containing supernatant. In a preferred embodiment of the present invention the process

- 14 -

steps of the upstream process may be summarised as a series comprising the following steps.

Thawing,

5

subcultivation,

50 l bioreactor,

10

200 l bioreactor,

1000 l bioreactor,

sedimentation,

15

depth and

0.2 µm filtration.

20

Of course, carrying out the cultivation steps from subcultivation to the 1000 l bioreactor is only one way of carrying out the invention. For example, the cultivation steps may be carried out in bioreactors with varying sizes as well. Of course, during the series of subcultivation steps, the person skilled in the art can determine suitable parameters like temperature, growth time, media, etc. The crucial factor is to achieve relevant harvest parameters, which may be a titer, the cell density, with the titer being preferably within a range of 0.5 g/l to 5 g/l, more preferably 1 g/l to 3 g/l, more preferably 1.5 g/l to 5 g/l and most preferably being 1.8 g/l to 2 g/l. Examples for preferred values of cell density are about 1×10^6 to 1×10^8 cells/ml, preferably about 1×10^7 cells/ml. In an especially preferred embodiment of the present invention the titer is about 1.8 g/l to about 2 g/l and the cell density is about 1×10^7 cells/ml.

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- 15 -

The method according to the present invention is preferably carried out in a pepton-containing basal medium and a chemically defined medium.

Step (b) may comprise capture chromatography, virus inactivation, a series
5 of anion and/or cation chromatography, virus filtration and/or adjustment to a desired final protein concentration.

The downstream process of purifying a composition comprising APG101
isoforms obtained by step (a) according to step (b) defined above comprises
10 chromatography steps, a virus inactivation step, an ultrafiltration step, a diafiltration step and a virus filtration step. According to a preferred embodiment, this downstream process comprises three different chromatographic steps. The first chromatography step is carried out with a resin to capture the target protein and/or to remove process-related
15 impurities (e.g., HCPs, DNA) and or to reduce the volume of the product-containing fraction. A corresponding resin can be selected by the person skilled in the art. An example of a resin is Mab Select SuRE, which is also a preferred embodiment according to the invention.

20 After this first chromatography step a virus inactivation step follows. Preferably, this virus inactivation step is performed under acidic conditions (e.g., pH 3.5 ± 0.2) followed by a conditioning of the inactivation pool or at a less acidic pH value such as pH 5.0. The buffer matrix for virus inactivation and subsequent pH 5.0 adjustment may be solely based on 20 nM Na-citrate
25 buffer.

After this virus inactivation step chromatography, an ion exchange step is carried out in order to reduce process-related impurities such as DNA. According to the present invention an anion exchange chromatography
30 (AEX) step is preferred, particular in a flow-through mode. The target protein passes the AEX column, whereas DNA binds to the resin. Preferably, the AEX flow-through pool is subsequently processed without any conditioning using a further column-based step. This optional further step contributes to

- 16 -

the overall reduction of virus contamination and residual HCP, DNA and bleached protein-A ligand. According to a preferred embodiment a mix-mode resin capto-MMC operated column in bind/eluate mode is used.

5 The eluate is passed through a virus filter (VF) and applied to an ultra-diafiltration step (UF/DF) subsequently. According to the invention a specific volumetric load of $\leq 100 \text{ l/m}^2$ can be obtained on the virus filtration step. Preferably, a membrane with about a 30 kD cut-off is used. Of course, single purification steps described above can be replaced by steps known to the
10 person skilled in the art achieving the same or a comparable effect.

Finally, the UF/DF retentate is formulated and the concentration of the APG101 composition according to the present invention is adjusted to the desired protein concentration such as $20 \pm 2 \text{ mg/ml}$.

15

Figure 2 illustrates the flow scheme of a preferred embodiment of a downstream process according to the present invention. As can be taken from Figure 3 the inventive downstream process is characterised by a number of advantages over downstream processes known from the prior art.

20 For example, after virus inactivation no holding step at a neutral pH value is required. With regard to the virus filtration step, a volumetric load $\leq 100 \text{ l/m}^2$ is possible compared to 37 g/m^2 known in prior processes. Further, using the formulation buffer of the present invention high protein concentrations such as 20 mg/ml can be reached compared to 10 mg/ml in PBS.

25

The method for producing a composition according to the present invention, which is described herein, results in APG101 isoforms in pI range of 4.0 to 8.5. A composition provided this way only contains very small amounts of unwanted higher molecular weight forms such as dimers or aggregates.
30 APG101 isoforms provided this way are characterised by high amounts of sialic acid content as well as Fc-based N-terminal glycosylation comprising high amounts of fucosylated forms.

- 17 -

Another aspect of the present invention is a fusion protein comprising at least an extracellular CD95 domain or a functional fragment thereof and at least a Fc domain or a functional fragment thereof.

5 The extracellular CD95 domain can be a human extracellular CD95 domain. The extracellular CD95 domain can comprise SEQ ID NO:7 and sequences having at least 70%, at least 80%, at least 90%, at least 95%, or at least 97% identity to SEQ ID NO:7.

10 In the fusion protein according to the present invention, disulfide bridges can be present in the CD95 domain or the functional fragment thereof linking positions 34 and 48, 38 to 57, 60 and 76, 79 and 94, 82 and 102, 104 and 118, 110 and 115, 121 and 132, or/and 124 and 140 with reference to SEQ ID NO:7. A preferred fusion protein comprises a disulfide bridge at position
15 110 to 115 with reference to SEQ ID NO:7. A disulfide bridge can also be present in the Fc domain or a functional fragment thereof linking position 43 and 103 or/and position 149 and 207 with reference to SEQ ID NO:8.

It is contemplated that a reference to a specific position of SEQ ID NO:7 or
20 SEQ ID NO:8 includes a reference to corresponding positions of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, or SEQ ID NO:19, if applicable. For example, the disulfide bridge
25 at position 104 and 118 with reference to SEQ ID NO:7 corresponds to a disulfide bridge at position 129 to 143 with reference to SEQ ID NO:1.

In the present invention, it has surprisingly been found that in the fusion protein, the N terminal truncation of the extracellular CD95 domain of up to
30 33 amino acids in SEQ ID NO:7 does not reduce stability compared with full-length APG101. For example, fusions proteins of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, and SEQ ID NO:6 provide a stability which is at least the stability of the full-length APG101 (Example 2). Another aspect of the

- 18 -

present invention is thus a fusion protein comprising a functional fragment of the extracellular CD95 domain of SEQ ID NO:7 being truncated until position 33. In the fusion protein, the functional fragment of the extracellular CD95 domain can comprise SEQ ID NO:7 truncated by up to 33 N terminally located amino acids. In the fusion protein of the present invention, the functional fragment of the extracellular CD95 domain can comprise an amino acid sequence wherein 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, or 33 N terminal amino acids are truncated in SEQ ID NO:7.

10

In a preferred aspect, 13 N terminal amino acids are truncated in the extracellular CD95 domain (SEQ ID NO:3).

15

In another preferred aspect, 14 N terminal amino acids are truncated in the extracellular CD95 domain (SEQ ID NO:4).

In yet another preferred aspect, 29 N terminal amino acids are truncated in the extracellular CD95 domain (SEQ ID NO:5).

20

In yet another preferred aspect, 31 N terminal amino acids are truncated in the extracellular CD95 domain (SEQ ID NO:6).

25

In a further aspect, the fusion protein of the present invention can comprise a functional fragment comprising an amino acid sequence selected from the group consisting of SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, and sequences having at least 70%, at least 80%, at least 90%, at least 95%, or at least 97% identity to SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, or SEQ ID NO:12. In particular, the fusion protein can comprise a functional fragment of the extracellular CD95 domain comprising an amino acid sequence selected from the group consisting of SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, and SEQ ID NO:12.

30

In the fusion protein according to the present invention the at least a Fc

- 19 -

domain can be a human Fc domain. Suitable Fc domains and Fc fragments are described herein. In particular the at least a Fc domain can comprise an amino acid sequence selected from the group consisting of SEQ ID NO:8 and sequences having at least 70%, at least 80%, at least 90%, at least
5 95%, or at least 97% identity to SEQ ID NO:8.

The fusion protein according to the present invention can be free of a signal peptide, as the signal peptide present in the immature expression product will be cleaved off during maturation.

10 In another aspect, the fusion protein according to the present invention can comprise an N terminally located signal peptide.

The signal peptide can be a naturally occurring CD95 signal peptide, as, for
15 example a signal peptide comprising SEQ ID NO:14. The signal peptide can be a modified natural signal peptide, for example a signal peptide comprising SEQ ID NO:13. SEQ ID NO:13 corresponds to positions 1 to 25 of SEQ ID NO:1. SEQ ID NO:13 corresponds to SEQ ID NO:14, except position 2 (Leu in SEQ ID NO:14, Val in SEQ ID NO:13).

20 In a preferred aspect, in the fusion protein of the present invention, the N terminally located signal peptide is an artificial signal peptide. More preferably, the signal peptide comprises SEQ ID NO:2 or a sequence having at least 90%, or at least 95% identity to SEQ ID NO:2.

25 In the fusion protein according to the present invention, the extracellular CD95 domain or the functional fragment thereof can be located N terminally of the at least a Fc domain or the functional fragment thereof. The signal peptide, if present, can be directly fused to the extracellular CD 95 domain or
30 the functional fragment thereof.

