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(54) Titre : MUTEINES COMPETENTES DE SECRETION DE SOUS-UNITE ALPHA DE L'IL-27 HUMAINE
(54) Title: SECRETION-COMPETENT MUTEINS OF THE HUMAN IL-27 ALPHA-SUBUNIT

(57) **Abrégé/Abstract:**

The present invention refers to a secretion-competent mutein of the α -subunit of human Interleukin 27 and to a human heterodimeric Interleukin 27. The present invention further refers to a nucleic acid molecule comprising a nucleotide sequence encoding a secretion-competent mutein of the α -subunit of human Interleukin 27 or the human heterodimeric Interleukin 27, to a host cell containing a nucleic acid molecule comprising a nucleotide sequence encoding a secretion-competent mutein of the α -subunit of human Interleukin 27 or of the human heterodimeric Interleukin 27. The invention also refers to an immune modulator comprising a secretion-competent mutein of the α -subunit of human Interleukin 27 or of the human heterodimeric Interleukin 27, to the respective use thereof as well as to a method of producing said secretion-competent muteins and to a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 and a secretion-competent mutein of the β -subunit of mouse Interleukin 27.

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(54) Title: SECRETION-COMPETENT MUTEINS OF THE HUMAN IL-27 ALPHA-SUBUNIT

(57) Abstract: The present invention refers to a secretion-competent mutein of the α -subunit of human Interleukin 27 and to a human heterodimeric Interleukin 27. The present invention further refers to a nucleic acid molecule comprising a nucleotide sequence encoding a secretion-competent mutein of the α -subunit of human Interleukin 27 or the human heterodimeric Interleukin 27, to a host cell containing a nucleic acid molecule comprising a nucleotide sequence encoding a secretion-competent mutein of the α -subunit of human Interleukin 27 or of the human heterodimeric Interleukin 27. The invention also refers to an immune modulator comprising a secretion-competent mutein of the α -subunit of human Interleukin 27 or of the human heterodimeric Interleukin 27, to the respective use thereof as well as to a method of producing said secretion-competent muteins and to a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 and a secretion-competent mutein of the β -subunit of mouse Interleukin 27.

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SECRETION-COMPETENT MUTEINS OF THE HUMAN IL-27 ALPHA-SUBUNIT

FIELD OF THE INVENTION

[001] The present invention refers to a secretion-competent mutein (mutant proteins) of the alpha-subunit of human Interleukin 27 (SEQ ID NO: 1) and to a secretion-competent mutein of human heterodimeric Interleukin 27, wherein the alpha-subunit thereof is a secretion-competent mutein of the alpha-subunit of human Interleukin 27 (SEQ ID NO: 1). The invention also refers to a secretion-competent mutein of the alpha-subunit of human Interleukin 27, wherein the mutein comprises at least 76 % sequence identity to the alpha-subunit of human Interleukin 27 (SEQ ID NO: 1). The invention also refers to a secretion-competent mutein of human heterodimeric Interleukin 27, wherein the alpha-subunit thereof comprises at least 76 % sequence identity to the alpha-subunit of human Interleukin 27 (SEQ ID NO: 1). Interleukin 27 comprises the alpha-subunit p28 and the beta-subunit EBI3. The invention further refers to a nucleic acid molecule comprising a nucleotide sequence encoding a secretion-competent mutein of the alpha-subunit of human Interleukin 27 or encoding a secretion-competent mutein of the human heterodimeric Interleukin 27, wherein the alpha-subunit thereof is a secretion-competent mutein of the alpha-subunit of human Interleukin 27 as described herein. The invention further refers to a host cell containing a nucleic acid molecule comprising a nucleotide sequence encoding a secretion-competent mutein of the alpha-subunit of human Interleukin 27 or a secretion-competent mutein of the human heterodimeric Interleukin 27, wherein the alpha-subunit thereof is a secretion-competent mutein of the alpha-subunit of human Interleukin 27 as described herein. The invention also refers to an immune modulator comprising a secretion-competent mutein of the alpha-subunit of human Interleukin 27 or a secretion-competent mutein of the human heterodimeric Interleukin 27, wherein the alpha-subunit thereof is a secretion-competent mutein of the alpha-subunit of human Interleukin 27 as described herein, to the use of a secretion-competent mutein of the alpha-subunit of human Interleukin 27 as described herein or a secretion-competent mutein of the human heterodimeric Interleukin 27 as described herein for the manufacture of a medicament, to a method of treating an Interleukin 27-mediated disease comprising the step of administering a composition comprising a mutein of the present invention to a mammal in need thereof as well as to a method of producing a secretion-competent mutein of the alpha-subunit of human

Interleukin 27 or a secretion-competent mutein of the human heterodimeric Interleukin 27, wherein the alpha-subunit thereof is a secretion-competent mutein of the alpha-subunit of human Interleukin 27 as described herein or a secretion-competent mutein comprising at least 76 % sequence identity to the alpha-subunit of human Interleukin 27. Additionally, the present invention refers to any mutein as described herein for use in the treatment of infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma. The invention further refers to a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10), wherein at least one of the two cysteine residues at amino acid positions 103 and 158 is/ are mutated or deleted. Due to such a mutation or deletion, the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10), which is in general secretion-competent, becomes secretion-incompetent, meaning that the secretion now depends on the presence of EBI3. Thereby, the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) behaves like the α -subunit of human Interleukin 27 (SEQ ID NO: 1), which is extremely necessary for mouse models, which aim at imaging the human immune system.

[002] The present invention also provides a secretion-competent mutein of the beta-subunit of mouse Interleukin 27 (SEQ ID NO: 35), wherein at least one of the amino acid residues at amino acid position 198 is mutated or deleted. The human beta-subunit of Interleukin 27 can be secreted alone, while – naturally - the mouse beta-subunit of Interleukin 27 is secretion-incompetent. Both, the mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) and the secretion-competent mutein of the beta-subunit of mouse Interleukin 27 (SEQ ID NO: 35) as described herein together display a phenocopy of the human system.

[003] Additionally, the present invention also provides a mutein of mouse Interleukin 27, comprising an α -subunit p28 and a β -subunit EBI3, wherein the α -subunit is a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) as described herein and/or wherein the β -subunit is a secretion-competent mutein of the β -subunit of mouse Interleukin 27 (SEQ ID NO: 35) as described herein.

BACKGROUND OF THE INVENTION

[004] A central tenet of the human immune system is the balanced regulation of pro- and anti-inflammatory responses. This allows rapid eradication of threats while protecting the host. Interleukins (ILs) are structurally diverse small secreted proteins that mediate pro- and anti-inflammatory responses to maintain this balance. Among those, the Interleukin 12 (IL-12) family, which comprises four established members (IL-12, IL-23, IL-27 and IL-35)¹, epitomizes this concept of balanced immune regulation: IL-12 and IL-23 are mostly pro-inflammatory cytokines, whereas IL-35 performs immune-suppressive roles^{1,2}. IL-27 is functionally diverse with immunomodulatory pro- and anti-inflammatory functions, acting on different types of T cells³. It can promote pro-inflammatory responses and synergize with IL-12 to induce interferon γ (IFN γ) production by naïve T cells and natural killer (NK) cells⁴; but IL-27 can also dampen immune responses by inducing IL-10 as an anti-inflammatory cytokine⁵⁻⁷ or inhibiting responses of T_H17 cells^{8,9}, a cell type that has come into focus due to its role in a large variety of immune-mediated human diseases¹⁰.

[005] Interleukin 12 (IL-12) cytokines regulate T cell function and development, decisively influencing pro- *versus* anti-inflammatory responses. Each family member is a heterodimer, and additionally their isolated subunits regulate immune reactions. This endows the IL-12 family with unparalleled regulatory capacities but also puts high demands on their biosynthesis. The inventors of the present invention have surprisingly found out that differences in a single amino acid determine if IL-12 family subunits can be secreted autonomously, acting as an independent cytokine, or if they depend on heterodimerization for secretion.

[006] Features shared by the IL-12 family, however, go beyond this central role in connecting innate and adaptive immunity. All IL-12 cytokines show structural hallmarks that set this family apart from other interleukins: Each of the IL-12 family members is a heterodimer composed of a 4-helical bundle α -subunit (IL-12 α /p35, IL-23 α /p19 and IL-27 α /p28, respectively) and of a β -subunit composed of two fibronectin (Fn) domains (EBI3) or two Fn and one immunoglobulin (Ig) domains (IL-12 β /p40)^{11,12}. Of note, despite their distinct roles in regulating immune responses, all heterodimeric IL-12 family members are made up of only these three α - and two β -subunits and even further members may exist¹³. IL-12 β is shared by the pro-inflammatory family members IL-12 and IL-23 and EBI3 is shared by the immunomodulatory/anti-inflammatory members IL-27 and IL-35.

This raises important questions about structural features that mediate assembly specificity *versus* promiscuity within this family. It also poses an extra demand on the machinery of protein folding and quality control in the endoplasmic reticulum (ER), where all IL-12 family members are assembled prior to secretion. Insights into IL-12 family cytokine folding and assembly are very limited so far. It has been shown that all human α -subunits are retained in cells in isolation and depend on assembly with their cognate β -subunit in order to be secreted^{4,14,15}. In the case of the family's founding member, IL-12, assembly-induced folding of the IL-12 α -subunit by IL-12 β underlies these processes¹⁶, but otherwise the underlying mechanisms remain ill-defined.

[007] Concerning the present invention, the inventors have focused on the structurally ill-characterized yet functionally highly diverse family member IL-27. Interestingly, when discovering IL-27, it was found that in contrast to its human orthologue, the mouse IL-27 α -subunit (p28) can be secreted in isolation without its beta-subunit, whereas the secretion of human IL-27 α strictly depends on EBI3⁴. And importantly, the mouse IL-27 α -subunit has been shown to exert immunomodulatory effects on IL-27 signaling by competing for IL-27 receptor binding¹⁷. These differences raise intriguing structural and evolutionary questions about assembly control of IL-27 in the ER and the different physiological roles of heterodimeric IL-27 *versus* its isolated α -subunit IL-27 α . Moreover, the mouse IL-27 α -subunit is under discussion as possible competitive inhibitor of IL-27 signalling or could even exercise autonomous immunoregulatory functions. Accordingly, it would be desirable to have a human secretion-competent α -subunit of human IL-27 that can be secreted without the presence of its β -subunit. It is thus an object of the present invention to provide such secretion-competent proteins. Another object of the present invention is to provide a mouse IL-27 α -subunit which can only be secreted together with its beta-subunit EBI3 as the basis for mouse models that better resemble the human immune system.

[008] Thus, the inventors of the present invention have analysed the underlying structural determinants and have revealed that a conformational switch coupled to disulfide bond formation regulates retention *versus* secretion concerning mutants of the α -subunit of IL-27. Using these insights, the inventors provide a more human-like IL-12 system in mice and add a new biologically active member to the human interleukin repertoire. The findings of the present inventors reveal a close link between protein folding and immunoregulation that can be used to engineer an organism's cytokine repertoire.

SUMMARY OF THE INVENTION

[009] In a first aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated. The invention also provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1). The present invention also provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated. The invention also provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0010] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues at sequence positions 160 to 165 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated. The present invention also provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues at sequence positions 160 to 163 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated. Additionally, the present invention provides a secretion-competent mutein comprising at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues at sequence positions 160 to 165 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated. Additionally, the present invention provides a secretion-competent mutein comprising at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues at sequence positions 160 to 163 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.

[0011] In another aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated. Further, the present invention provides a secretion-competent mutein comprising at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated. In another aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is mutated.

[0012] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine. In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated to cysteine. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated to cysteine.

[0013] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine. Additionally, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine.

[0014] The term "secreting" or "secretion" is the active export of a protein from a cell into the extracellular environment. Generally secretion occurs through a secretory pathway in the cell, for example, in eukaryotic cells, this generally involves the endoplasmic reticulum and the golgi apparatus.

[0015] A mutein according to the present invention is "secretion-competent" or "comprises secretion competence", when the mutein is able to perform a complete passage through the secretory pathway of the cell and through the cytoplasmic membrane.

[0016] In contrast thereto, the term "non-secretion competent" muteins means in the context of the present invention muteins, which are not naturally secreted from the cell into the extracellular environment. This term also comprises that the "non-secretion" competent mutein can only be secreted from the cell into the extracellular environment when the β -subunit EBI3 is present. The term "secretion-incompetent" is used interchangeably herein with the term "non-secretion competent". These terms can also comprise that the respective mutein comprises a modulating secretion competency.

[0017] In a second aspect, the present invention provides a secretion-competent mutein of human Interleukin 27, which is secretion-competent as heterodimer, comprising an α -subunit p28 and a β -subunit EBI3, wherein the α -subunit is a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1). In a further embodiment thereof, the α -subunit is a secretion-competent mutein comprising at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) as described herein.

[0018] In a third aspect, the present invention provides a nucleic acid molecule comprising a nucleotide sequence encoding the secretion-competent mutein of human

Interleukin 27 or the secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) according to the present invention. In a further embodiment thereof, the nucleic acid molecule comprises a nucleotide sequence encoding a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the secretion-competent mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1). In yet another aspect, the invention provides the nucleic acid molecule as described herein for use as a therapeutic agent.

[0019] In a fourth aspect, the present invention provides also a host cell containing a nucleic acid molecule according to the present invention.

[0020] In a fifth aspect, the present invention provides an immune modulator comprising a mutein according to the present invention.

[0021] In a sixth aspect, the present invention provides the use of a mutein according to the present invention for the manufacture of a medicament for treating infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal.

[0022] In a related aspect, the present invention provides a mutein according to the present invention for use as a medicament. Further, the present invention provides a mutein according to the present invention for use in the treatment of infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma.

[0023] The present invention also provides a method of treating an Interleukin 27-mediated disease, preferably an infectious disease, an autoimmune disease, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, a chronic inflammatory disease, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal, comprising the step of administering a composition comprising a mutein as described herein to a mammal in need thereof.