In the fusion protein according to the present invention the extracellular CD95 domain or the functional fragment thereof can be directly fused to an

- 20 -

Fc domain or the functional fragment thereof. An overlap of one amino acid (for example, Ser at position 172 of SEQ ID NO:1 and at corresponding positions of other sequences disclosed herein) can be present.

5 In another aspect of the present invention, the fusion protein is APG101, or a polypeptide having at least 70%, at least 80%, at least 90%, at least 95%, or at least 97% identity to APG101 and/or a functional fragment of APG101. The fusion protein of the present invention can comprise SEQ ID NO:1, or a sequence having at least 70%, at least 80%, at least 90%, at least 95%, or at
10 least 97% identity to SEQ ID NO:1. The fusion protein of the present invention can also comprise SEQ ID NO:15, or a sequence having at least 70%, at least 80%, at least 90%, at least 95%, or at least 97% identity to SEQ ID NO:15.

15 In yet another aspect of the present invention, the fusion protein can comprise a sequence selected from the group consisting of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, SEQ ID NO:6, and sequences having at least 70%, at least 80%, at least 90%, at least 95%, or at least 97% identity to SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, or SEQ ID NO:6. SEQ ID
20 NOs: 3-6 provide a sequence including a signal peptide of SEQ ID NO:2.

In yet another aspect of the present invention, the fusion protein can comprise a sequence selected from the group consisting of SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, and sequences having at
25 least 70%, at least 80%, at least 90%, at least 95%, or at least 97% identity to SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, or SEQ ID NO:19. SEQ ID NOs: 16-19 are free of a signal peptide.

In another aspect of the present invention, in the fusion protein, the at least a
30 Fc domain or a functional fragment thereof can provide a pI in the range of 4.0-8.5, preferably in the range of 4.5 - 7.8, more preferably 5.0 - 7.5, as described herein in the context of the mixture of fusion proteins.

- 21 -

In one aspect of the present invention, the fusion protein of the present invention is not glycosylated in the CH2 domain of the Fc domain or the functional fragment thereof. It is preferred to prevent glycosylation by replacing the Asn residue N250 in SEQ ID NO:1 (or at a corresponding
5 position in another sequence disclosed herein, for example position 79 in SEQ ID NO:8) by serine.

In yet another aspect of the present invention, the fusion protein can comprise high amounts of sialic acids, as described herein in the context of
10 the mixture of fusion proteins.

In yet another aspect of the present invention, in the fusion protein, the Fc based N-linked glycosylation is characterized by high amounts of fucosylated forms, as described herein in the context of the mixture of fusion proteins.

15 In yet another aspect of the present invention, the fusion protein comprises N-terminally blocked fusion proteins, such as fusion proteins blocked by pyro-Glu modification and/or comprising fusion proteins having a free N-terminus, as described herein in the context of the mixture of fusion proteins.
20 The fusion protein can comprise 80-99 mol-% N-terminally blocked fusion proteins and/or 1-20 mol-% fusion proteins having a free N-terminus, as described herein in the context of the mixture of fusion proteins.

The fusion protein of the present invention can be an isolated fusion protein.

25 Yet another aspect of the present invention is a nucleic acid molecule encoding the fusion protein of the present invention. Said nucleic acid preferably is in operative linkage to at least one expression control sequence suitable for expression in a host cell as described herein. The skilled person
30 knows suitable expression control sequences, for example promoters, enhancers, terminators etc.

Yet another aspect of the present invention is a host cell comprising a

- 22 -

nucleic acid molecule of the present invention. The host cell can be an eukaryotic cell, in particular a mammalian cell, more particular a human cell. Preferred cell lines include HEK293 and CHO. Most preferred is a CHO suspension cell, which can be pre-adapted to a chemically defined culture medium.

Yet another aspect of the present invention is a formulation comprising a fusion protein according to the present invention, or/and a nucleic acid molecule according to the present invention. The formulation is in particular a pharmaceutical composition optionally comprising a carrier, diluent or/and auxiliary substance, as described herein. The formulation can be used in the treatment of a disease or condition, as described herein.

The formulation of the present invention can further comprise:

- (a) phosphate, preferably about 20 mM to about 100 mM phosphate, more preferably about 50 mM phosphate,
- (b) a viscosity enhancing agent, such as sorbitol, preferably about 0.1-10 weight-% viscosity enhancing agent, more preferably about 5 weight-% viscosity enhancing agent, and/or
- (c) having a pH value in the range of 4-8.

Yet another aspect of the present invention is a method for producing a fusion protein according to the present invention, comprising recombinant expression of a nucleic acid molecule encoding the fusion protein, in particular in a host cell as described herein. The skilled person knows suitable methods. The method can comprise the steps

- (a) production of a fusion protein according to the present invention by a fed-batch production process providing a cell harvest, and
- (b) isolation of the fusion protein according to the present invention from the cell harvest.

In the method for producing a fusion protein step (a) can comprise a series

- 23 -

of cultivation steps of a given master cell batch until relevant harvest parameters are reached, followed by cell sedimentation and filtration of fusion protein containing supernatant, and/or step (b) can comprise capture chromatography, virus inactivation, a series of anion and/or cation chromatography, virus filtration and/or adjustment to a desired final protein concentration.

Yet another aspect of the present invention is a polypeptide comprising SEQ ID NO:2 or a sequence having at least 90%, or at least 95% identity to SEQ ID NO:2. SEQ ID NO:2 describes an artificial signal peptide capable of transporting a peptide or protein expressed in a eukaryotic host cell to the cell surface. Preferably, the signal peptide consists of a SEQ ID NO:2. It has surprisingly been found that in the expression of a protein or polypeptide having a Lys, Thr, Asp or Gln in the first position of the mature polypeptide, a signal peptide comprising SEQ ID NO:2 results in a mature peptide precisely cut between the signal peptide and the first amino acid of the mature peptide. In contrast, a signal sequence, as for example in positions 1 to 25 in SEQ ID NO:1, provides variable cleavage behind position 16, 20 or 25 so that a mixture of cleavage products is obtained. In this case, fusion proteins can be obtained having a first amino acid being Arg17, Lys21 or Pyro-Glu26 with reference to SEQ ID NO:1. Any peptide or protein can be expressed in a eukaryotic cell with the aid of the signal peptide comprising SEQ ID NO:2 or a sequence having at least 90%, or at least 95% identity to SEQ ID NO:2. In particular, the polypeptide to be expressed with the aid of a signal peptide comprising SEQ ID NO: 2, or a sequence having at least 90%, or at least 95% identity to SEQ ID NO:2, can be a fusion protein as described herein, for example a fusion protein of any one of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, and SEQ ID NO:19.

30

Yet another aspect is a nucleic acid encoding a polypeptide comprising SEQ ID NO:2, or a sequence having at least 90%, or at least 95% identity to SEQ ID NO:2.

- 24 -

Other aspects of the present invention relate to truncated extracellular CD95 domains, as described herein. Preferred is a truncated extracellular CD95 domain comprising SEQ ID NO: 9, SEQ ID NO:10, SEQ ID NO:11 or SEQ ID NO:12. Further aspects relate to nucleic acids encoding truncated extracellular CD95 domains, as described herein.

SEQ ID NO:1 describes APG101 including a signal peptide.

SEQ ID NO:2 describes an artificial signal peptide.

SEQ ID NO:3 describes a truncated form of APG101 termed APG130, including the artificial signal peptide of SEQ ID NO:2.

SEQ ID NO:4 describes a truncated form of APG101 termed APG131, including the artificial signal peptide of SEQ ID NO:2.

SEQ ID NO:5 describes a truncated form of APG101 termed APG132, including the artificial signal peptide of SEQ ID NO:2.

SEQ ID NO:6 describes a truncated form of APG101 termed APG133, including the artificial signal peptide of SEQ ID NO:2.

SEQ ID NO: 7 describes a human CD95 extracellular domain (positions 26 to 172 of SEQ ID NO:1).

SEQ ID NO: 8 describes a human Fc domain domain (positions 172 to 400 of SEQ ID NO:1).

SEQ ID NO:9 describes a truncated form of the extracellular domain of human CD95 (positions 21 to 154 of SEQ ID NO:3).

SEQ ID NO:10 describes a truncated form of the extracellular domain of

- 25 -

human CD95 (positions 21 to 153 of SEQ ID NO:4).

SEQ ID NO:11 describes a truncated form of the extracellular domain of human CD95 (positions 21 to 138 of SEQ ID NO:5).

5

SEQ ID NO:12 describes a truncated form of the extracellular domain of human CD95 (positions 21 to 136 of SEQ ID NO:6)

10

SEQ ID NO:13 describes a modified human CD95 signal peptide (position 1 to 25 of SEQ ID NO:1).

SEQ ID NO:14 describes a human CD95 signal peptide.

15

SEQ ID NO:15 describes a mature form of APG101 (position 26-400 of SEQ ID NO:1).

SEQ ID NO:16 describes a mature form of APG130 (position 21-382 of SEQ ID NO:3).

20

SEQ ID NO:17 describes a mature form of APG131 (position 21-381 of SEQ ID NO:4).

SEQ ID NO:18 describes a mature form of APG132 (position 21-366 of SEQ ID NO:5).