[0024] Additionally, the present invention provides a method for producing a mutein as described herein, comprising the steps of:

introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or a polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 or of a polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182, and

introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

[0025] The present invention also provides a method for producing a mutein as described herein, comprising the steps of:

introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182, and

introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

[0026] The present invention also provides a method for producing a mutein as described herein, comprising the steps of:

introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 selected from the group consisting of sequence positions 161, 162 and 163, and

introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

[0027] In yet another aspect the invention provides a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10), wherein at least one of the two cysteines at amino acid positions 103 and 158 is/are mutated (i.e. replaced by another amino acid residue) or deleted. This means in this embodiment that the secretion of this mutein is

not-autonom, but depends on the presence of EBI3. This secretion-dependent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO:10) thus behaves like the human α -subunit of Interleukin 27 (SEQ ID NO:1).

[0028] In another aspect, the present invention also provides a secretion-competent mutein of the beta-subunit of mouse Interleukin 27 (SEQ ID NO: 35), wherein the amino acid residue at amino acid positions 198 is mutated or deleted. It is preferred in this embodiment that a secretion-competent mutein of the beta-subunit of mouse Interleukin 27 (SEQ ID NO: 35) is provided, wherein the amino acid residue at amino acid positions 198 is replaced by a tyrosine (SEQ ID NO: 36).

[0029] These aspects of the invention will be more fully understood in view of the following drawings, detailed description and non-limiting examples.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] The accompanying drawings are included to further an understanding of the embodiments that are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and together with the description serve to explain principles of embodiments. Other embodiments and many of the intended advantages of embodiments will be readily appreciated, as they become better understood by reference to the detailed description. The elements of the drawings are not necessarily to scale relative to each other.

[0031] **Figure 1** shows the protein sequence of the wild-type α -subunit of human Interleukin 27 (SEQ ID NO:1) as also deposited under UniProtKB accession number Q8NEV9.

[0032] **Figure 2** shows that human and murine IL-27 α differ in their secretion behavior from mammalian cells. **Figure 2(a)** shows schematically heterodimeric IL-27 comprising the α -subunit p28 and the β -subunit EBI3 and how they are bound to its heterodimeric receptor. **Figure 2(b)** shows that human IL-27 α depends on co-expression of its β -subunit EBI3 for secretion. The human IL-27 α -subunit (hIL-27 α) was transfected alone or co-expressed with the human IL-27 β -subunit EBI3 (hEBI3, SEQ ID NO: 9) in 293T cells as indicated (mock displays an empty pSVL vector). 2 % lysate (L) or medium (M) were immunoblotted against Hsc70 as loading control, the V5 epitope tag (hIL-27 α) or

hEBI3 (SEQ ID NO: 9). **Figure 2(c)** shows that O-glycosylation gives rise to two species of secreted V5-tagged hIL-27 α . 4 % medium of cells co-transfected with hIL-27 α (SEQ ID NO: 1) and hIL-27 β (hEBI3 is β -subunit, SEQ ID NO: 9) was treated (displayed by the symbol +) with N-glycosidases (EndoH, PNGaseF) or an O-glycosidase as indicated, and subsequently immunoblotted against V5. Controls without enzyme are signed by (-). **Figure 2(d)** shows that murine IL-27 α can be secreted in isolation. The mouse IL-27 α (mIL-27 α) (SEQ ID NO: 10) subunit was transfected alone or co-expressed with hEBI3 (SEQ ID NO: 9) in 293T cells as indicated (mock displays empty pSVL vector). 2 % lysate (L) or medium (M) were immunoblotted against Hsc70 as loading control, V5 (mIL-27 α) or hEBI3 (SEQ ID NO: 9). The protein sequence of the wild-type alpha-subunit of mouse Interleukin 27 (SEQ ID NO: 10) is also deposited as genebank identifier NP_663611.1.

[0033] **Figure 3** shows that oxidative folding permits secretion of IL-27 α in isolation. **Figure 3(a)** shows potentially folding-relevant differences in the amino acid sequence of human and murine IL-27 α . Identical residues are highlighted in grey (not black) without a box with dashed line, homologous residues are highlighted by a box with dashed line. Differences with a potential impact on (ER) folding are highlighted with a box with solid line, namely, the presence or absence of a predicted N-glycosylation site, an extra cysteine, or a lysine insertion interrupting a poly-glutamate stretch. Arrows indicate the position of cysteines. **Figure 3(b)** shows the substitution of leucine 162 with cysteine (L162C, SEQ ID NO: 2) in human IL-27 α , which leads to its secretion in isolation. hIL-27 α (SEQ ID NO: 1), hIL-27 α^{D89N} (SEQ ID NO: 31), hIL-27 α^{L162C} (SEQ ID NO: 2), hIL-27 $\alpha^{K168\text{insertion}}$ (SEQ ID NO: 32) or empty pSVL vector (mock) were transfected in 293T cells and 2 % lysate (L) or medium (M) were immunoblotted against Hsc70 and V5. **Figure 3(c)** shows structural models of mIL-27 α (SEQ ID NO: 10) and hIL-27 α (SEQ ID NO: 1). Homology models of mIL-27 α (SEQ ID NO: 10) and hIL-27 α (SEQ ID NO: 1) were generated using iTasser. Cysteines in mIL-27 α (SEQ ID NO: 10) and the corresponding residues in hIL-27 α (SEQ ID NO: 1) are shown in a CPK representation. **Figure 3(d)** shows the superposition of murine and human IL-27 α structural models. RMSD calculations were performed using Yasara structure. **Figure 3(e)** shows that secreted hIL-27 α^{L162C} (SEQ ID NO: 2) forms a disulfide bridge. Left: Secreted hIL-27 α^{L162C} (SEQ ID NO: 2) was analyzed by non-reducing SDS-PAGE. 2 % medium of cells were transfected, as indicated, with hIL-27 α^{L162C} (SEQ ID NO: 2), hEBI3 (SEQ ID NO: 9) or empty pSVL vector (mock) and were

immunoblotted against V5 and EBI3. Where indicated with (+) in the line β -Me, samples were treated with β -mercaptoethanol. Dashed lines are shown to guide the eye and highlight mobility differences between reduced/ non-reduced samples. Right: Same conditions were applied as in the experiment seen left, however, as indicated with (-) in the line β -Me, without treatment of β -mercaptoethanol.

[0034] Figure 4 shows determinants and chaperone recognition of incompletely folded hIL-27 α (SEQ ID NO: 1). **Figure 4(a)** shows that the single free cysteine does not lead to ER retention of hIL-27 α (SEQ ID NO: 1). hIL-27 α^{C107L} (SEQ ID NO: 28) is retained in the cell when expressed alone and secreted upon co-expression of hEBI3 (SEQ ID NO: 9). 293T cells were transfected with hIL-27 α^{C107L} (SEQ ID NO: 28) and hEBI3 (SEQ ID NO: 9) as indicated and 2 % of lysate (L) or medium (M) was immunoblotted against Hsc70, V5 and EBI3. **Figure 4(b)** shows that the flexible poly-glutamate loop does not cause ER retention of hIL-27 α (SEQ ID NO: 1). hIL-27 $\alpha^{\Delta 164-176}$ (SEQ ID NO: 24), hIL-27 $\alpha^{\Delta 164-180}$ (SEQ ID NO: 25) and hIL-27 $\alpha^{164-180toGS}$ (SEQ ID NO: 26) are retained in the cell in isolation, whereas co-expression of hEBI3 (SEQ ID NO: 9) induces their secretion. hIL-27 $\alpha^{\Delta 164-176}$ (SEQ ID NO: 24), hIL-27 $\alpha^{\Delta 164-180}$ (SEQ ID NO: 25) or hIL-27 $\alpha^{164-180toGS}$ (SEQ ID NO: 26) and hEBI3 (SEQ ID NO: 9) were co-transfected in cells as indicated and 2 % of lysate (L) or medium (M) were immunoblotted against Hsc70, V5 and EBI3. **Figure 4(c)** shows that the chaperone BiP binds significantly better to wild type hIL-27 α (SEQ ID NO: 1) than to hIL-27 α^{L162C} (SEQ ID NO: 2). 20 % lysate of cells were transfected with hIL-27 α (SEQ ID NO: 1) or hIL-27 α^{L162C} (SEQ ID NO: 2) and hamster BiP or empty pSVL vector (mock) and, as indicated, were immunoprecipitated with anti-V5 antibody and immunoblotted against BiP and V5 (N=4 $\pm$ SD; *p<0.05). Normalization was performed as described in the Examples section with the signals of the wild type (wt) set to 1. **Figure 4(d)** shows molecular dynamics simulations and reveals locally confined reduced flexibility in hIL-27 α^{L162C} (SEQ ID NO: 2). The root means square fluctuation (RMSF) for wt hIL-27 α (SEQ ID NO: 1) and hIL-27 α^{L162C} (SEQ ID NO: 2) with its disulfide bridge formed are overlayed. **Figure 4(e)** shows regions with reduced flexibility in hIL-27 α^{L162C} (SEQ ID NO: 2) with its formed disulfide bridge as compared to wt hIL-27 α (shown as balls). A putative cluster of hydrophobic residues is shown in a stick representation. **Figure 4(f)** shows that hIL-27 α needs to be secreted as a heterodimer with hEBI3 (SEQ ID NO: 9). 293T cells were transfected with hIL-27 α (SEQ ID NO: 1) alone or together with hEBI3 (SEQ ID NO:

9) or hEBI3^{KDEL} (SEQ ID NO: 27). 2 % of lysate (L) or medium (M) was immunoblotted against Hsc70, V5 and EBI3.

[0035] **Figure 5** displays a species comparison of IL-27 α secretion. **Figure 5(a)** shows a sequence alignment of IL-27 α from different species and reveals differences in their cysteine content and localization. Cysteines and corresponding positions are highlighted by boxes. **Figure 5(b)** shows IL-27 α from three different species as indicated, which were either expressed in isolation or in the presence of human EBI3 (SEQ ID NO: 9). 2 % of lysate (L) or medium (M) of cells transfected with the indicated constructs was immunoblotted against Hsc70, V5 and hEBI3 (SEQ ID NO: 9). Due to the different expression levels/ intensities of IL-27 α from different species, the middle blot is separated in sections with optimal exposure each. **Figure 5(c)** shows that the substitution of cysteine 158 with leucine (C158L) in mouse IL-27 α (SEQ ID NO: 29) leads to its dependency of EBI3 co-expression for secretion. The indicated constructs were transfected in 293T cells and 2 % lysate (L) or medium (M) were immunoblotted against Hsc70, V5 and EBI3.

[0036] **Figure 6** shows the interaction between the murine IL-27 α subunits (SEQ ID NO: 10) (SEQ ID NO: 29) and hEBI3 (SEQ ID NO: 9). Secreted mIL-27 α (SEQ ID NO: 10) and mIL-27 α ^{C158L} (SEQ ID NO: 29) both interact with hEBI3 (SEQ ID NO: 9). 1 % medium of cells transfected with mIL-27 α (SEQ ID NO: 10), mIL-27 α ^{C158L} (SEQ ID NO: 29), empty pSVL vector (mock) and/or hEBI3 (SEQ ID NO: 9) as indicated was immunoblotted against V5 and EBI3 (SEQ ID NO: 9) (inputs). 15 % medium of cells transfected with mIL-27 α (SEQ ID NO: 10), mIL-27 α ^{C158L} (SEQ ID NO: 29) and/ or hEBI3 (SEQ ID NO: 9) were immunoprecipitated with α -V5 or an isotype control antibody and immunoblotted against EBI3.

[0037] **Figure 7** shows that disulfide bond formation at and near the amino acid position 162 of hIL-27 α leads to its secretion competency. **Figure 7(a)** shows the structural models of hIL-27 α (SEQ ID NO: 1), hIL-27 α N161C (SEQ ID NO: 4), hIL-27 α L162C (SEQ ID NO: 2), hIL-27 α P163C (SEQ ID NO: 5), and hIL-27 α L181C (SEQ ID NO: 7). The structural model of hIL-27 α was generated by iTasser. Muteins (hIL-27 α ^{N161C}, hIL-27 α ^{L162C}, hIL-27 α ^{P163C} and hIL-27 α ^{L181C}) were generated with Yasara structure. A disulfide bond was introduced between the two cysteines *in silico* and structures were subsequently energy minimized using Yasara structure. Cysteines are highlighted in ball/ CPK representation. **Figure 7(b)** shows that in addition to hIL-27 α ^{L162C}, the muteins hIL-

$27\alpha^{N161C}$ and $hIL-27\alpha^{P163C}$ are secretion competent in isolation. $hIL-27\alpha$ and $hEBI3$, $hIL-27\alpha^{N161C}$, $hIL-27\alpha^{L162C}$, $hIL-27\alpha^{P163C}$, $hIL-27\alpha^{L181C}$ or empty pSVL vector (mock) were transfected in 293T cells and 2 % medium (M) were immunoblotted against Hsc70, V5 and $hEBI3$. An image with increased contrast is shown on the side for $hIL-27\alpha^{N161C}$. **Figure 7(c)** shows that in addition to $hIL-27\alpha^{L162C}$, $hIL-27\alpha^{N161C}$ and $hIL-27\alpha^{P163C}$ form a disulfide bond. Secreted $hIL-27\alpha$, $hIL-27\alpha^{N161C}$, $hIL-27\alpha^{L162C}$ and $hIL-27\alpha^{P163C}$ were analyzed by non-reducing SDS-PAGE. 2 % medium of cells transfected as depicted was immunoblotted against V5 and $EBI3$. Where indicated (+) samples were treated with β -mercaptoethanol. Dashed lines are shown to highlight mobility differences between reduced/ non-reduced samples. An image with increased contrast is shown on the side for $hIL-27\alpha^{N161C}$.

[0038] Figure 8 shows in **Figure 8(a)** the concentration determination of Expi293-secreted $hIL-27\alpha^{L162C}$ using $hIL-27\alpha^{L156C}His_6$ from bacteria as a reference. Same volumes of cell supernatants of $hIL-27\alpha^{L162C}$ expressing Expi293 cells and $hIL-27\alpha^{L156C}His_6$ standards with different concentrations were loaded onto SDS-PAGE gels and immunoblotted against $IL-27\alpha$. The Expi293-expressed $hIL-27\alpha^{L162C}$ concentration was determined by a linear fit to the signals of the bacterially expressed $hIL-27\alpha^{L156C}His_6$ standards. Where indicated, samples were further concentrated by ultrafiltration. Additionally, **Figure 8(b)** shows that Expi293 expressed $hIL-27\alpha^{L162C}$ forms a disulfide bond. 0.03 % cell supernatant of $hIL-27\alpha^{L162C}$ -transfected Expi293 cells was analyzed on SDS-PAGE gel under reducing and non-reducing conditions and immunoblotted against $hIL-27\alpha$. Where indicated (+) samples were treated with β -mercaptoethanol. Dashed lines are shown to guide the eye and highlight mobility differences between reduced/ non-reduced samples.

[0039] Figure 9 shows that $IL-27\alpha^{L162C}$ adds a new member to the human cytokine repertoire. **Figure 9(a)** shows that $hIL-27\alpha^{L162C}$ increases the secretion of the pro-inflammatory cytokine $IL-6$ from LPS-stimulated THP-1 macrophages ($N=8\pm SEM$, $*p<0.05$). Effects can be inhibited by an anti-human $IL-27$ antibody. **Figure 9(b)** shows that $hIL-27\alpha^{L162C}$ increases the secretion of the pro-inflammatory cytokine $TNF-\alpha$ from LPS-stimulated (1 $\mu g/mL$) THP-1 macrophages ($N=6\pm SEM$, $*p<0.05$). THP-1 macrophages were stimulated with 0.5 $\mu g/mL$ Expi293-expressed $hIL-27\alpha^{L162C}$ and secreted $TNF-\alpha$ levels were determined using ELISA. Effects are specific, as they can be inhibited by an anti- $hIL-27$ antibody.

[0040] **Figure 10** shows that the presence of an epitope tag does not influence the secretion-competence of the muteins of the present invention. **Figure 10(a)** shows that even without a tag human alpha-subunit of Interleukin 27 depends on Ebi3 for secretion. **Figure 10(b)** further shows that the mutein hIL-27 α^{L162C} (SEQ ID NO: 2) is also secretion-competent without a tag.

[0041] **Figure 11** shows the amino acid alignment of human (SEQ ID NO: 9) and mouse beta-subunit of Interleukin 27 (SEQ ID NO: 35), wherein the straight boxes show the cysteines, which are present in human and mouse beta-subunit of Interleukin 27, while the dashed box shows the cysteine, which is present in the mouse beta-subunit of Interleukin 27, but not in the human beta-subunit of Interleukin 27. This reveals that the mouse beta-subunit of Interleukin 27 (SEQ ID NO: 35) has a free cysteine, which is not present in the secretion-competent human beta-subunit of Interleukin 27 (SEQ ID NO: 9).

DETAILED DESCRIPTION OF THE INVENTION

[0042] The following language and descriptions of certain preferred embodiments of the present invention are provided in order to further an understanding of the principles of the present invention. However, it will be understood that no limitations of the present invention are intended, and that further alterations, modifications, and applications of the principles of the present invention are also included.

[0043] In general, the present invention is directed to a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated. The present invention also provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated. Further, the present invention also provides these secretion-competent muteins of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) as described herein, wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0044] Additionally, the present invention is directed to a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) as described herein, wherein at least one of the amino acid residues at sequence positions 160 to 165 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues at sequence positions 160 to 165 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.

[0045] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated. In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is mutated. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is/ are mutated.

[0046] In another aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine. Further, the present invention provides a secretion-competent

mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine.

[0047] In another aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated to cysteine. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated to cysteine.

[0048] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine. The present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is mutated to cysteine. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine. Further, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) and wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1)

selected from the group consisting of sequence positions 161, 162 and 163 is mutated to cysteine.

[0049] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is/ are mutated compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0050] The present invention also provides a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 161, 162 and 163 is/ are mutated compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0051] The present invention additionally provides a secretion-competent mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is/ are mutated compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0052] The present invention additionally provides a secretion-competent mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is/ are mutated compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 161, 162 and 163 is/ are mutated compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0053] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0054] In a further aspect, the present invention provides a secretion-competent mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 160, 161, 162, 163, 164 and 165 is/are mutated to cysteine compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0055] The present invention additionally provides a secretion-competent mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 %, 77 %, 78 %, 79 %, 80 %, 81 %, 82 %, 83 %, 84 %, 85 %, 86 %, 87 %, 88 %, 89 %, 90 %, 91 %, 92 %, 93 %, 94 %, 95 %, 96 %, 97 %, 98 %, 99 %, 99.1 %, 99.2 %, 99.3 %, 99.4 %, 99.5 %, 99.6 %, 99.7 %, 99.8 %, 99.9 % or even 100 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein in this mutein at least one of the amino acid residues selected from the group consisting of sequence positions 161, 162 and 163 is mutated to cysteine compared to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[0056] It is noted here that the present invention is based on the inventor's analysis of the molecular determinants of IL-27 α retention *versus* secretion. This analysis revealed that the presence or absence of a single Cys residue defines the ability of IL-27 α to form an internal disulfide bridge, fold, pass ER quality control and be secreted. The inventors surprisingly found that in the absence of such a single disulfide bridge, IL-27 α depends on interaction with its beta-subunit EBI3 for secretion. A single point mutation within IL-27 α thus determines assembly-dependent *versus* autonomous secretion in mouse and man. The present invention structurally and mechanistically reveals the underlying reactions and makes it able to extend the findings to various different species, thus, providing insights into how protein folding influences an organism's cytokine repertoire and immune regulation. Lastly, due to the present invention, it is possible to design an autonomously folding human IL-27 alpha-subunit, which acts as a novel immune modulator. In this context, it is noted that the term "human IL-27 alpha-subunit" or "human IL-27 α -subunit" as used herein refers to the polypeptide sequence of SEQ ID NO: 1 that has been deposited under UniProtKB accession number Q8NEV9. The term "human IL-27 beta-subunit" or "EBI3" as used herein refers to the polypeptide sequence deposited under UniProtKB accession number Q14213 that associates with the human IL-27 alpha-subunit to form the IL-27 Interleukin, a heterodimeric cytokine which functions in innate immunity. The term "mouse IL-27 alpha-subunit" or "mIL-27 α " as used herein refers to the polypeptide sequence deposited under genbank identifier NP 663611.1. The term "mouse IL-27 beta-subunit" or "mEBI3" as used herein refers to the polypeptide sequence deposited under UniProtKB accession number O35228. Accordingly, the term "IL-27" or "Interleukin 27" refers to the heterodimeric cytokine formed by the IL-27 alpha- and IL-27 beta-subunit.

[0057] The inventors of the present invention have found that a single cysteine residue toggles IL-27 α between being secretion competent in isolation or depending on heterodimerization with EBI3 as a prerequisite to leave the cell. On the other hand, introducing a point mutation into one of the cysteines in mouse IL-27 α (SEQ ID NO: 10) renders it dependent on EBI3 for secretion. This establishes a molecular phenocopy of the human IL-27 system for future studies and may also reveal novel functions of IL-27 *versus* IL-27 α . This is important since in mice, deletion of EBI3 will indeed ablate IL-27 – but not free IL-27 α . In fact, removing its interaction partner EBI3 may potentially even increase levels of free IL-27 α with its independent functions. Analogously, deleting IL-27 α will ablate IL-27 but also IL-27 α functions in mice. It is shown by the inventors of the present

invention that this can be circumvented by introducing a single point mutation into one of the cysteines in mouse IL-27 α , thus rendering it dependent on EBI3 for secretion as a molecular phenocopy of the human system. *Vice versa*, by a single point mutant the inventors of the present invention provide a secretion-competent human IL-27 α with biological activity on immune cells. The secretion-competent IL-27 α according to the present invention, does not block IL-27 function but acts as a cytokine itself. This is of particular relevance since murine IL-27 α dampens Graft-*versus*-Host disease and counteracts sepsis. No good treatment options for these diseases are available yet but interleukins are promising candidates. The muteins of the present invention may provide the basis for new treatment options thereof.

[0058] The term "secreting" or "secretion" is used in the present invention in its regular meaning to mean the active export of a protein from a (eukaryotic such as a human) cell into the extracellular environment. Generally secretion occurs through a secretory pathway in the cell, for example, in eukaryotic cells, which involves the endoplasmic reticulum and the golgi apparatus. Accordingly, a mutein according to the present invention is "secretion-competent" or "comprises secretion competence", when the mutein is able to perform a complete passage through the secretory pathway of the cell and through the cytoplasmic membrane. In contrast thereto, the term "non-secretion competent" muteins refers in the present invention to muteins, which are not naturally secreted from the cell into the extracellular environment.

[0059] In accordance with the above disclosure, in the mutein of the α -subunit of human Interleukin 27 of the present invention, at least one of the amino acid residues at sequence positions 160 to 163 and/or at least one of the amino acid residues at sequence positions 180 to 182 can be mutated. It is preferred that in accordance with the above disclosure, in the mutein of the α -subunit of human Interleukin 27 of the present invention at least one of the amino acid residues at sequence positions 161 to 163 can be mutated. It is also preferred that in accordance with the above disclosure, in the mutein of the α -subunit of human Interleukin 27 of the present invention at least one of the amino acid residues at sequence positions 180 to 182 can be mutated. This means, a mutein of the present invention can comprise a single mutation at one of these sequence positions but also a mutation at two or more of these sequence positions. The mutation can be any amino acid that renders the mutein secretion-competent, for example, a cysteine residue or a non-natural amino acid that comprises a free thiol group.

[0060] In one embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 160 can be replaced by cysteine.

[0061] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 161 can be replaced by cysteine.

[0062] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 162 can be replaced by cysteine.

[0063] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 163 can be replaced by cysteine.

[0064] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 164 can be replaced by cysteine (SEQ ID NO: 33).

[0065] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 165 can be replaced by cysteine (SEQ ID NO: 34).

[0066] In still another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 180 can be replaced by cysteine.

[0067] In a further embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 %

sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 181 can be replaced by cysteine.

[0068] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at sequence position 182 can be replaced by cysteine.

[0069] In yet another embodiment of the present invention, in the mutein comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at at least one of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 can be replaced by a non-natural amino acid, such as, but not limited to, selenocysteine or pyrrolysine or by a non-natural amino acid, which builds a covalent bond. In yet another embodiment of the present invention, in the mutein comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residues at at least two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 can be replaced by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by the mentioned replacements.

[0070] The present invention also refers to the muteins as described herein, wherein the mutein further comprises one or more disulfide-bridge(s).

[0071] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residue at at least one of sequence positions 161, 162, 163, 164 and 165 can be replaced by a non-natural amino acid, such as, but not limited to, selenocysteine or pyrrolysine or by a non-natural amino acid, which builds a covalent bond. In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), the amino acid residues at at least two of the sequence positions 161, 162, 163, 164 and 165 can be replaced by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by the mentioned replacements.

[0072] In line with the above, it is within the scope of the present invention that the above mentioned muteins of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), which are mutated at the amino acid residues 160, 161, 162, 163, 164, 165, 180, 181 and 182 to cysteines, can form muteins with 1, 2, 3, 4, 5, 6 or 7 cysteines at any of the mentioned positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of the muteins comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1). It is also thus possible that a mutein of the α -subunit of human Interleukin 27 comprising an amino acid sequence with at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention can further comprise one or more disulfide-bridges.

[0073] In one embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 160 can be replaced by cysteine (SEQ ID NO: 3).

[0074] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 161 can be replaced by cysteine (SEQ ID NO: 4).

[0075] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 162 can be replaced by cysteine (SEQ ID NO: 2).

[0076] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 163 can be replaced by cysteine (SEQ ID NO: 5).

[0077] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 164 can be replaced by cysteine (SEQ ID NO: 33).

[0078] In another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 165 can be replaced by cysteine (SEQ ID NO: 34).

[0079] In still another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 180 can be replaced by cysteine (SEQ ID NO: 6).

[0080] In a further embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 181 can be replaced by cysteine (SEQ ID NO: 7).

[0081] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at sequence position 182 can be replaced by cysteine (SEQ ID NO: 8).

[0082] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the amino acid residue at at least one of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 can be replaced by a non-natural amino acid, such as, but not limited to, selenocysteine or pyrrolysine or by a non-natural amino acid, which builds a covalent bond.

[0083] In yet another embodiment of the present invention, in the mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of the present invention, the mutein further comprises one or more salt bridges. Preferably, wherein the one or more salt bridge is build by replacing at least two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 by equally-charged amino acids, more preferably by replacing two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 by aspartic acid and glutamic acid or arginine and lysine.

[0084] In line with the above, it is within the scope of the present invention that the above mentioned mutations of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at the amino acid residues 160, 161, 162, 163, 164, 165, 180, 181 and 182 to cysteine can form muteins with 1, 2, 3, 4, 5, 6 or 7 cysteines at any of the mentioned positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of the α -subunit of human Interleukin 27. It is also thus possible that a mutein of the α -subunit of human Interleukin 27 of the present invention can further comprise one or more disulfide-bridges.