25

SEQ ID NO:19 describes a mature form of APG133 (position 21-364 of SEQ ID NO:6).

Figures

30

Figure 1: Comparison of the inventive upstream process with a non-inventive upstream process

- 26 -

- Figure 2:** Flow scheme showing a preferred embodiment of the downstream process of the invention
- Figure 3:** Comparison of the inventive downstream process with a non-inventive downstream process
- Figure 4a:** IEF of AEX fraction of an APG101 mixture obtained by the inventive method.
- Figure 4b:** IEF of AEX fraction of an APG101 mixture obtained by the non-inventive method.
- Figure 5:** Schematic overview of the potency assay.
- Figure 6:** In vitro biological activity (EC_{50}) of APG101 isoform mixtures obtained by the inventive method compared with APG101 obtained by non-inventive methods.
- Figure 7:** Functional APG101 molecule.
- Figure 8:** Thermal stability shift assay of APG101 (CD95-Fc) and mature, i.e. truncated forms of CD95-Fc (APG130, APG131, APG132 and APG133) employing Sypro Orange as fluorophor. Sypro Orange was used as a 1:1000 dilution. Melting points of the proteins were calculated and are displayed in Table 4.

- 27 -

Example 1

Method for producing a composition according to the invention

5 The method for providing a composition according to the present invention comprises an upstream process and a downstream process as defined above.

1. Upstream process

10

1.1 Batch definition

The composition comprising APG101 isoforms is produced in a fed-batch cultivation. Two vials of the master cell bank MCB1AGA are thawed. The viability of the third subcultivation has to be > 90%, the viable cell count has to be >1.5x10⁶ cells/mL. If both vials fulfill these specifications, the culture with the higher viability is used for the fourth subcultivation and inoculation of the seed reactor. The culture with lower viability will be discarded after third subcultivation. The cell culture is expanded in shake flasks up to ≥ 4 L total volume before inoculating the first seed bioreactor. As first seed bioreactor a 20 50 L Xcellerex disposable bioreactor (XDR) is used. The cell culture is cultivated for three days before being transferred into the second seed reactor 200 L XDR. After another 3 days of cultivation, the 1000L production reactor is inoculated. Harvesting procedure is started at day 13 or earlier, if the viability drops below 61%.

25

1.2 Cell line

The utilized Master Cell Bank (MCB) is designated "MCB1AGA".

1.3 Thawing and subcultivations

30 Two cryo vials of the MCB are resuscitated consecutively. The following thawing procedure is applied for each vial: The cryo vials are thawed in a beaker with WFI at 36.8 °C (setpoint) until a small ice crystal remains. Cells

are then transferred into approx. 10 mL of cooled (at 5 ± 3 °C) growth media (media no. 3001772, purchased from PAA), supplemented with 6 mM L-glutamine (final concentration) and 50 nM MTX (final concentration). To remove residual DMSO, a washing step in cooled (5 ± 3 °C) medium is performed via centrifugation. The cell pellet is resuspended in 50 mL of prewarmed (36.8 ± 1 °C) medium after the centrifugation step. Cell concentration and viability are measured with the Cedex™ cell counter. This Out-of-Freeze culture is finally incubated in a shaker incubator with a working volume of 50 ml using 250 ml shake flasks.

10

The first and second subcultures are stability splits performed with a working volume of 120 ml (first subculture) and 150 mL (second subcultures) using 500 ml shake flasks. The third and fourth subcultures are the first expansion phase and performed in 2000 mL shake flasks with a working volume of 800 mL. For these initial four passages, the prewarmed (at 36.8 ± 1 °C) growth media (media no. 3001772, purchased from PAA), supplemented with 6 mM L-glutamine and 50 nM MTX (final concentrations), is used as cultivation medium.

20 Measurement of cell concentration and viability is performed prior to each cultivation step using a Cedex cell counter. The next subculture is prepared depending on the cell growth.

25 At subculture no. 5, the shake flasks are pooled in a 5L glass bottle. This pool is sampled for cell concentration and viability. Depending on the actual VCC the required cell culture volume is then transferred into a 50 L seed bioreactor.

1.4 Seed Bioreactor (50L)

30 The 50 L seed bioreactor is equipped with a bottom-mounted magnetic drive agitator system and 1 mm sparger discs. Prior to inoculation the 50 L bioreactor is filled with approx. 20 L of growth media (media no. 3001772, purchased from PAA) supplemented with 6 mM L-glutamine (final

- 29 -

concentration). These parameters apply to the medium pre-conditioning and to the seed train cultivation process.

When the process parameters are stable within their acceptable ranges the inoculum transfer is started. After inoculation the reactor is filled up with medium to a final working volume of 25 L. During cell mass expansion in the 50 L bioreactor no feed addition is applied to the process. The pH is controlled with CO₂ via sparger. The oxygen level is controlled by submerge aeration with oxygen on demand. An overlay gas flow of air is applied to the headspace. Submerge aeration with pressurized air with a flow rate of 0.1 L/min, which can be adapted for adjusting pCO₂, is performed. The expected cultivation time in the seed bioreactor is 3 days before inoculation of a 200 L seed bioreactor.

1.5 Seed bioreactor (200 L)

The 200 L seed bioreactor is equipped with a bottom-mounted magnetic drive agitator system and 1 mm sparger discs. Prior to inoculation the 200 L bioreactor is filled with approx. 100 L of growth media (media no. 3001772, purchased from PAA) supplemented with 6 mM L-glutamine (final concentration). These parameters apply to the medium pre-conditioning and to the seed train cultivation process.

When the process parameters are stable within their acceptable ranges the inoculum transfer is started. After inoculation, medium is added to a final working volume of 120L. During cell mass expansion in the 200 L bioreactor no feed addition is applied to the process. The pH is corrected with CO₂ gas. The oxygen level is controlled by submerge aeration with oxygen on demand. An overlay gas flow of air is applied to the headspace. Submerge aeration with pressurized air with a flow rate of 0.4 L/min, which can be adapted for adjusting pCO₂, is performed. The expected cultivation time in the seed bioreactor is 3 days before cells are transferred into a 1000 L production bioreactor.

- 30 -

1.6 Fed-Batch Production Process

The production process of a composition comprising APG101 isoforms is a fed-batch cultivation. A 1000 L production bioreactor is equipped with a bottom-mounted magnetic drive agitator system and 1 mm sparger discs. Prior to inoculation the 1000 L bioreactor is filled with approx. 580 L growth medium (media no. 3001829, purchased from Becton Dickison) and supplemented with 6 mM L-glutamine (final concentration, calculated on the final starting volume of 720L). When the process parameters are within their acceptable ranges the inoculum transfer from the seed bioreactor to the production bioreactor is started. The target cell concentration after inoculation in the production bioreactor is 0.3×10^6 viable cells/mL in a total volume of 720L. The required volume of the seed bioreactor cell culture is transferred to the production reactor, which is then filled up with growth medium (media no. 3001829, purchased from Becton Dickison) until the starting volume of 720L is reached. The cell culture is fed with Feedmedium A (PM30728) starting at day 3, and Glucose Feedmedium B (PM30729).

Daily feeding is started with Feed B separately, Feed A and Glucose can be fed simultaneously.

- Feedmedium B:

Bolus feed starts at day 3 after sampling.

Feeding rate day 3-6: 5.184 g/L/d (calculated on start volume of 720L)

Feeding rate day 7-12: 2.592 g/L/d (calculated on start volume of 720L)

- Feedmedium A:

Bolus feed starts at day 3 after sampling.

Feeding rate day 3-5: 43.2 g/L/d (calculated on start volume of 720L)

Feeding rate day 6-12: 21.6 g/L/d (calculated on start volume of 720L)

- D-Glucose Feed: Glucose is added when the actual D-glucose concentration is < 5 g/L starting at day 7. The concentration of D-glucose is adjusted to 5 g/L by adding the required amounts of D-Glucose feed.

The oxygen level is controlled by application of a oxygen controller cascade

- 31 -

with 3 priorities: Priority 1 consists of a flow of process air on demand until an gas flow of 10 L/min is reached. Then the agitation (priority 2) is increased continuously until a stirring speed of 100 rpm is reached. The third priority consists of submerge sparging O₂ on demand.

5

An air overlay flow is applied to the headspace.

The pH is controlled with CO₂. If necessary 1 M Na₂CO₃ is prepared to be added if necessary. Formation of foam is observed regularly and antifoam is added if necessary.

10

The harvesting procedure is started at cultivation day 13, or earlier if the viability drops below < 61% (Cedex). First step of the procedure is the sedimentation of cells, where the cell broth is cooled down to 10 ± 5 °C. When the temperature is below 20 °C, stirrer, aeration and pH control are switched off. After a minimum of 12 h of sedimentation the clarification step is started. Supernatant is clarified by a two step depth filtration and 0.2 µm filtration.

15

20 *1.7 Sedimentation*

The harvesting procedure is started by a sedimentation step. Culture broth is cooled down to finally 10 ± 5°C. When the temperature is < 20°C, a gitation, pO₂ and pH-control are inactivated. After min. 12 h and max. 22 h hours of sedimentation, depth filtration is started.

25

1.8 Filtration

The depth filtration is performed with the Stax™ Disposable Depth Filter Systems from Pall, loading 7x PDK5 and 2x PDD1 depth filters. The clarification is followed by a 0.2 µm filtration. The depth filters are flushed with approx. 900 L PBS at a flux rate of ≤ 100 L/m²/h. The residual liquid is blown out of the system with air. Filtration process is run with a pump flow rate of ≤ 3,5 L/min and a maximum pressure of 1.0 bar. To increase the product recovery, the filters are rinsed afterwards with approx. 60L PBS pH

30

- 32 -

7,25 and blown out with pressurized air at a maximum pressure at 0.8 bar. Filtrated harvest is transferred directly through the wall duct into the GD suite, collected in a 1000L Mixtainer and stored at room temperature.

5 2. Downstream Process

For illustration purposes a description of the individual purification steps during the downstream process will be given in the following.

2.1 *Protein A capture (C10)*

10 The filtration material from above was transferred depth filtrated (0.2 μm) and tempered to 5 ± 3 °C. Prior to processing the harvest was split in four equal aliquots and stored at room temperature over night to achieve final process temperature of 21 ± 3 °C. The processing of harvest was carried out without any further conditioning on in four cycles.

15 The elution was induced via a low pH step. The UV280 profiles of the four cycles were highly congruent and show the expected shape including the typical single peak. within the elution step.

20 The yields of the Protein A runs varied between 94 to 98 %. Hence, the product recovery of the Protein A runs was in the expected range. Furthermore, all recoveries were comparable with each other and confirmed the data acquired during process transfer and adaptation.

25 2.2 *Virus inactivation (V10)*

Immediately after collecting the Protein A eluate a fixed volume addition (specification: pH 3.5 ± 0.2) was executed with 20 mM citric acid within 5 min to inactivate enveloped viruses. The obtained virus inactivation solutions were incubated separately for 75 ± 15 min at room temperature (21 ± 3 °C).
30 Finally, the pH of the inactivation solutions was adjusted to pH 5.0 ± 0.2 via addition of a fixed volume of 20 mM $\text{Na}_3\text{-Citrate}$ to stop virus inactivation. The entire conditioning schemes were as follows:

Subsequently, the conditioned virus inactivation solutions were filtered via a 0.22 µm filter (Sartobran™ P) to separate potentially formed precipitates and to inhibit microbial growth in the process solution. Each conditioned virus inactivation batch was stored at 21 ± 3 °C and finally pooled prior to processing via the ALEX (C20) step.

2.3 ALEX (C20) -Column

Subsequently to the virus inactivation, pH adjustment and filtration the conditioned virus inactivation pool was processed over a Capto™ Q column in FT mode in two cycles. The method comprises the cleaning in place step 1 (buffer 0.5 M NaOH), an equilibration step (20 mM Na-citrate, pH 5), a load step of conditioned virus inactivation solution, a washing step (20 mM Na-citrate, pH 5.0), a regeneration step (20 mM Na-citrate, 1 M Na-Cl, pH 5.5), a cleaning in place step 2 (0.5 M NaOH) and a storage step (0.01 M NaOH).

The UV280 profiles of the two cycles are congruent and show the expected increase of the UV280 absorption profile during application of the conditioned Protein A eluate.

Each obtained flow through fraction was finally 0.22 µm filtered (Sartobran P) in order to address bioburden reduction. Afterwards, the separate fractions were pooled and stored at 21 ± 3 °C until further processing via the MMC step (C30). A comparison of ALEX fractions of a mixture of APG101 isoforms obtained by the inventive method and of APG101 obtained by a non-inventive method by IEF is shown in Figures 4a and 4b.

The yields of the ALEX runs were around 100 %.

2.4 MMC (C30) – Column

After the C20 step the ALEX product pool was processed over a Capto MMC column in three cycles. The method comprised a cleaning in place step (buffer 0.5 M NaOH), an equilibration step (20 mM Na-citrate, pH 5.0), a load step using the ALEX product/wash, a wash step (20 mM Na-citrate, pH 5.0),

an elution step (50 mM Na-phosphate, 105 mM NaCl, pH 7.4), a regeneration step (3 M NaCl, pH 11), a cleaning in place step (0.5 M NaOH), a conditioning step (50 mM Na-phosphate, 105 mM NaCl, pH 7.4) and a storage step (20 mM Na-phosphate, 20% ethanol, pH 7.5).

5

The elution was induced via an increase of the pH. The UV280 profiles of the three cycles are highly congruent and show the expected shape including the typical single peak within the elution step.

10 Subsequently, the eluate fractions were each filtered over a 0.22 µm filter (Sartobran P) and stored at 21 ± 3 °C. Prior to further processing via the virus filtration step the particular Capto MMC eluate fractions were pooled.

The yields of the MMC runs range around 100 %.

15

2.5 Virus filtration (I10)

Subsequent to the C30 step the Capto MMC eluate pool (1181 mL) was passed over a Durapore™ 0.1 µm filter (Millipak™ 20) prior to the virus filtration. The virus filtration was executed applying an aliquot of the 0.1 µm filtrate (887 mL) on a Planova™ 15N virus filter (100 cm²) equilibrated with 50 mM PBS, pH 7.4 (Capto MMC elution buffer) at a working pressure of 0.8 ± 0.1 bar. The post-wash volume was 0.5 mL/cm² using equilibration buffer. Filter testing was done prior to filter usage based on detection of pressurized air bubbling. The filtrate flux remained constant during processing (ca. 22 L/m²*h).

25

The virus filtration resulted in 99 % yield.

Subsequently, the residual 0.1 µm filtrate and the filtrate fraction of the virus filtration was pooled and stored at 5 ± 3 °C until further processing via subsequent UF/DF step.

30

- 35 -

2.6 Ultrafiltration/Diafiltration (I20)

Prior to diafiltration the I10 filtrate was concentrated on an ÄKTA Crossflow system to a protein concentration of $25.0 \pm 2.0 \text{ mg}_{\text{APG101}}/\text{mL}$ using two Pellicon 3 30 kDa cassettes. Afterwards, a diafiltration was executed to
5 change the buffer system to the following buffer:

50 mM Na-Phosphate, 5 % Sorbitol, pH 6.5

The material was ultrafiltrated to the above mentioned concentration and
10 diafiltrated by factor 7.0 ± 0.5 . The parameters for the ultra- and diafiltration were:

Retentate flow: $450 \text{ L}/(\text{m}^2 \cdot \text{h})$

TMP: $1.2 \pm 0.1 \text{ bar}$

15

The UF/DF yielded in 97 % product recovery.

2.7 Drug substance concentration adjustment

For final concentration adjustment a defined volume (107 mL) of the
20 formulation buffer (50 mM Na-Phosphate, 5 % Sorbitol, pH 6.5) was added to the UF/DF retentate pool. The final drug substance concentration obtained by A280 was 20.4 mg/mL . Finally, the drug substance was $0.22 \mu\text{m}$ filtered (Sartobran P). Subsequently, aliquots of the drug substance with a volume of $200 \mu\text{L}$ were bottled in $500 \mu\text{L}$ vials.

25

2.8 Total yield

The step and total yields obtained from ProA-HPLC and A280 analysis are listed in Table 1. The sampling of the target molecule was not taken into account for the calculation of the yields.

30

- 36 -

Table 1: Overview of step yield

Sample	Total yield (%)	
Protein A capture (C10)	96 ^{#1}	101 ^{#2}
Virus inactivation (V10)	90	94
AIEX (C20)	90	94
MMC (C30)	90	94
Virus filtration (I10)	89	93
UF/DF (I20)	86	90
Formulation (I30)	86	90

#1 Load determined via ProA-HPLC harvest method, Eluate via ProA-HPLC.

#2 Load determined via ProA-HPLC harvest method, Eluate via A280.

5 The identity of the mixture of APG101 isoforms was confirmed via non-reducing SDS Page and IEF. The isoform pattern showed additional basic bands compared to the reference material and a slight shift in the isoform distribution towards acidic pI.

10 This is shown, for example, by a comparison of an IEF gel of AX fractions obtained by the method of the present invention and an APG101 mixture obtained by the non-inventive method according to Figure 1.

15 The APG101 isoform mixture of the present invention further differs in the presence of carbohydrates (N-glycans sialic acid).

Carbohydrates (antennarity/N-glycans)

20 In Table 2 the analysis of the carbohydrate structure is summarized. Despite a comparable carbohydrate structure between the reference material and the inventive composition the distribution of carbohydrate structures differs.

- 37 -

Table 2: N-glycans (carbohydrates) analysis result

Peak/Sample	Reference material (Mol-%)	Inventive composition (Mol-%)
cF1GN2	34.1	18.2
cF1GN2G1	19.2	17.8
cF1GN2G3	30.1	51.5
cF1GN2G3	9.1	7.6
Other	7.6	4.9

Carbohydrates (sialic acids)

- 5 The analysis of the amount of sialic acid per mol of APG101 of the inventive composition is summarized in Table 3.

Table 3: Sialic acid (carbohydrate) analysis

Sample	Sialic acid content (mol NeuAc / mol APG101)
Inventive composition	5.1
Reference material	3.9

- 10 The reference material always relates to an APG101 mixture which was not produced by the method of the present invention.

Finally, an assay was carried out to measure the bioactivity of the mixture according to the present invention comprising APG101 isoforms.