[0085] In addition or alternatively, the mutein of the α -subunit of human Interleukin 27 of the present invention can further comprise one or more salt bridges that act as structural homologue of the intra-chain disulfide bridge formed, for example, between the naturally occurring cysteine residue present at sequence position 107 of the α -subunit of

human Interleukin 27 and a cysteine residue introduced at any of the positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of the α -subunit of human Interleukin 27. The salt bridge may, for example, arise from the anionic carboxylate (RCOO^-) group of either aspartic acid or glutamic acid and the cationic ammonium (RNH_3^+) from lysine or the guanidinium ($\text{RNHC}(\text{NH}_2)_2^+$) of arginine. Although these are the most common, other residues with ionizable side chains such as histidine, tyrosine, and serine can also participate in the formation of a salt bridge. Thus, muteins of the α -subunit of human Interleukin 27 of the present invention may comprise an amino acid such as aspartic acid or glutamic acid that has a negatively charged side chain moiety under physiological conditions such as aspartic acid or glutamic acid at any of the positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of the α -subunit of human Interleukin 27 and an amino acid such as lysine or arginine that has a positively charged side chain moiety under physiological conditions at sequence position 107 of the α -subunit of human Interleukin 27.

[0086] Alternatively, muteins of the α -subunit of human Interleukin 27 as described herein, also secretion-competent muteins comprising at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1), may comprise an amino acid such as aspartic acid or glutamic acid that has a negatively charged side chain moiety under physiological conditions such as aspartic acid or glutamic acid at sequence position 107 of the α -subunit of human Interleukin 27 and an amino acid such as lysine or arginine that has a positively charged side chain moiety under physiological conditions at any of the positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of the α -subunit of human Interleukin 27.

[0087] The present invention also provides a secretion-competent mutein of human Interleukin 27, comprising an α -subunit p28 and a β -subunit EBI3, wherein the α -subunit is a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) as described herein. For example, in one embodiment thereof, the α -subunit is a secretion-competent mutein of the α -subunit of human Interleukin 27 comprising at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1) as described herein.

[0088] In such a mutein of human Interleukin 27 according to the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 165 can be mutated and/or at least one of the amino

acid residues at sequence positions 180 to 182 can be mutated. In such a mutein of human Interleukin 27 according to the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 163 can be mutated and/or at least one of the amino acid residues at sequence positions 180 to 182 can be mutated.

[0089] In a further embodiment of the present invention, in such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is/ are mutated. In a further embodiment of the present invention, in such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160 to 163 is/ are mutated.

[0090] In a further embodiment of the present invention, in such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is/ are mutated.

[0091] In such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is/ are mutated to cysteine.

[0092] In such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is/ are mutated to cysteine.

[0093] In a further embodiment of the present invention, in such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is/ are mutated to cysteine.

[0094] In a further embodiment of the present invention, in such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -

subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160 to 163 is/ are mutated to cysteine.

[0095] In a further embodiment of the present invention, in such a mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is/ are mutated to cysteine.

[0096] In such a mutein of human Interleukin 27 of the present invention at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 165 can be mutated. In another embodiment, such a mutein of human Interleukin 27 of the present invention at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 163 can be mutated.

[0097] Further, in the mutein of human Interleukin 27 of the present invention at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 180 to 182 can be mutated.

[0098] In line with the above, in the mutein of human Interleukin 27 of the present invention, the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 160 can be replaced by cysteine.

[0099] In addition or alternatively, in the mutein of human Interleukin 27 of the present invention, the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 161 can be replaced by cysteine.

[00100] In addition or alternatively, in the mutein of human Interleukin 27 of the present invention the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 162 can be replaced by cysteine (SEQ ID NO: 2).

[00101] It is also possible that in the mutein of human Interleukin 27 of the present invention, the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 163 is replaced by cysteine.

[00102] In addition or alternatively, in the mutein of human Interleukin 27 of the present invention the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 164 can be replaced by cysteine (SEQ ID NO: 33).

[00103] In addition or alternatively, in the mutein of human Interleukin 27 of the present invention the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 165 can be replaced by cysteine (SEQ ID NO: 34).

[00104] In yet other embodiments, in the mutein of human Interleukin 27 of the present invention, the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 180, the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 181, or the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 182 can be replaced by cysteine.

[00105] In other embodiments of the present invention, in the mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine. In other embodiments of the present invention, in the mutein of human Interleukin 27 of the present invention, at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162 and 163 is mutated to cysteine.

[00106] In yet another embodiment, in the mutein of human Interleukin 27 of the present invention the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at at least one of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 can be replaced by a non-natural amino acid, such as, but not limited to, selenocysteine or pyrrolysine or by a non-natural amino acid, which builds a covalent bond. In yet another embodiment of the present invention, in the mutein of human Interleukin 27 of the present invention the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at at least two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 can be replaced by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by these mentioned replacements.

[00107] In yet another embodiment of the present invention, in the mutein of human Interleukin 27 of the present invention the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at at least one of sequence positions 161, 162, 163, 164 and 165 can be replaced by a non-natural amino acid, such as, but not limited to, selenocysteine

or pyrrolysine or by a non-natural amino acid, which builds a covalent bond. In yet another embodiment of the present invention, in the mutein of human Interleukin 27 of the present invention the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at at least two of the sequence positions 161, 162, 163, 164 and 165 can be replaced by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by these mentioned replacements.

[00108] In yet another embodiment of the present invention, in the mutein of human Interleukin 27 of the present invention the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at at least one of sequence positions 161, 162 and 163 can be replaced by a non-natural amino acid, such as, but not limited to, selenocysteine or pyrrolysine or by a non-natural amino acid, which builds a covalent bond. In yet another embodiment of the present invention, in the mutein of human Interleukin 27 of the present invention the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at at least two of the sequence positions 161, 162 and 163 can be replaced by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by these mentioned replacements.

[00109] It is within the scope of the present invention, that the above mentioned mutations of the human Interleukin 27 at the amino acid residues 160, 161, 162, 163, 164, 165, 180, 181 and 182 to cysteine can form muteins with 1, 2, 3, 4, 5, 6 or 7 cysteines at any of the mentioned positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of human Interleukin 27.

[00110] The mutein of human Interleukin 27 of the present invention may thus further comprise one or more disulfide-bridges as explained above. Additionally or alternatively, the mutein of human Interleukin 27 of the present invention can further comprise one or more salt bridges as explained above.

[00111] The present invention also provides a nucleic acid molecule comprising a nucleotide sequence encoding the secretion-competent mutein of human Interleukin 27 of the present invention or the secretion-competent mutein of the α -subunit of human Interleukin 27 of the present invention. In an embodiment thereof, the nucleic acid molecule comprises a nucleotide sequence encoding a secretion-competent mutein of the α -subunit of

human Interleukin 27 (SEQ ID NO: 1), wherein said secretion-competent mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

[00112] A nucleic acid molecule according to the present invention may comprise a nucleotide sequence encoding a mutein of SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7 or SEQ ID NO: 8.

[00113] It is preferred, that the nucleic acid molecule of the present invention is operably linked to a regulatory sequence to allow expression of the nucleic acid molecule. This regulatory sequence may comprise a promoter sequence. The term "promoter" or "promoter sequence" means a DNA sequence which initiates and directs the transcription of a gene into an RNA transcript in cells.

[00114] The nucleic acid molecule according to the present invention may be comprised in a vector. As used herein, the term "vector" refers to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. One type of vector is a "plasmid", which refers to a circular double stranded DNA loop into which additional DNA segments can be ligated. Another type of vector is a viral vector, wherein additional DNA segments can be ligated into the viral genome.

[00115] In yet another aspect the invention provides the nucleic acid molecule as described herein for use as a therapeutic agent.

[00116] The present invention also provides a host cell containing a nucleic acid molecule of the present invention as described above. A host cell can be any prokaryotic (e.g., E. coli) or eukaryotic cell (e.g., insect cells, yeast or mammalian cells).

[00117] The present invention also provides an immune modulator comprising a mutein of the present invention. An immune modulator is any protein, substance or composition that is able to carry out immunomodulation, which is the adjustment of the immune response to a desired level, as e.g. in immunopotential, immunosuppression, or induction of immunologic tolerance.

[00118] The present invention also provides the use of a mutein of the present invention for the manufacture of a medicament for treating a disease in a mammal, preferable a human. Suitable diseases include, but are not limited to, infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-

disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma.

[00119] The present invention also provides a mutein of the present invention for use as a medicament. Additionally, the present invention also provides a mutein of the present invention for use in the treatment of diseases, including the afore-mentioned infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma.

[00120] The present invention also provides a method of treating an Interleukin 27-mediated disease, preferably an infectious disease, an autoimmune disease, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, a chronic inflammatory disease, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal, comprising the step of administering a composition comprising a mutein of the α -subunit of human Interleukin 27 of the present invention or a mutein of human Interleukin 27 of the present invention to a mammal in need thereof. Preferably, the mammal is a human.

[00121] The present invention also provides a method for producing a mutein according to the present invention, comprising the steps of:

(a) introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or a polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 or of a polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182, and

(b) introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

[00122] The present invention also provides a method for producing a mutein according to the present invention, comprising the steps of:

(a) introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence

mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182, and

(b) introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

[00123] The present invention also provides a method for producing a mutein according to the present invention, comprising the steps of:

(a) introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 selected from the group consisting of sequence positions 161, 162, and 163, and

(b) introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

[00124] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 165.

[00125] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 163.

[00126] It is further preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -

subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 161 to 163.

[00127] It is also preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 180 to 182.

[00128] In the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence can be introduced mutating at least one of the amino acid residues at sequence positions 160 to 165 and/or at sequence positions 180 to 182.

[00129] In a preferred embodiment, in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence can be introduced mutating at least one of the amino acid residues at sequence positions 160 to 163.

[00130] It is further preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 165 to cysteine.

[00131] It is further preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 163 to cysteine.

[00132] It is further preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 161 to 163 to cysteine.

[00133] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 180 to 182 to cysteine.

[00134] In the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence can be introduced mutating at least one of the amino acid residues at sequence positions 160 to 165 and/or at sequence positions 180 to 182 to cysteine. It is further preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence can be introduced mutating at least one of the amino acid residues at sequence positions 160 to 163 and/or at sequence positions 180 to 182 to cysteine.

[00135] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 160 to cysteine.

[00136] It is further preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human

Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 161 to cysteine.

[00137] It is also preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 162 to cysteine.

[00138] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 163 to cysteine.

[00139] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 164 to cysteine (SEQ ID NO: 33).

[00140] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 165 to cysteine (SEQ ID NO: 34).

[00141] It is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit

polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 180 to cysteine.

[00142] Further, it is preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 181 to cysteine.

[00143] It is also preferred that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at sequence position 182 to cysteine.

[00144] In yet another embodiment, in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating the amino acid residue at at least one of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 to a non-natural amino acid, such as, but not limited to, selenocysteine or pyrrolysine or by a non-natural amino acid, which builds a covalent bond. In yet another embodiment of the present invention, in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced replacing at at least two of the sequence positions 161, 162, 163, 164 and 165 by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by the mentioned replacements. In yet another embodiment of the present invention, in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the

human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced replacing at at least two of the sequence positions 161, 162 and 163 by equally-charged amino acids, such as, but not limited to, aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys). Thereby, for example, a salt bridge can be build by the mentioned replacements.

[00145] The present invention also comprises that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating 1, 2, 3, 4, 5, 6 or even all 7 of the amino acid residues at sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 to cysteine.

[00146] The present invention also comprises that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating 1, 2, 3, 4, 5, 6 or even all 7 of the amino acid residues at sequence positions 160, 161, 162, 163, 180, 181 and 182 to cysteine.

[00147] The present invention also comprises that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating 1, 2, 3, 4, 5, 6 or even all 7 of the amino acid residues at sequence positions 160, 161, 162, 163, 164 and 165 to cysteine.

[00148] The present invention also comprises that in the method for producing a mutein according to the present invention, in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide, a nucleotide sequence is introduced mutating 1, 2, 3, 4, 5, 6 or even all 7 of the amino acid residues at sequence positions 161, 162 and 163 to cysteine.

[00149] The present invention also provides a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10), wherein at least one of the two cysteines at amino acid positions 103 and 158 is/are mutated (i.e. replaced by another amino acid) or deleted. In this embodiment "secretion-incompetent" means that the secretion of this specific mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) depends on the presence of the beta-subunit EBI3. This secretion-dependent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) thus behaves like the human α -subunit of Interleukin 27 (SEQ ID NO: 1). In a preferred embodiment, in the secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) at least one of the two cysteine residues at amino acid positions 103 and 158 is replaced by a hydrophobic amino acid residue. In a further preferred embodiment, in the secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) at least one of the two cysteines at amino acid positions 103 and 158 (SEQ ID NO: 29) is/are mutated to leucine or serine, or alanine. In this connection, it is noted that the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) has an amino acid length of 234 residues, while the α -subunit of human Interleukin 27 (SEQ ID NO: 1) has an amino acid length of 243 residues. The sequence identity between the SEQ ID NO: 1 and the SEQ ID NO: 10 has been determined as being 75 %.

[00150] By "identity" or "sequence identity" is meant a property of sequences that measures their similarity or relationship. The term "sequence identity" or "identity" as used in the present invention means the percentage of pair-wise identical residues - following (homology) alignment of a sequence of a polypeptide of the invention with a sequence in question - with respect to the number of residues in the longer of these two sequences. Identity is measured by dividing the number of identical residues by the total number of residues and multiplying the product by 100.

[00151] The percentage of sequence homology or sequence identity can, for example, be determined herein using the program BLASTP, version blastp 2.2.5 (November 16, 2002; cf. Altschul, S. F. et al. (1997) *Nucl. Acids Res.* **25**, 3389-3402). In this embodiment the percentage of homology is based on the alignment of the entire polypeptide sequences (matrix: BLOSUM 62; gap costs: 11.1; cutoff value set to 10^{-3}) including the respective sequences. It is calculated as the percentage of numbers of "positives" (homologous amino acids) indicated as result in the BLASTP program output divided by the total number of amino acids selected by the program for the alignment.