15

3. Method for the determination of the in vitro potency of APG101 isoforms

- 20 A cellular assay with a Jurkat A3 permanent T-cell line is used for the determination of biological activity of the APG101. This potency is schematically shown in Figure 5.

With this apoptosis assay employing Jurkat A3 cells, EC50 values for the inhibition of APG293 (=CD95L-T4; 250 ng/ml) induced apoptosis by APG101

are determined.

In brief, Jurkat A3 cells are grown in flasks with RPMI 1640-medium + GlutaMAX™ (GibCo) supplemented with 10 % FBS, 100 units/ml Penicillin and 100 µg/ml Streptomycin. 100,000 cells are seeded per well into a 96-well microtiter plate. CD95L-T4 (APG293) at a constant concentration of 250 ng/ml is incubated in a separate 96-well microtiter plate for 30 minutes at 37°C with different concentrations of APG101. The addition of the APG101/CD95L-T4 mixture to the cells is followed by 3 hours incubation at 37°C. Cells are lysed by adding lysis buffer (250 mM HEPES, 50 mM MgCl₂, 10 mM EGTA, 5 % Triton-X-100™, 100 mM DTT, 10 mM AEBSF, pH 7.5) and plates are put on ice for 30 minutes to 2 hours. Apoptosis is paralleled by an increased activity of Caspases (e.g. caspases 3 and 7). Hence, cleavage of the Caspase substrate Ac-DEVD-AFC is used to determine the extent of apoptosis. In fact, caspase activity correlates with the percentage of apoptotic cells determined morphologically after staining the cells with propidium iodide and Hoechst-33342.

For the caspase activity assay, 20 µl cell lysate is transferred to a black 96-well microtiter plate. After the addition of 80 µl buffer containing 50 mM HEPES, 1 % Sucrose, 0.1 % CHAPS, 50 µM Ac-DEVD-AFC, and 25 mM DTT, pH 7.5, the plate is transferred to a Tecan™ microtiter plate reader and the increase in fluorescence intensity over a given time frame is monitored (excitation wavelength 400 nm, emission wavelength 505 nm). Employing the GraphPad™ Prism software, EC50 values for APG101 (i.e. reduction of apoptosis induction of the given concentration of CD95L by 50%) are calculated.

Determination of the biological activity of APG101 employing the potency assay enables:

- a high specificity. Via its interaction with CD95, CD95L-T4 induces apoptosis on Jurkat A3 cells. The CD95/CD95L-T4 interaction is specifically blocked by the addition of APG101.

- 39 -

- the use of a relevant cellular system; induction of apoptosis is one important physiological feature of the CD95/CD95L signalling and can be monitored in the well characterised human T-cell line Jurkat A3.
- a high sample throughput due to the application of 96 well microtiter plates and short incubation times.

5

Figure 6 shows the biological activity (EC₅₀) of APG101 isoforms mixtures obtained by the inactive method (inventive samples) compared to APG101 obtained by non-inventive methods. The activity is comparable.

10

- 40 -

Example 2*Background:*

Environmentally-sensitive dyes, such as Sypro Orange, have been applied to the detection of protein unfolding in thermal shift assays, by a procedure referred to as the ThermoFluor technique. In the procedure, dyes interact with exposed hydrophobic regions generated by partial or full unfolding of proteins.

10 *Method procedure:*

The investigated proteins and Sypro Orange were pipetted to Flat Cap Strips (BioRad, cat. no. TCS0803) in a 48-well plate (low white, BioRad, cat. no. MLL4851). In a final volume of 25 μ l the concentration of the investigated proteins was 500 μ g/ml (diluted with PBS, pH 7.4) and 1:1000 for Sypro Orange (Invitrogen, cat. no. S6650). The cycler (BioRad MiniOpticon) was run as follows: 2 minutes at 25°C, then plate read; from 25°C to 95°C an increment of 1°C every 10 seconds with a plate read after each 1°C increment.

20 *Results:*

As can be seen in Figure 8, the truncated form of CD95-Fc (APG101) have the same stability compared with CD95-Fc as expressed by essentially the same melting point T_m (Table 4).

25 **Table 4:** Melting points (T_m) of APG101 (CD95-Fc) and truncated forms of APG101 (APG130, APG131, APG132 and APG133). The respective thermal stability shift assay curves employing Sypro Orange as fluorophor are displayed in Figure 8.

	APG101	APG130	APG131	APG132	APG133
T_m (°C)	69	68	69	68	68

Claims

1. A fusion protein comprising (i) a functional fragment of an N-terminally truncated extracellular cluster of differentiation 95 (CD95) domain, wherein the functional fragment of the N-terminally truncated extracellular CD95 domain consists of the amino acid sequence of SEQ ID NO: 11 or 12, or a sequence having at least 97% identity to SEQ ID NO: 11 or 12, and (ii) an Fc domain or a functional fragment thereof, wherein the Fc domain is a human Fc domain consisting of the amino acid sequence of SEQ ID NO: 8 or a sequence having at least 97% identity to SEQ ID NO: 8.
2. The fusion protein according to claim 1, wherein the functional fragment of the N-terminally truncated extracellular CD95 domain consists of the amino acid sequence of SEQ ID NO:11 or SEQ ID NO:12.
3. The fusion protein according to claim 1 or 2, said fusion protein being free of a signal peptide.
4. The fusion protein according to claim 1 or 2, comprising an N-terminally located signal peptide.
5. The fusion protein according to claim 4, wherein the N-terminally located signal peptide is a naturally occurring CD95 signal peptide.
6. The fusion protein according to claim 5, wherein the N-terminally located signal peptide is an artificial signal peptide.
7. The fusion protein according to claim 6, wherein the N-terminally located signal peptide comprises SEQ ID NO:2 or a sequence having at least 90%, or at least 95% identity to SEQ ID NO:2.
8. The fusion protein according to any one of claims 1 to 7, wherein the functional fragment of the N-terminally truncated extracellular CD95 domain is located N-terminally to the Fc domain or the functional fragment thereof.
9. The fusion protein according to claim 6, wherein the signal peptide is directly fused to the functional fragment of the N-terminally truncated extracellular CD95 domain.
10. The fusion protein according to any one of claims 1 to 9, wherein the functional fragment of the N-terminally truncated extracellular CD95 domain is directly fused to the N-terminal of the Fc domain or to the functional fragment thereof, wherein the two domains have an overlapping amino acid of serine.

11. The fusion protein according to claim 10, comprising a sequence selected from the group consisting of SEQ ID NO:5, SEQ ID NO:6, and a sequence having at least 97% identity to SEQ ID NO:5, or SEQ ID NO:6.
12. The fusion protein of any one of claims 1 to 11, wherein the Fc domain or the functional fragment thereof provides a pI in the range of 4.0-8.5.
13. The fusion protein according to claim 12, wherein the pI is in the range of 4.5-7.8.
14. The fusion protein according to any one of claims 1 to 13, comprising sialic acids.
15. The fusion protein according to any one of claims 1 to 14, which is N-terminally blocked.
16. The fusion protein according to any one of claims 1 to 15, which is not glycosylated in the CH2 domain of the Fc domain or of the functional fragment thereof.
17. A formulation comprising the fusion protein according to any one of claims 1 to 16 and a pharmaceutically acceptable carrier.
18. The formulation of claim 17 further comprising: (a) a phosphate, (b) a viscosity enhancing agent, and (c) having a pH value in the range of 4-8.
19. The fusion protein according to claim 15, wherein the N-terminally blocked fusion protein is blocked by pyro-Glu modification.
20. The formulation of claim 18, wherein the phosphate is in an amount of 20 mM to 100 mM, and the viscosity enhancing agent is sorbitol in an amount of 0.1 to 10 weight %.
21. A nucleic acid molecule encoding the fusion protein according to any one of claims 1 to 16.
22. An isolated host cell comprising the nucleic acid molecule of claim 21.
23. A method for producing the fusion protein according to any one of claims 1 to 16, comprising recombinantly expressing a nucleic acid molecule encoding the fusion protein.
24. The method of claim 23, comprising the steps of: (a) producing the fusion protein according to any one of claims 1 to 16 by a fed-batch production process providing a cell harvest, and (b) isolating the fusion protein from the cell harvest.

25. The method according to claim 24, wherein step (a) comprises a series of cultivation steps of a given master cell batch until relevant harvest parameters are reached, followed by cell sedimentation and filtration of fusion protein containing supernatant.

26. The method according to claim 24 or 25, wherein step (b) comprises one or more of the following steps: capture chromatography, virus inactivation, anion chromatography, cation chromatography, virus filtration and adjustment to a desired final protein concentration.