[00152] The present invention reveals that the secretion of IL-27 α and thus potential immune regulation by this subunit depend on a single Cys residue for mouse and man. It could be shown by the inventors of the present invention that this characteristic was conserved in other species, including model organisms like pig and monkey. Although different cysteine configurations existed for different species, the inventors of the present invention observed complete agreement with this hypothesis for all species tested.

[00153] Whenever a disulfide bond was present in IL-27 α it was secretion-competent in isolation. Otherwise its secretion was dependent on EBI3. In line with these findings, the inventors of the present invention replaced the second cysteine in mIL-27 α by a leucine (C158L), so that mIL-27 α^{C158L} was now retained in cells in isolation and its secretion was induced by EBI3, just like its human counterpart.

[00154] In another aspect, the present invention also provides a secretion-competent mutein of the beta-subunit of mouse Interleukin 27 (SEQ ID NO: 35), wherein the amino acid residue at amino acid position 198 is mutated or deleted. It is preferred in this embodiment that a secretion-competent mutein of the beta-subunit of mouse Interleukin 27 (SEQ ID NO: 36) is provided, wherein the amino acid residue at amino acid position 198 is/are replaced by tyrosine. In this connection, it has to be considered that the human beta-subunit of Interleukin 27 can be secreted alone. However, naturally, the mouse beta-subunit of Interleukin 27 is secretion-incompetent⁴⁴. The inventors of the present invention have however discovered that due to the mutations as described herein the mouse beta-subunit of Interleukin 27 becomes secretion-competent.

[00155] In a further aspect, the present invention also provides a mutein of mouse Interleukin 27, comprising an α -subunit p28 and a β -subunit EBI3, wherein the α -subunit is a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) as described herein and/or wherein the β -subunit is a secretion-competent mutein of the β -subunit of mouse Interleukin 27 (SEQ ID NO: 35) as described herein.

[00156] The invention is further illustrated by the following experimental Examples.

EXAMPLES

[00157] Constructs for mammalian expression:

[00158] Interleukin cDNAs were obtained from (hIL-27 α and hEBI3) or GeneArt (mIL-27 α , Thermo Fisher Scientific) and cloned into the pSVL vector (Amersham) for mammalian expression. hIL-27 α (SEQ ID NO: 1), mIL-27 α (SEQ ID NO: 10) and hEBI3 (SEQ ID NO: 9) amino acid sequences correspond to the UniProt accession numbers Q8NEV9, Q8K3I6, and Q14213, respectively. For a species comparison of IL-27 α , sequences corresponding to genbank identifiers NP_001158125.1 (Bos taurus) (SEQ ID NO: 11), XP_012398754.1 (Sarcophilus harrisii) (SEQ ID NO: 12), and XP_008683452.1 (Ursus maritimus) (SEQ ID NO: 13) were additionally synthesized by Geneart (Thermo Fisher Scientific) with optimized codon-usage for human expression. Where indicated, a (GS)₄-linker followed by a V5 tag was introduced at the C-terminus of the different IL-27 α constructs. Mutants were generated by site-directed mutagenesis. Constructs for BiP expression have been described previously³². All constructs were sequenced.

[00159] Cell culture and transient transfections:

[00160] HEK293T cells were grown in Dulbecco's modified Eagle's medium (DMEM) containing L-Ala-L-Gln (AQmedia, Sigma-Aldrich) supplemented with 10% (v/v) fetal bovine serum (Biochrom) at 37°C and 5% CO₂. The medium was complemented with a 1% (v/v) antibiotic-antimycotic solution (25 μ g/ml amphotenicin B, 10 mg/ml streptomycin, and 10,000 units of penicillin; Sigma-Aldrich) (complete DMEM). Transient transfections were carried out for 24h in either p35 poly D-lysine coated dishes (Becton Dickinson) or p60 dishes (Techno Plastic Products) using GeneCellin (BioCellChallenge) according to the manufacturer's protocol. Equal amounts of constructs or empty vector were transfected with a total DNA amount of 3 μ g (p35) or 6 μ g (p60). For BiP interaction studies, a 3:1 ratio of α subunit over chaperone DNA was used.

[00161] Secretion and redox experiments:

[00162] For secretion and redox-status experiments by immunoblotting cells were transfected for 8 h, washed twice with PBS and then supplemented with 0.5 ml (p35) or 2 ml (p60) fresh medium for another 16 h. Prior to lysis, cells were washed twice in ice cold PBS, supplemented with 20 mM NEM if samples were to be run on non-reducing SDS-PAGE gels. Cell lysis was carried out in RIPA buffer (50 mM Tris/HCl, pH 7.5, 150 mM

NaCl, 1.0% Nonidet P40 substitute, 0.5% sodium deoxycholate, 0.1% SDS, 1x Roche complete Protease Inhibitor w/o EDTA; Roche Diagnostics). 20 mM NEM was added to the lysis buffer for non-reducing SDS-PAGE gels. To analyze secreted proteins, the medium was centrifuged for 5 min, 300 g, 4°C. Subsequently, samples were supplemented with 0.1 volumes of 500 mM Tris/HCl, pH 7.5, 1.5 M NaCl (and 200 mM NEM in the case of non-reducing SDS-PAGE) and protease inhibitor and centrifuged for 15 min, 20.000 g, 4°C. Samples were supplemented with 0.2 volumes of 5x Laemmli containing either β -mercaptoethanol for reducing SDS-PAGE or 100 mM NEM for non-reducing SDS-PAGE. Endo H/ PNGase F/ O-glycosidase (New England Biolabs) deglycosylation experiments were carried out according to the protocols of the manufacturer.

[00163] Immunoblots and immunoprecipitation experiments:

[00164] For immunoblots, samples were run on 12% SDS-PAGE gels, transferred to PVDF membranes and blotted with anti-Hsc70 (Santa Cruz, sc-1059 or sc-7298, 1:1,000 in gelatin buffer (0.1% gelatin, 15 mM Tris/HCl, pH 7.5, 130 mM NaCl, 1 mM EDTA, 0.1% Triton X-100, 0.002% NaN₃)), anti-V5 (Thermo Fisher Scientific, MA5-15253, 1:1,000 in TBS, 0.05% Tween, 5% milk) or anti-hIL-27 antibodies (R&D Systems, AF2526, 1:200 in TBS, 0.05% Tween, 5% milk). Anti-EBI3 and anti-BiP antisera have been described previously^{33,34}. Species-specific HRP-conjugated secondary antibodies (in TBS, 0.05% Tween, 5% milk or gelatin buffer) were used (Santa Cruz). Blots were detected using Amersham ECL prime (GE Healthcare) and a Fusion Pulse 6 imager (Vilber Lourmat). Immunoprecipitations were performed using the same antibodies as for immunoblotting with suitable isotype controls (purified mouse IgG1, κ isotype control, BioLegend). After PBS-washing cells were lysed with NP40 lysis buffer (50 mM Tris/HCl, pH 7.5, 150 mM NaCl, 0.5% NP40, 0.5% DOC, 1x Roche complete Protease Inhibitor w/o EDTA; Roche Diagnostics) and centrifugation-cleared lysates (15 min, 20.000 g, 4°C) incubated rotating o/n at 4°C with 2 μ g target-specific antibody or isotype control. For co-immunoprecipitation of BiP, the lysis buffer was supplemented with 10 U/ml apyrase (Sigma Aldrich) and 20 mM NEM. After addition of 25 μ l Protein A/G agarose (Santa Cruz) for 1 h, beads were washed three times with NP40-wash buffer (50 mM Tris/HCl pH 7.5, 400 mM NaCl, 0.5% NP40, 0.5% DOC) and proteins were eluted by boiling in 2 x Laemmli buffer containing β -mercaptoethanol for reducing SDS-PAGE. For immunoprecipitations of secreted proteins, the medium was treated as described for the

analysis of secreted protein, precleared for 1 h with 30 μ l Protein A/G agarose (Santa Cruz) and subsequently treated like the lysate, using 2.5 μ g of antibody.

[00165] Recombinant protein production.

[00166] Human IL-27 α cDNA optimized for expression in *E.coli* (without ER-import sequence) was obtained from GeneArt (Thermo Fisher Scientific) and cloned into the pET21a vector (Merck Millipore) with an N-terminal hexa-Histidine-tag and TEV protease cleavage site after the tag. The L162C mutation was introduced by site-directed mutagenesis. Proteins were expressed as inclusion bodies in selective LB medium. The culture was induced at OD₆₀₀=0.6 with 1 mM IPTG and harvested after another 4 h by centrifugation (5.000 rpm, 15 min, 4 °C). To isolate inclusion bodies, cells were lysed by sonication on ice in 100 mM Tris/HCl, pH 7.5, 100 mM NaCl, 5 mM EDTA, SigmaFAST protease inhibitor and subsequently spun down (20.000 g, 20 min, 4 °C). The cell pellet was resuspended, washed twice with 100 mM Tris/HCl, pH 7.5, 500 mM NaCl, 5 mM EDTA, 1.0 % Triton X-100, and finally once with 100 mM Tris/HCl, pH 7.5, 100 mM NaCl. Inclusion bodies were solubilized in 50 mM sodium phosphate, pH 7.5, 250 mM NaCl, 6 M GdmCl and 10 mM β -mercaptoethanol at 4 °C. After o/n solubilization, the solution was cleared by centrifugation (20.000 g, 20 min, 20 °C). The supernatant was diluted with 1 volume of 50 mM sodium phosphate, pH 7.5, 250 mM NaCl, 5 M GdmCl and applied to Ni-Sepharose HP column (GE Healthcare). Bound protein was washed with 50 mM sodium phosphate, pH 7.5, 250 mM NaCl, 5 M GdmCl, 30 mM imidazole, 1 mM DTT and eluted with 50 mM sodium phosphate, pH 3.5, 250 mM NaCl, 5 M GdmCl and 1 mM DTT. Eluted protein was further purified and buffer exchanged into 50 mM MES pH 6.0, 6 M urea, 1 mM EDTA by size exclusion chromatography using a HiPrep 16/60 Sephacryl S-400 HR column (GE Healthcare). Protein concentrations were determined spectrophotometrically using A_{280nm}. Human IL-27 α ^{L162C} cDNA optimized for expression in *H. sapiens* was obtained from GeneArt (Thermo Fisher Scientific) and cloned into the pHEK293 Ultra Expression Vector I (TaKaRa Clontech) for mammalian cell expression. Protein expression was carried out with the Expi293 expression system according to the manufacturer's protocol (Thermo Fisher Scientific). 48 h post-transfection, the medium was harvested by centrifugation (300 g, 15 min, 4 °C), concentrated to 1.8 to 6.2 μ g/mL using Amicon Ultra-15, PLBC Ultracel-PL membrane, 3 kDa (Sigma-Aldrich) and used for immunological assays. hIL-27 α ^{L156C}His₆ purified from inclusion bodies in *E.coli* was used as a reference to

obtain a standard curve with linear fit for quantification of hIL-27 α ^{L162C} in Expi293 supernatants using Western blot signals.

[00167] Quantification and statistics:

[00168] Western blots were quantified using the Bio-1D software (Vilber Lourmat). Western blot signals of co-immunoprecipitated BiP were normalized for BiP expression levels by dividing by the respective BiP input signals. BiP binding was determined by dividing the normalized BiP signal by the signal of immunoprecipitated α -subunit. Statistical analyses were performed using GraphPad, version 6.0 (GraphPad Software). Where indicated, data were analyzed with two-tailed, unpaired Student's *t*-tests. Differences were considered statistically significant with $p < 0.05$. Where no statistical data are shown, all experiments were performed at least three times, and one representative experiment was selected.

[00169] Sequence analysis and homology modeling:

[00170] Multiple DNA sequence alignments were performed using Clustal Omega³⁵. For a species comparison of IL-27 α , additionally, sequences corresponding to genbank identifiers XP_004268682.1 (Orcinus orca) (SEQ ID NO: 14), XP_018867076.1 (Gorilla gorilla gorilla) (SEQ ID NO: 15), XP_012398754.1 (Criteculus griseus) (SEQ ID NO: 16), XP_001496678.1 (Equus caballus) (SEQ ID NO: 17), EHH31550.1 (Macaca mulatta) (SEQ ID NO: 18), NP_001007521.1 (Sus scrofa) (SEQ ID NO: 19), XP_017198096.1 (Oryctolagus cuniculus) (SEQ ID NO: 20), XP_344963.5 (Rattus norvegicus) (SEQ ID NO: 21), XP_007894866.1 (Callorhinchus milii) (SEQ ID NO: 22) and XP_014457024.1 (Alligator mississippiensis) (SEQ ID NO: 23) were used. iTasser³⁶ was used for homology modeling of human and murine IL-27 α structures. Structural alignments were generated using Yasara Structure (www.yasara.org).

[00171] Molecular dynamics simulations.

[00172] Comparative Molecular Dynamics (MD) simulations were performed starting from the human wt hIL-27 α and hIL-27 α ^{L162C} model structures, respectively, including a disulfide bond between L162C and C107 in the case of hIL-27 α ^{L162C}. All MD simulations and the analysis of root-mean square deviation (RMSD) and fluctuations (RMSF) were performed using the Amber14 package³⁷ and the parm14SB force field³⁸. Proteins were first solvated in octahedral boxes including explicit Na⁺ and Cl⁻ ions (~0.15

M) and explicit (TIP3P) water molecules³⁹ keeping a minimum distance of 10 Å between any protein atom and the box boundary. The simulation systems were first energy minimized (5000 steps) followed by heating up to 300 K in steps of 100 K with position restraints on all non-hydrogen atoms of the proteins. Subsequently, positional restraints were gradually removed from an initial 12 kcal•mol⁻¹•Å⁻² to 0.5 kcal•mol⁻¹•Å⁻² within 0.5 ns followed by a 1 ns unrestrained equilibration phase at 310 K. All production simulations (200 ns) were performed at a temperature of 310 K and a pressure of 1 bar.

[00173] It is clear from the homology modeling and subsequent molecular dynamics simulations that a disulfide bridge between two cysteine residues can be formed, when at least one of the amino acid residues at the positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 of the α-subunit of human Interleukin 27 or of human Interleukin 27 is mutated to cysteine. Such a disulfide bridge can then be formed between any of the mentioned positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 and the cysteine at the amino acid position 107 of the α-subunit of human Interleukin 27 (SEQ ID NO: 1). Alternatively, it is also possible that instead of a disulfide bridge a salt bridge as defined herein can be formed between an amino acid residue present at sequence position 107 that have a charged side chain (under physiological conditions) with an amino acid residue that is present at any of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 and that has a charged side chain of opposite charge under physiological conditions.

[00174] IL-27 cytokine and macrophage assays.

[00175] THP-1 cells were grown in RPMI-1640 medium containing L-Ala-L-Gln (AQmedia, Sigma-Aldrich) supplemented with 10 % (v/v) fetal bovine serum (Biochrom) at 37 °C and 5 % CO₂. The medium was complemented with a 1 % (v/v) antibiotic-antimycotic solution (25 µg/ml amphotericin B, 10 mg/ml streptomycin, and 10,000 units of penicillin; Sigma-Aldrich) (complete RPMI-1640). THP-1 cells were seeded at a density of 2x10⁵ cells/mL in 0.5 mL and differentiated to macrophages by incubation with 25 nM PMA for 48 h (Lund et al., 2016). Subsequently, the medium was exchanged against PMA-free complete RPMI-1640. After 24 h, the cells were pre-incubated for 2 h with 0.5 µg/mL of Expi293 expressed hIL-27α^{L162C}/control medium and then stimulated for another 4 h with 1 µg/mL LPS in the presence of hIL-27α^{L162C}/control medium. Cell supernatants were harvested by centrifugation (300 g, 15 min, 4 °C). As a control, hIL-27α^{L162C} was pre-mixed with anti-IL-27 antibody (R&D Systems, AF2526; final concentration: 10 µg/mL) and

added to the cells. IL-6 and TNF- α levels in the macrophage supernatant were determined using human IL-6 or human TNF- α DuoSet ELISA kits following the manufacturer's instructions (R&D systems). Duplicates of each biological replicate were measured and cytokine concentrations were determined using standard curves analyzed with a linear fit.

Example 1: The present invention shows that a single point mutation renders human IL-27 α secretion-competent in isolation

[00176] The α and β subunit (IL-27 α /p28 and EBI3, respectively) of IL-27 can assemble non-covalently to form the bioactive heterodimeric IL-27. IL-27 signals *via* the heterodimeric IL-27R α (WSX-1)/gp130 receptor^{4,18} (see Figure 2(a)). So far, human IL-27 α (hIL-27 α) retains in isolation in transfected 293T cells and co-expression of its β -subunit, hEBI3 (SEQ ID NO: 9), induces its secretion (see Figure 2(b)).

[00177] The inventors used hIL-27 α with a C-terminal V5-epitope tag, separated by a flexible GS-linker, which together introduced a C-terminal O-glycosylation site into hIL-27 α (see Figure 2(c)). Since O-glycosylation occurs in the Golgi and the inventors did not observe any modification of this site in hIL-27 α in the absence of hEBI3 (see Figure 2(b)), hIL-27 α (SEQ ID NO: 1) appears to be retained in the ER in the absence of hEBI3 (SEQ ID NO: 9).

[00178] In contrast to the human IL-27 α subunit, its mouse ortholog (mIL-27 α , SEQ ID NO: 10) can be secreted in isolation (see Figure 2(d))⁴. Of note, human EBI3 (hEBI3) (SEQ ID NO: 9) also further increased the secretion of mIL-27 α (SEQ ID NO: 10) (see Figure 2(d)), which proves a conserved IL-27 interface between mouse and man. In agreement with this, the interaction between the two subunits, mIL-27 α (SEQ ID NO: 10) and hEBI3 (SEQ ID NO: 9), was detected by co-immunoprecipitation experiments.

[00179] The difference in secretion between human and mouse IL-27 α is intriguing, in particular since immunomodulatory functions have been attributed to the mouse ortholog¹⁷. To identify differences between the two proteins that may cause this distinct behavior the inventors have compared their primary sequences. This sequence alignment revealed several striking differences between two otherwise highly conserved sequences of human and mouse IL-27 α (see Figure 3(a)):

[00180] First, mIL-27 α (SEQ ID NO: 10) possesses a predicted N-glycosylation site, whereas its human ortholog does not, which is in agreement with our deglycosylation data (see Figure 2(c)).

[00181] Second, two cysteines are found in the sequence of mIL-27 α (SEQ ID NO: 10) (positions 103 and 158), whereas only one is found in hIL-27 α (position 107).

[00182] And third, a poly-glutamate stretch in IL-27 α , which has been associated with its localization to bone structures¹⁹, is interrupted by a lysine in mIL-27 α (SEQ ID NO: 10), but not in hIL-27 α (SEQ ID NO: 1).

[00183] To assess the impact of these sequence differences, the inventors individually introduced corresponding mutations into hIL-27 α (D89N (SEQ ID NO: 31), L162C (SEQ ID NO: 2) and K168 insertion (SEQ ID NO: 32), respectively) and monitored secretion of the mutant proteins in isolation. As expected to occur upon N-glycosylation, hIL-27 α ^{D189N} (SEQ ID NO: 31) now shifted upwards in molecular weight. However, no secretion was observed for this mutant, and neither was hIL-27 α ^{K168 insertion} (SEQ ID NO: 32) secreted (see Figure 3(b)). In striking contrast, hIL-27 α ^{L162C} (SEQ ID NO: 2) was now almost exclusively found in the media and became O-glycosylated, arguing for *bona fide* secretion (see Figure 3(b)). Thus, it was surprisingly found by the inventors of the present invention that a single point mutation renders hIL-27 α secretion-competent in isolation.

[00184] To understand this effect in more detail, the inventors modeled the structures of human and mouse IL-27 α . Both showed 4-helical bundle structures that were superimposable with an RMSD of only 1.0 Å (see Figures 3(c) and (d)). Of note, within this structure the two cysteines in mouse IL-27 α were in proximity and could thus form a disulfide bridge connecting the second helix of the 4-helical bundle fold with the N-terminal part of the unique poly-glutamate stretch that separates helices 3 and 4 in IL-27 α (see Figure 3(c)). To assess disulfide bridge formation in the different proteins, the inventors compared the mobility of the secreted proteins on non-reducing and reducing SDS-PAGE gels²⁰. Even though no mobility shift was observed for mIL-27 α (SEQ ID NO: 10), they observed a clear mobility shift for hIL-27 α ^{L162C} (SEQ ID NO: 2) under reducing *versus* non-reducing conditions, which was not observed for wild type (wt) hIL-27 α (SEQ ID NO: 1). This shows formation of a disulfide bridge in hIL-27 α ^{L162C} (SEQ ID NO: 2) and renders it secretion-competent in isolation.

Example 2: Assessing molecular determinants of human IL-27 α retention versus secretion

[00185] As hIL-27 α (SEQ ID NO: 1) is retained in the cell when expressed in isolation and can only be secreted upon co-expression of its betasubunit EBI3 (SEQ ID NO: 9)(see Figure 2(b)),the inventorsinvestigatedwhat led to retention of hIL-27 α (SEQ ID NO: 1) in absence of EBI3 and why it is dependent on forming a disulfide bridge for secretion. The inventors first mutated different structural elements in hIL-27 α that may be involved in its folding and retention, beginning with its free cysteine (C107, SEQ ID NO: 28, see Figure 4(a)). Thiol-based retention of free cysteines mediated by ERp44 constitutes an important step in e.g. IgM protein quality control²¹ and this single free cysteine could e.g. become inaccessible upon heterodimerization with EBI3. However, like wt hIL-27 α (SEQ ID NO: 1), isolated hIL-27 α^{C107L} (SEQ ID NO: 28) was retained in the cell but was secreted upon co-expression of EBI3 (see Figure 4(a)).Recognition of its free thiol thus does not account for hIL-27 α retention and C107 is dispensable for assembly-induced secretionof hIL-27 α (SEQ ID NO: 1) by EBI3.

[00186] Also, the inventors have focused on a characteristic feature of IL-27 α , a poly-glutamate stretch, which is predicted by homology modeling to be unstructured (see Figure 3(c)). It may thus be involved in retention of the protein either by being recognized directly by components of the ER quality control system or by entropically destabilizing the native state of the protein. To test these hypotheses, the inventors generated two loop-deletion mutants: In hIL-27 $\alpha^{\Delta 164-176}$ (SEQ ID NO: 24) the poly-glutamate stretch alone was eliminated and in hIL-27 $\alpha^{\Delta 164-180}$ (SEQ ID NO: 25) a few additional C-terminal residues predicted to also be part of the unstructured loop were included in the deletion. For both loop-deletion mutants the inventors observed cellular retention in isolation and secretion induced by EBI3 (see Figure 4(b)). In a third mutant, the inventors replaced the poly-glu sequence by a gly-ser linker (hIL-27 $\alpha^{\Delta 164-180toGS}$ (SEQ ID NO: 26)) to test for sequence specific effects of the poly-glu stretch on hIL-27 α *versus* entropic destabilization of the native state by this flexible linker without using deletion as a more drastic approach. Again, hIL-27 $\alpha^{\Delta 164-180toGS}$ (SEQ ID NO: 26) was retained in the cell and EBI3 induced its secretion (see Figure 4(b)). These findings proof of globally incomplete folding of hIL-27 α (SEQ ID NO: 1) as opposed to a specific effect of the poly-glu stretch and furthermore reveal that the poly-glu loop is not necessary for EBI3-mediated secretion of hIL-27 α (SEQ ID NO: 1).

Example 3: Recognition by ER chaperones

[00187] To further assess the folding status of hIL-27 α , the inventors tested if it was recognized by ER chaperones, leading to its retention. The inventors have therefore focused on the chaperone BiP (immunoglobulin heavy-chain binding protein), which binds hydrophobic amino acid stretches that are exposed by incompletely folded polypeptides in the ER^{22,23}. A good correlation between protein folding *in vitro*, *in vivo* and BiP binding exists and thus BiP binding can serve as a relevant proxy to assess the folding state of a protein in the cell²⁴. When the inventors tested for BiP binding to either wt hIL-27 α (SEQ ID NO: 1) or hIL-27 α ^{L162C} (SEQ ID NO: 2) by co-immunoprecipitation experiments the inventors surprisingly discovered that BiP binds to wild type (wt) hIL-27 α (SEQ ID NO: 1) significantly better than to hIL-27 α ^{L162C} (SEQ ID NO: 2) (see Figure 4(c)). This reveals a globally unstructured hIL-27 α (SEQ ID NO: 1), which is retained in the ER in the absence of EBI3 due to chaperone binding.

Example 4: Molecular dynamics simulations

[00188] To obtain further structural insights into hIL-27 α (SEQ ID NO: 1), the inventors performed molecular dynamics simulations on the homology model of wild type (wt) hIL-27 α (SEQ ID NO: 1) as well as on hIL-27 α ^{L162C} (SEQ ID NO: 2) with a disulfide bridge formed, which is present in this protein (see Figures 3(e) and (f)).

[00189] Whereas no global unfolding of either protein was observed during the simulations, the presence of the disulfide bond significantly reduced the dynamics of two large loops within hIL-27 α ^{L162C} (SEQ ID NO: 2). For one of those, the poly-glu loop, this was expected as the disulfide bridge directly restrains its N-terminus (see Figure 4(d) and (e)). Interestingly, in the presence of the disulfide bond the inventors surprisingly found reduced dynamics of the loop connecting helices 1 and 2 in hIL-27 α (SEQ ID NO: 1) (see Figure 4(d) and (e)). This loop contains several hydrophobic residues that, due to the disulfide-bridge, also become restricted in dynamics and can interact with and potentially shield hydrophobic residues in the C-terminal end of the poly-glu loop as well as in helices 2 and 4 of hIL-27 α (SEQ ID NO: 1) and thus stabilizes the native state.

[00190] It is shown that EBI3 is able to release otherwise unfolded hIL-27 α (SEQ ID NO: 1) from ER retention. However, it was not known up to now, if EBI3 is only needed to induce correct folding of the IL-27 α subunit, or if stable heterodimerization is needed

for secretion of hIL-27 α (SEQ ID NO: 1). To address this question, the inventors designed a humanEBI3 construct that contained a C-terminally fused ER retention sequence (hEBI3^{KDEL} (SEQ ID NO: 27)). When co-expressed with hEBI3^{KDEL} (SEQ ID NO: 27), hIL-27 α (SEQ ID NO: 1) was not secreted into the medium (see Figure 4(f)). hIL-27 α (SEQ ID NO: 1), however, shows higher levels in the presence of hEBI3^{KDEL} (SEQ ID NO: 27) than in isolation, arguing that assembly with EBI3 stabilizes hIL-27 α . Taken together, stable heterodimerization with EBI3 is a prerequisite for folding of hIL-27 α and its release from ER retention.

Example 5: Assembly-induced versus autonomous secretion of IL-27 α is evolutionary conserved, affecting an organism's cytokine repertoire

[00191] The secretion behavior of IL-27 α and thus potential immune regulation mediated by this subunit is dependent on a single Cys residue for mouse and man. It was therefore the question, if this was a feature conserved for other species.