Figure 1

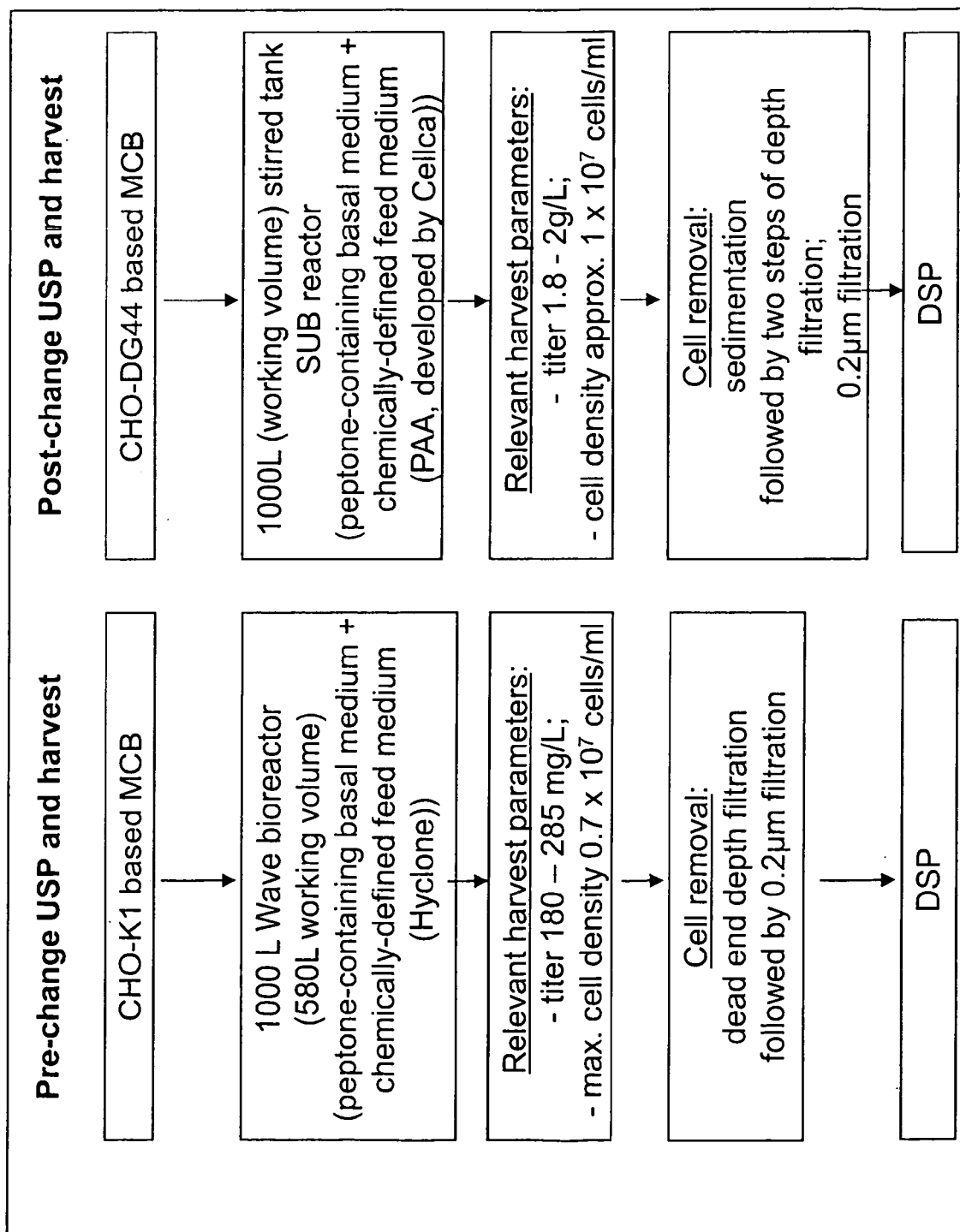


Figure 2

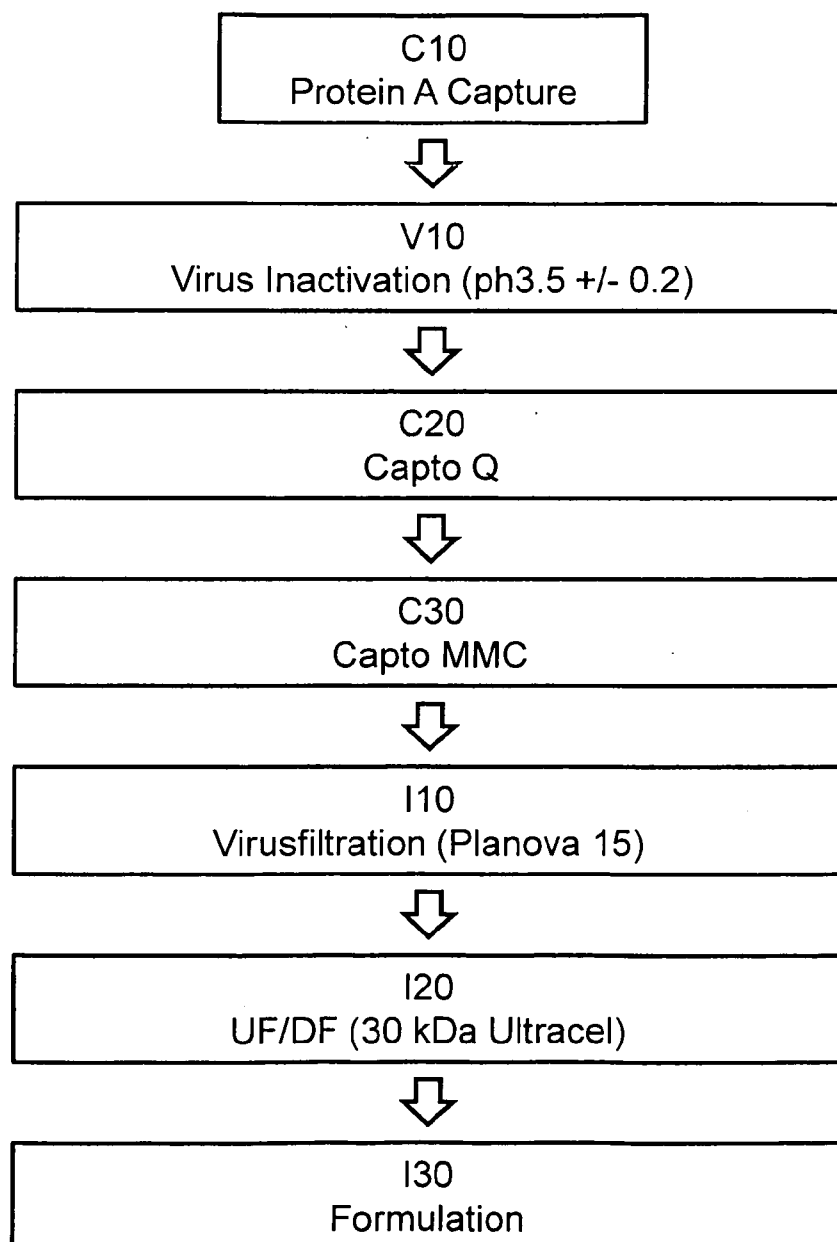
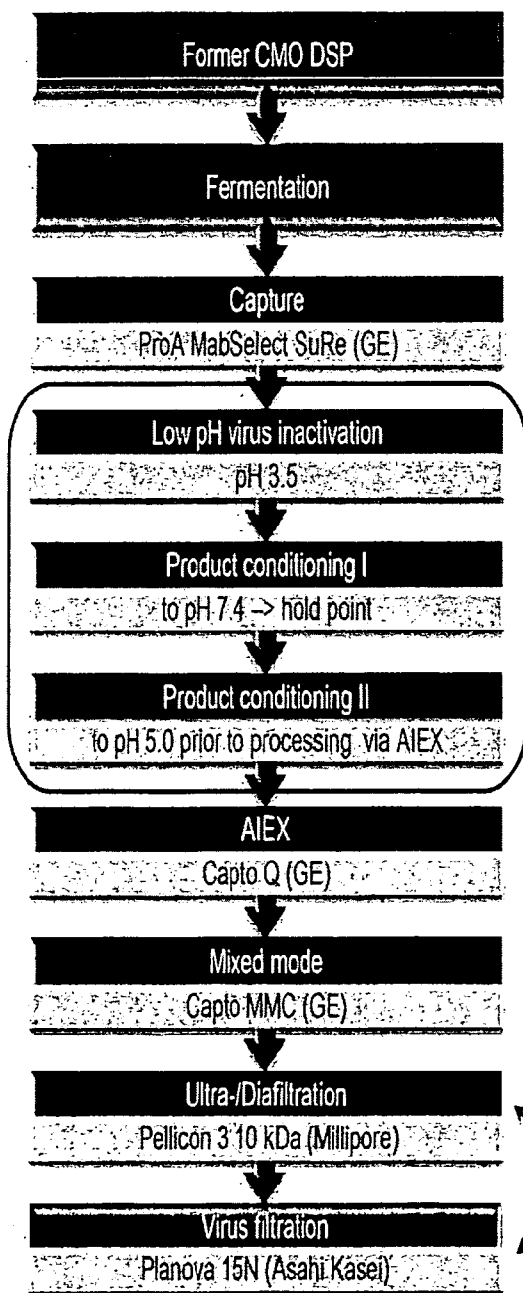