[00192] A sequence alignment of several species revealed surprising differences:

[00193] The first cysteine residue in IL-27 α was generally highly conserved, with an exception e.g. in Bos Taurus (SEQ ID NO: 11) (see Figure 5(a)). Interestingly, the Criteculus griseus sequence (SEQ ID NO: 16) was very similar to its close relative mus musculus (SEQ ID NO: 10), whereas rat (SEQ ID NO: 21) and rabbit (SEQ ID NO: 20) even had three cysteines (see Figure 5(a)). The sequences of gorilla (SEQ ID NO: 15) and pig (SEQ ID NO: 19) were reminiscent of the human in terms of cysteines, whereas for e.g. equus caballus (SEQ ID NO: 17) and ursus maritimus (SEQ ID NO: 13) interestingly the first cysteine residue was conserved yet a second one was only found close to the C-terminus (see Figure 5(a)).

[00194] To analyze the impact of the variations on IL-27 α secretion, the inventors picked sequences representative of most of the Cys combinations: Sarcophilus harrisii (SEQ ID NO: 12) (one cysteine), Ursus maritimus (SEQ ID NO: 13) (two cysteines, but one C-terminal) and Bos taurus (SEQ ID NO: 11) (no cysteine).

[00195] Strikingly, S. harrisii IL-27 α (SEQ ID NO: 12) was retained in isolation and its secretion could be induced by EBI3, as expected from its "human-like" sequence. U. maritimus IL-27 α (SEQ ID NO: 13) was secreted even in isolation, suggesting that a C-

terminal cysteine could potentially also act stabilizing. B. taurus IL-27 α (SEQ ID NO: 11) was retained in isolation and secreted upon co-expression of EBI3 (see Figure 5(b)).

[00196] Taken together, a disulfide bridge/Cys pair generally has a stabilizing role on IL-27 α and decisively influences whether this subunit can be secreted in isolation and thus potentially perform immunoregulatory roles. For IL-27 α derived from all species tested, human EBI3 increased/induced its secretion, arguing for a highly conserved IL-27 α -EBI3 interface.

[00197] To further confirm the important role of the disulfide bridge in IL-27 α secretion, the inventors replaced the second cysteine in mouse IL-27 α by a leucine (C158L) (SEQ ID NO: 29), thus providing a construct more similar to the human sequence. mIL-27 α^{C158L} (SEQ ID NO: 29) was now retained in the cell in isolation and its secretion could be induced by human EBI3 (see Figure 5(c)).

Example 6: hIL-27 α^{L162C} increases the secretion of the pro-inflammatory cytokine IL-6 from LPS-stimulated THP-1 macrophages

[00198] To assess biological consequences of IL-27 α -induced signaling in human immune cells, the inventors of the present invention stimulated THP-1 macrophages with LPS either in the absence or presence of hIL-27 α^{L162C} . hIL-27 α^{L162C} increased the secretion of the pro-inflammatory cytokines IL-6 (Figure 9(a)) and TNF- α (Figure 9(b)), corroborating its role as a functional cytokine⁴¹ that modulates immune cell function. These findings show that the muteins of the present invention is active on human immune cells.

The invention is further characterized by the following items:

Items:

1. A secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated.
2. The mutein of item 1, wherein at least one of the amino acid residues at sequence positions 160 to 163 is mutated
3. The mutein of item 1 or 2, wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.
4. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 160 is replaced by cysteine (SEQ ID NO: 3).
5. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 161 is replaced by cysteine (SEQ ID NO: 4).
6. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 162 is replaced by cysteine (SEQ ID NO: 2).
7. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 163 is replaced by cysteine (SEQ ID NO: 5).
8. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 180 is replaced by cysteine (SEQ ID NO: 6).
9. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 181 is replaced by cysteine (SEQ ID NO: 7).

10. The mutein of any of the preceding items, wherein the amino acid residue at sequence position 182 is replaced by cysteine (SEQ ID NO: 8).
11. The mutein of any of the preceding items, wherein the mutein further comprises one or more salt bridges.
12. The mutein of any of the preceding items, wherein the mutein further comprises one or more disulfide-bridges.
13. A secretion-competent mutein of human Interleukin 27, comprising an α -subunit p28 and a β -subunit Ebi3, wherein the α -subunit is a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of any of items 1 to 12.
14. The mutein of item 13, wherein at least one of the amino acid residues at sequence positions 160 to 163 is mutated
15. The mutein of items 13 or 14, wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.
16. The mutein of any of items 13 to 15, wherein the amino acid residue at sequence position 160 is replaced by cysteine.
17. The mutein of any of items 13 to 16, wherein the amino acid residue at sequence position 161 is replaced by cysteine.
18. The mutein of any of items 13 to 17, wherein the amino acid residue at sequence position 162 is replaced by cysteine.
19. The mutein of any of items 13 to 18, wherein the amino acid residue at sequence position 163 is replaced by cysteine.
20. The mutein of any of items 13 to 19, wherein the amino acid residue at sequence position 180 is replaced by cysteine.

21. The mutein of any of items 13 to 20, wherein the amino acid residue at sequence position 181 is replaced by cysteine.
22. The mutein of any of items 13 to 21, wherein the amino acid residue at sequence position 182 is replaced by cysteine.
23. The mutein of any of items 13 to 22, wherein the mutein further comprises one or more salt bridges.
24. The mutein of any of items 13 to 23, wherein the mutein further comprises one or more disulfide-bridges.
25. A nucleic acid molecule comprising a nucleotide sequence encoding the secretion-competent mutein of human Interleukin 27 or the secretion-competent mutein of the α -subunit of human Interleukin 27 of any of items 1 to 24.
26. A nucleic acid molecule according to item 25, comprising a nucleotide sequence encoding a mutein of SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7, SEQ ID NO: 8.
27. A nucleic acid molecule of items 25 or 26, wherein the nucleic acid molecule is operably linked to a regulatory sequence to allow expression of the nucleic acid molecule.
28. A nucleic acid molecule of item 27, wherein the regulatory sequence comprises a promoter sequence.
29. The nucleic acid molecule of any of items 25 to 28 comprised in a vector.
30. A host cell containing a nucleic acid molecule of any of items 25 to 29.
31. An immune modulator comprising a mutein of any of items 1 to 24.
32. Use of a mutein of any of items 1 to 24 for the manufacture of a medicament for treating infectious diseases, autoimmune diseases, cancer, chronic inflammatory diseases, such as

chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal.

33. The mutein of any of items 1 to 24 for use in the treatment of infectious diseases, autoimmune diseases, cancer, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma.
34. A method of treating an Interleukin 27-mediated disease, preferably an infectious disease, an autoimmune disease, cancer, a chronic inflammatory disease, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal, comprising the step of administering a composition comprising a mutein of any of items 1 to 24 to a mammal in need thereof.
35. Method for producing a mutein according to any of items 1 to 24, comprising the steps of:
- (a) introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182, and
 - (b) introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.
36. The method of item 35, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 163.
37. The method of item 35 or 36, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 180 to 182.

38. The method of any of items 35 to 37, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 163 to cysteine.
39. The method of any of items 35 to 38, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 180 to 182 to cysteine.
40. The method of any of items 35 to 39, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 160 to cysteine.
41. The method of any of items 35 to 40, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 161 to cysteine.
42. The method of any of items 35 to 41, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 162 to cysteine.
43. The method of any of items 35 to 42, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 163 to cysteine.
44. The method of any of items 35 to 43, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 180 to cysteine.

45. The method of any of items 35 to 44, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 181 to cysteine.
46. The method of any of items 35 to 45, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 182 to cysteine.
47. A secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10), wherein at least one of the two cysteine residues at amino acid positions 103 and 158 is/are mutated or deleted.
48. The secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 of item 47, wherein the at least one of the two cysteine residues at amino acid positions 103 and 158 is replaced by hydrophobic amino acid residue.
49. The secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 of item 47 or 48, wherein the at least one of the two cysteines at amino acid positions 103 and 158 is replaced by a serine, leucine, isoleucine or alanine residue.

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Claims

1. A secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1), wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is/ are mutated.
2. The mutein of claim 1, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is/ are mutated.
3. The mutein of claim 1 or 2, wherein the mutein comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).
4. The mutein of any one of the preceding claims, wherein at least one of the amino acid residues at sequence positions 160 to 165 is mutated and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.
5. A mutein of any one of the preceding claims, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated.
6. The mutein of any one of the preceding claims, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine.
7. The mutein of any one of the preceding claims, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 180, 181 and 182 is mutated to cysteine.
8. A mutein of any one of the preceding claims, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine.
9. The mutein of any one of the preceding claims, wherein at least one of the amino acid residues at sequence positions 160 to 163 is mutated.
10. The mutein of any one of the preceding claims, wherein at least one of the amino acid residues at sequence positions 161 to 163 is mutated.
11. The mutein of any one of the preceding claims, wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.

12. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 160 is replaced by cysteine (SEQ ID NO: 3).
13. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 161 is replaced by cysteine (SEQ ID NO: 4).
14. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 162 is replaced by cysteine (SEQ ID NO: 2).
15. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 163 is replaced by cysteine (SEQ ID NO: 5).
16. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 164 is replaced by cysteine (SEQ ID NO: 33).
17. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 165 is replaced by cysteine (SEQ ID NO: 34).
18. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 180 is replaced by cysteine (SEQ ID NO: 6).
19. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 181 is replaced by cysteine (SEQ ID NO: 7).
20. The mutein of any one of the preceding claims, wherein the amino acid residue at sequence position 182 is replaced by cysteine (SEQ ID NO: 8).
21. The mutein of any one of the preceding claims, wherein the mutein further comprises one or more salt bridges, preferably, wherein the one or more salt bridges is build by replacing at least two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 by equally-charged amino acids, more preferably by replacing two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 by aspartic acid and glutamic acid or arginine and lysine.
22. The mutein of any one of the preceding claims, wherein the mutein further comprises one or more disulfide-bridges.
23. A secretion-competent mutein of human Interleukin 27, comprising an α -subunit p28 and a β -subunit EBI3, wherein the α -subunit is a secretion-competent mutein of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) of any of claims 1 to 22.
24. The mutein of claim 23, wherein the α -subunit comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).
25. The mutein of claim 23 or 24, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 165 is mutated

and/or wherein at least one of the amino acid residues at sequence positions 180 to 182 is mutated.

26. The mutein of any one of claims 23 to 25, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated.

27. The mutein of any one of claims 23 to 26, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 is mutated to cysteine.

28. The mutein of any one of claims 23 to 27, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) selected from the group consisting of sequence positions 161, 162, 163, 164 and 165 is mutated to cysteine.

29. The mutein of any one of claims 23 to 28, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 163 is/ are mutated.

30. The mutein of any one of claims 23 to 29, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 160 to 163 is/ are mutated to cysteine.

31. The mutein of any one of claims 23 to 30, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 161 to 163 is/ are mutated.

32. The mutein of any one of claims 23 to 31, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 161 to 163 is/ are mutated to cysteine.

33. The mutein of any one of claims 23 to 32, wherein at least one of the amino acid residues of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence positions 180 to 182 is/ are mutated.

34. The mutein of any one of claims 23 to 33, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 160 is replaced by cysteine.

35. The mutein of any one of claims 23 to 34, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 161 is replaced by cysteine.

36. The mutein of any one of claims 23 to 35, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 162 is replaced by cysteine.
37. The mutein of any one of claims 23 to 36, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 163 is replaced by cysteine.
38. The mutein of any one of claims 23 to 37, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 164 is replaced by cysteine.
39. The mutein of any one of claims 23 to 38, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 165 is replaced by cysteine.
40. The mutein of any one of claims 23 to 39, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 180 is replaced by cysteine.
41. The mutein of any one of claims 23 to 40, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 181 is replaced by cysteine.
42. The mutein of any one of claims 23 to 41, wherein the amino acid residue of the α -subunit of human Interleukin 27 (SEQ ID NO: 1) at sequence position 182 is replaced by cysteine.
43. The mutein of any one of claims 23 to 41, wherein the mutein further comprises one or more salt bridges, preferably, wherein the one or more saltbridges is/are build by replacing at least two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 by equally-charged amino acids, more preferably by replacing two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 by aspartic acid and glutamic acid or arginine and lysine.
44. The mutein of any one of claims 23 to 43, wherein the mutein further comprises one or more disulfide-bridges.
45. A nucleic acid molecule comprising a nucleotide sequence encoding the secretion-competent mutein of human Interleukin 27 or the secretion-competent mutein of the α -subunit of human Interleukin 27 of any of claims 1 to 44.
46. A nucleic acid molecule according to claim 45, wherein the nucleotide sequence encodes a secretion-competent mutein of the α -subunit of human Interleukin 27, wherein said mutein

comprises at least 76 % sequence identity to the α -subunit of human Interleukin 27 (SEQ ID NO: 1).

47. A nucleic acid molecule according to claim 45 or 46, comprising a nucleotide sequence encoding a mutein of SEQ ID NO: 2, SEQ ID NO: 3, SEQ ID NO: 4, SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 7 or SEQ ID NO: 8.

48. A nucleic acid molecule of any one of claims 45 to 47, wherein the nucleic acid molecule is operably linked to a regulatory sequence to allow expression of the nucleic acid molecule.

49. A nucleic acid molecule of any one of claims 45 to 48, wherein the regulatory sequence comprises a promoter sequence.

50. The nucleic acid molecule of any one of claims 45 to 49 comprised in a vector.

51. A host cell containing a nucleic acid molecule of any one of claims 45 to 50.

52. An immune modulator comprising a mutein of any of claims 1 to 44.

53. Use of a mutein of any one of claims 1 to 44 for the manufacture of a medicament for treating a disease in a mammal, preferable a human, wherein the disease is/ are preferably infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal.

54. The mutein of any one of claims 1 to 44 for use as a medicament.

55. The mutein of any one of claims 1 to 44 for use in the treatment of infectious diseases, autoimmune diseases, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, chronic inflammatory diseases, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma.

56. A method of treating an Interleukin 27-mediated disease, preferably an infectious disease, an autoimmune disease, cancer, transplantation-related diseases, such as Graft-versus-Host-disease, a chronic inflammatory disease, such as chronic inflammatory bowel disease, acute inflammatory diseases, sepsis, septic shock, diabetes or asthma in a mammal, comprising the step of administering a composition comprising a mutein of any one of claims 1 to 44 to a mammal in need thereof.