Figure 3

Downstream process
known from prior art



Inventive downstream
process

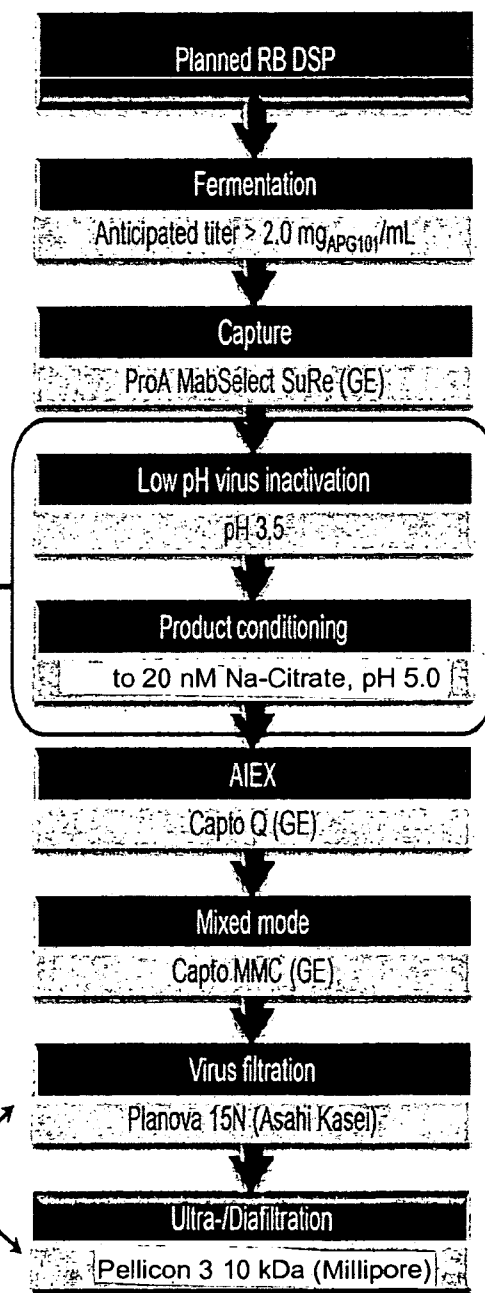
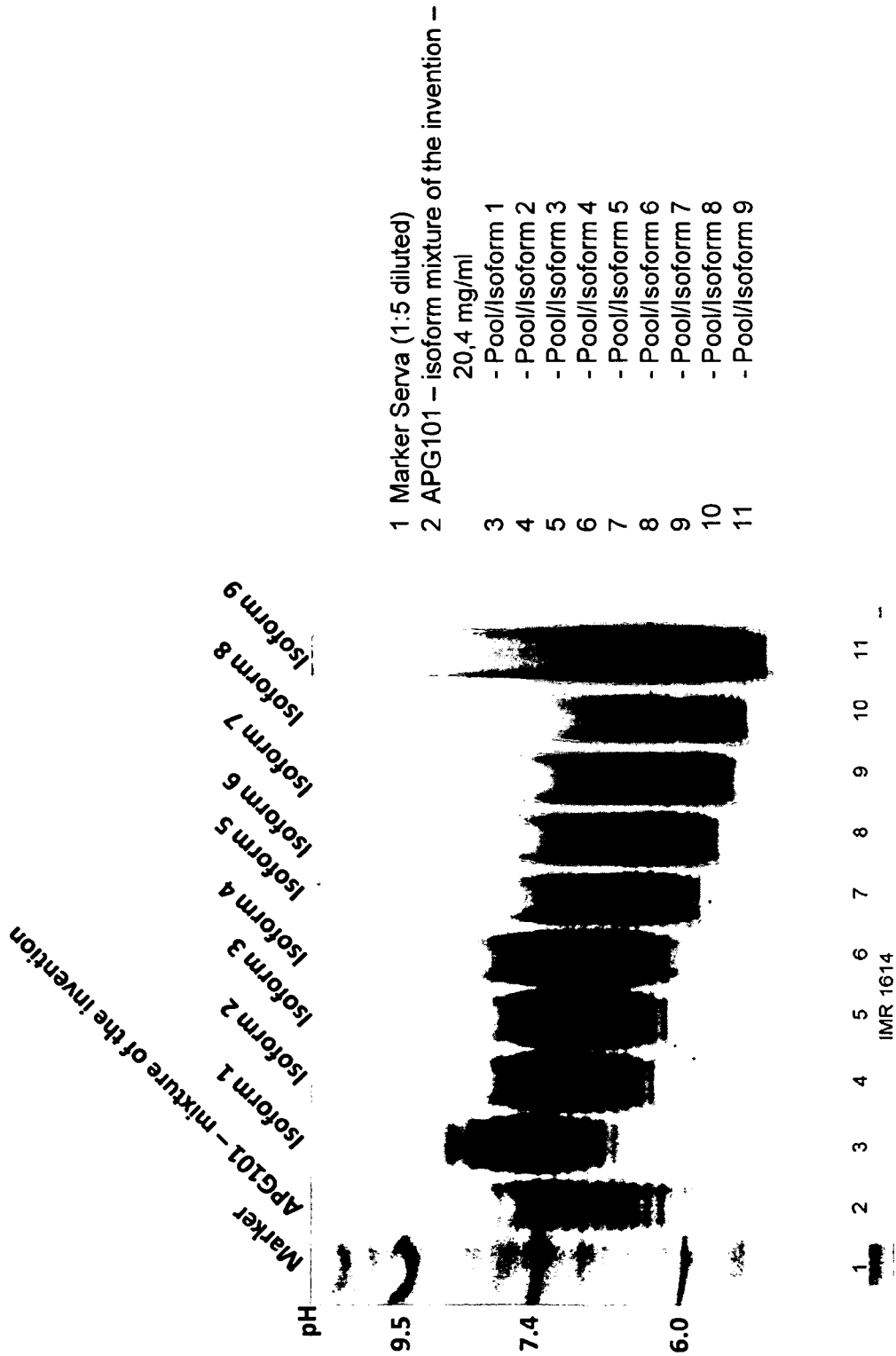


Figure 4a



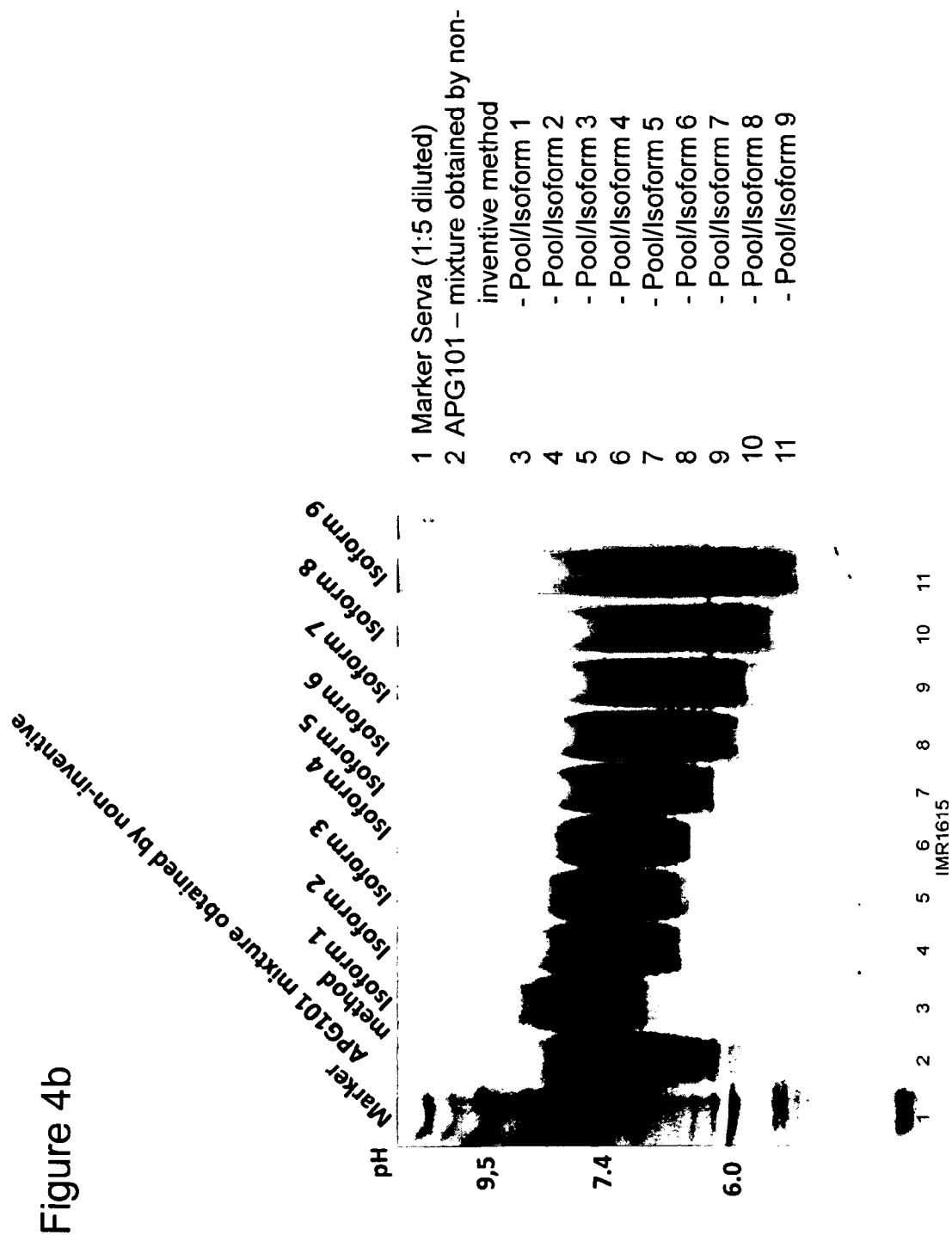
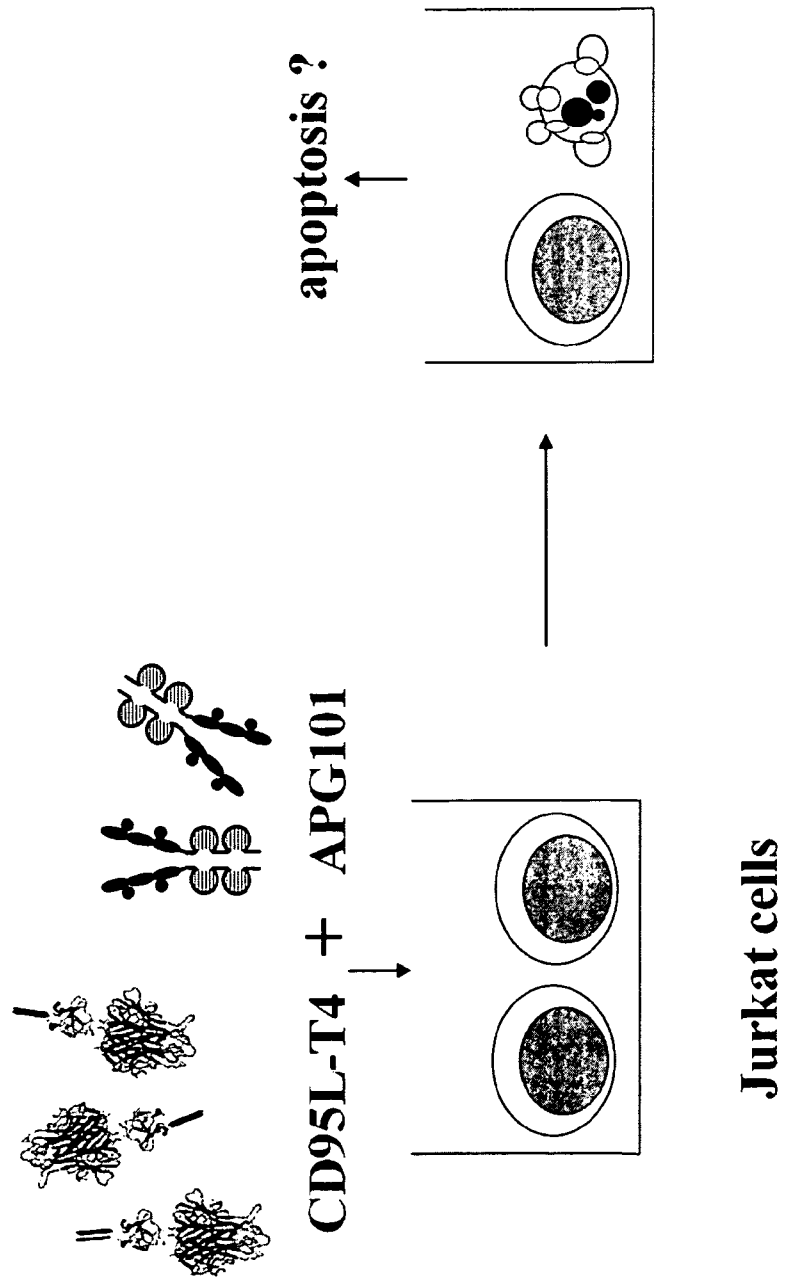


Figure 5



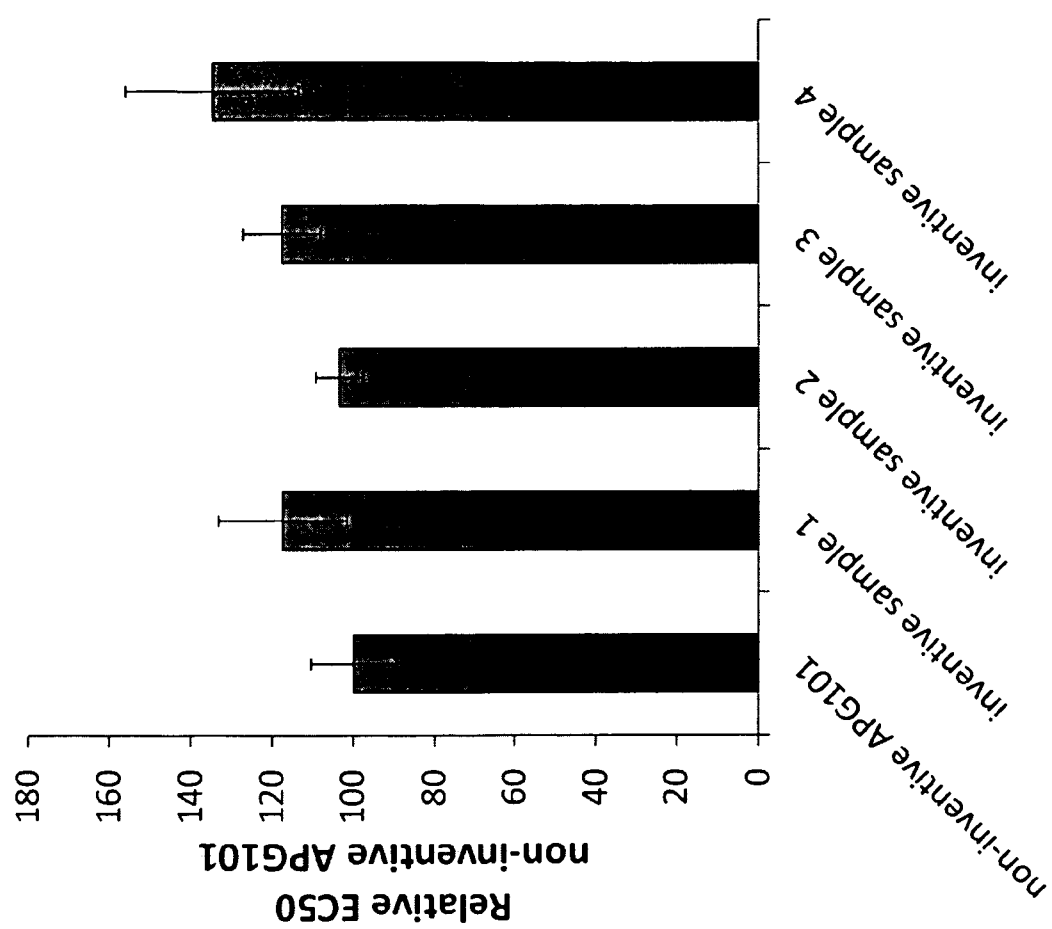


Figure 6

Figure 7

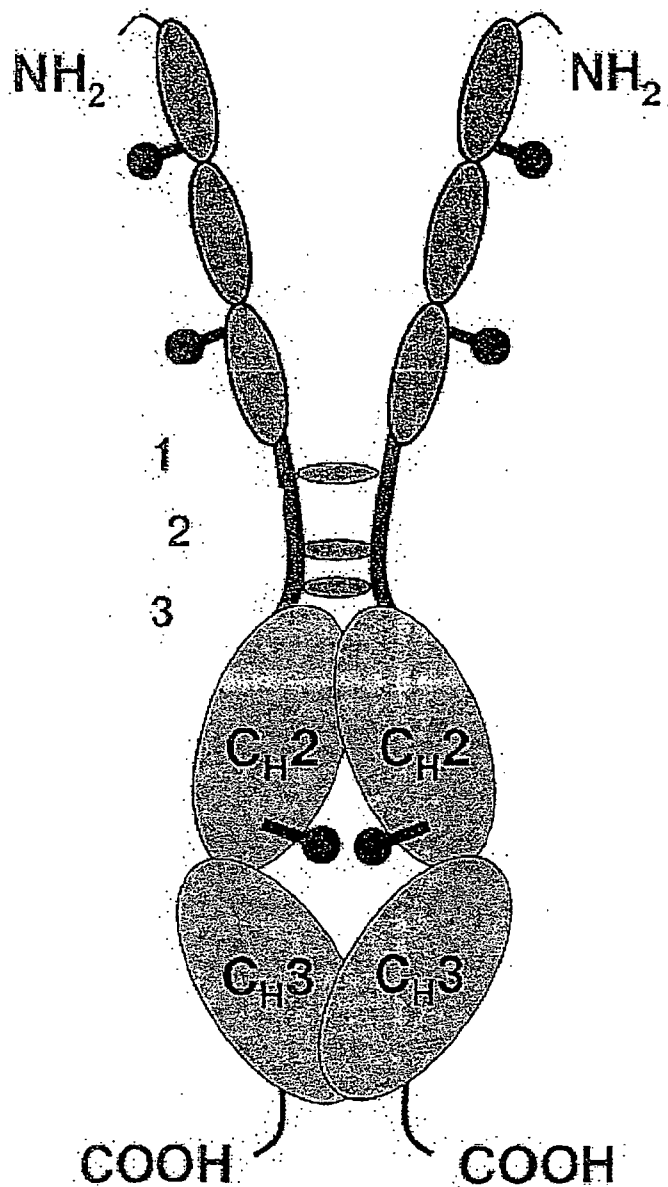


Figure 8