57. Method for producing a mutein according to any one of claims 1 to 44, comprising the steps of:

- (c) introducing into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or a polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit

polypeptide a nucleotide sequence mutating at least one amino acid residues of human Interleukin 27 or of the α -subunit of human Interleukin 27 or of a polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide selected from the group consisting of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182, and

(d) introducing the obtained nucleic acid molecule for expression into a suitable host cell or into a suitable cell extract or cell lysate.

58. The method of claim 57, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 165.

59. The method of claim 57 or 58, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 163.

60. The method of any one of claims 57 to 59, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 161 to 163.

61. The method of any one of claims 57 to 60, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 180 to 182.

62. The method of any one of claims 57 to 61, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 160 to 163 to cysteine.

63. The method of any one of claims 57 to 62, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -

subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 161 to 163 to cysteine.

64. The method of any one of claims 57 to 63, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating at least one of the amino acid residues at sequence positions 180 to 182 to cysteine.

65. The method of any one of claims 57 to 64, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 160 to cysteine.

66. The method of any of claims 57 to 65, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 161 to cysteine.

67. The method of any one of claims 57 to 66, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 162 to cysteine.

68. The method of any one of claims 57 to 67, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 163 to cysteine.

69. The method of any one of claims 57 to 68, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 164 to cysteine (SEQ ID NO: 33).

70. The method of any one of claims 57 to 69, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 165 to cysteine (SEQ ID NO: 34).

71. The method of any one of claims 57 to 70, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 180 to cysteine.

72. The method of any one of claims 57 to 71, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 181 to cysteine.

73. The method of any one of claims 57 to 72, wherein in step (a) into a nucleic acid molecule encoding the human Interleukin 27 polypeptide or the human Interleukin 27 α -subunit polypeptide or the polypeptide comprising at least 76 % sequence identity to the human Interleukin 27 α -subunit polypeptide a nucleotide sequence is introduced mutating the amino acid residue at sequence position 182 to cysteine.

74. A secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10), wherein at least one of the two cysteine residues at amino acid positions 103 and 158 is/are mutated or deleted.

75. The secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 of claim 74, wherein the at least one of the two cysteine residues at amino acid positions 103 and 158 is replaced by a hydrophobic amino acid residue.

76. The secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 of claim 74 or 75, wherein the at least one of the two cysteines at amino acid positions 103 and 158 is replaced by a serine, leucine, isoleucine or alanine residue.

77. The mutein of any one of claims 1 to 44, wherein in the mutein of the α -subunit of human Interleukin 27, the amino acid residue at at least one of sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 can be replaced by a non-natural amino acid, preferably by selenocysteine, pyrrolysine or a non-natural amino acid, which builds a covalent bond.

78. The mutein of any one of claims 1 to 44, wherein in the mutein of the α -subunit of human Interleukin 27, the amino acid residues at at least two of the sequence positions 160, 161, 162, 163, 164, 165, 180, 181 and 182 are replaced by equally-charged amino acids, preferably by aspartic acid (asp) and glutamic acid (glu) or arginine (arg) and lysine (lys).
79. A secretion-competent mutein of the β -subunit of mouse Interleukin 27 (SEQ ID NO: 35), wherein the amino acid residue at amino acid position 198 is mutated or deleted.
80. The mutein of claim 79, wherein the amino acid residue at amino acid position 198 is replaced by a tyrosine (SEQ ID NO: 36).
81. The nucleic acid molecule of any one of claims 45 to 50, for use as a therapeutic agent.
82. A mutein of mouse Interleukin 27, comprising an α -subunit p28 and a β -subunit EBI3, wherein the α -subunit is a secretion-incompetent mutein of the α -subunit of mouse Interleukin 27 (SEQ ID NO: 10) of any one of claims 74 to 76 and/or wherein the β -subunit is a secretion-competent mutein of the β -subunit of mouse Interleukin 27 (SEQ ID NO: 35) of claim 79 or 80.

Figure 1

10	20	30	40	50
MGQTAGDLGW	RLSLLLLPLL	LVQAGVWGFP	RPPGRPQLSL	QELRREFTVS
60	70	80	90	100
LHLARKLLSE	VRGQAHRFAE	SHLPGVNLYL	LPLGEQLPDV	SLTFQAWRRL
110	120	130	140	150
SDPERLCFIS	TTLQPFHALL	GGLGTQGRWT	NMERMQLWAM	RLDLRDLQRH
160	170	180	190	200
LRFQVLAAGF	NLPEEEEEEEE	EEEEEEKKGL	LPGALGSALQ	GPAQVSWPQL
210	220	230	240	
LSTYRLLHSL	ELVLSRAVRE	LLLLSKAGHS	VWPLGFPTLS	PQP

Figure 2

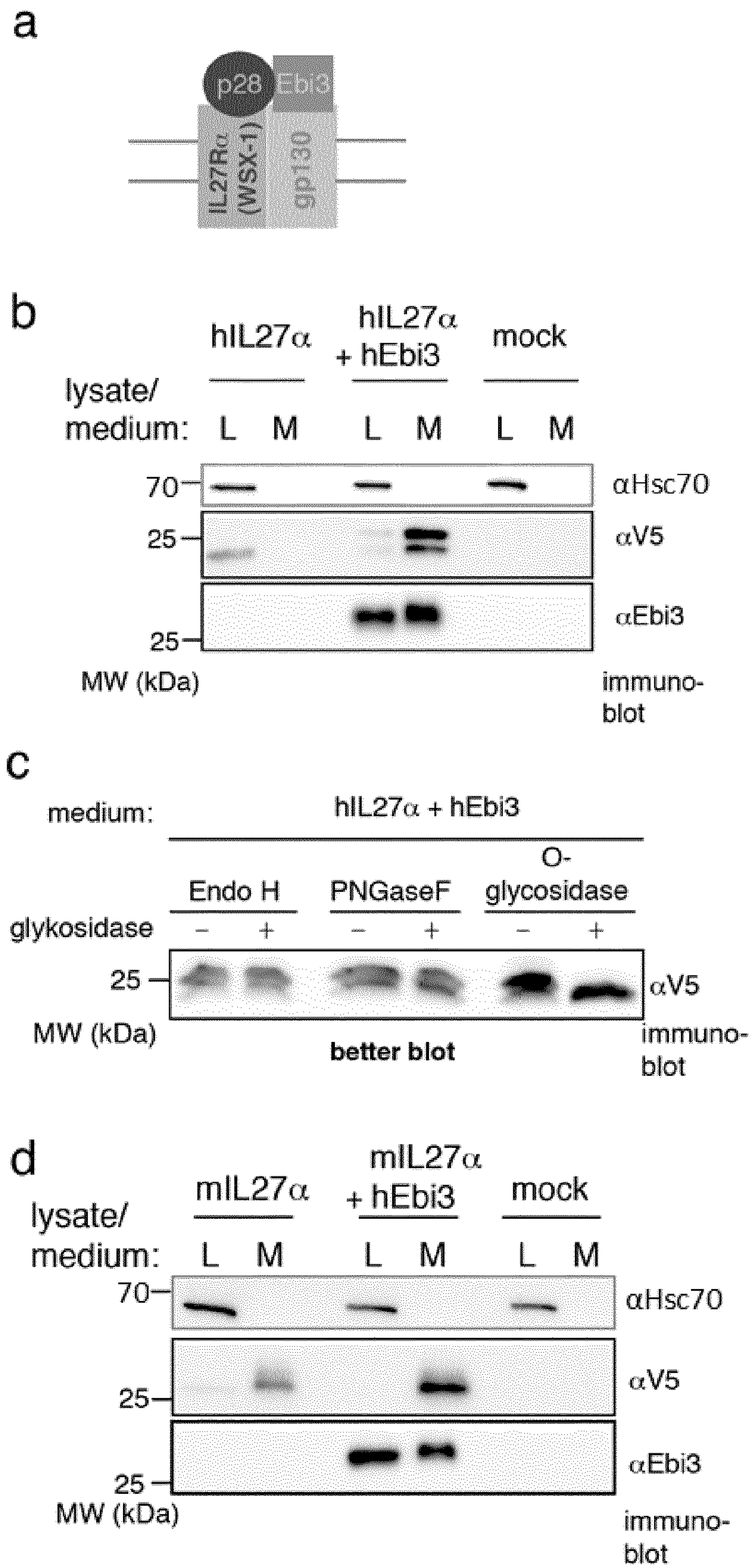


Figure 3

a

hIL27 α	MGQTA ~~GD~~ LGWRLSILLPLILLVOAGVWGFPP GRPQ LSLQELRREFTVSI ~~HL~~ ARKLLSEVR
mIL27 α	MGQVI ~~GD~~ LGWRLSILLPLILLVOAGSWGFPTDP---LSLQELRREFTVSI ~~YL~~ ARKLLSEVO
	.:** ** * *****:*****:
hIL27 α	Q ~~AR~~ FAESHLPGVNLYLLPLG EQ LIDVSLTFQAWRRLS DP ERLCFIS ~~TI~~ QPFHALGGCLG
mIL27 α	G ~~YV~~ HSFAESRLPGVNILDLLPLGYHLLINVSLTFQAWHHLS DS ERLCF LA TIRPF AM GGCLG
	*.******:*****:*****:*****:*****:*****:*****:
hIL27 α	TQGRW IN MERMQLWAMRLDLRD LQ RHLRFQVLAAGEN L PEEEEE EE ---EEEEERKGLPCA
mIL27 α	TQGTW IS SE RE QLWAMRLDLRD LH RHLRFQVLAAGE KCS KEEEE IK EEEEEEEE KK PLCA
	.*.***:*****:*****:*****:*****:*****:*****:
hIL27 α	LGSA LQ GP AQ VSWPQLISTVRL IL HSLELVLSRAV PE LLLLSKAG--H S V N PLGFPTLSPQP
mIL27 α	LG GP NQ VS SQ VSWPQLLY YV Q IL HSLELVLSRAV ED LLLLSLPRRPGS ANDS -----
	.*.***:*****:*****:*****:*****:*****:*****:

Figure 3 cont'd

b

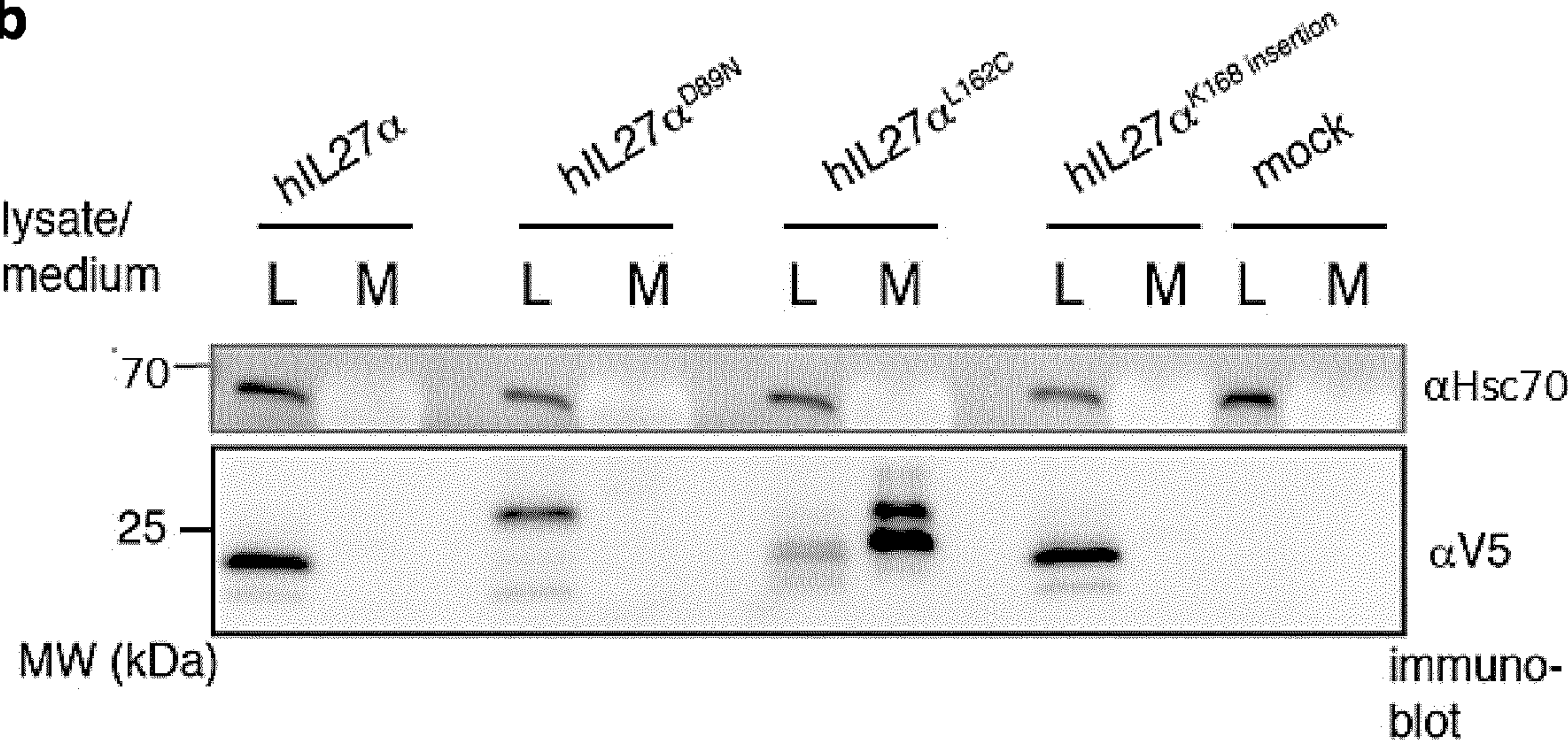


Figure 3 cont'd

C

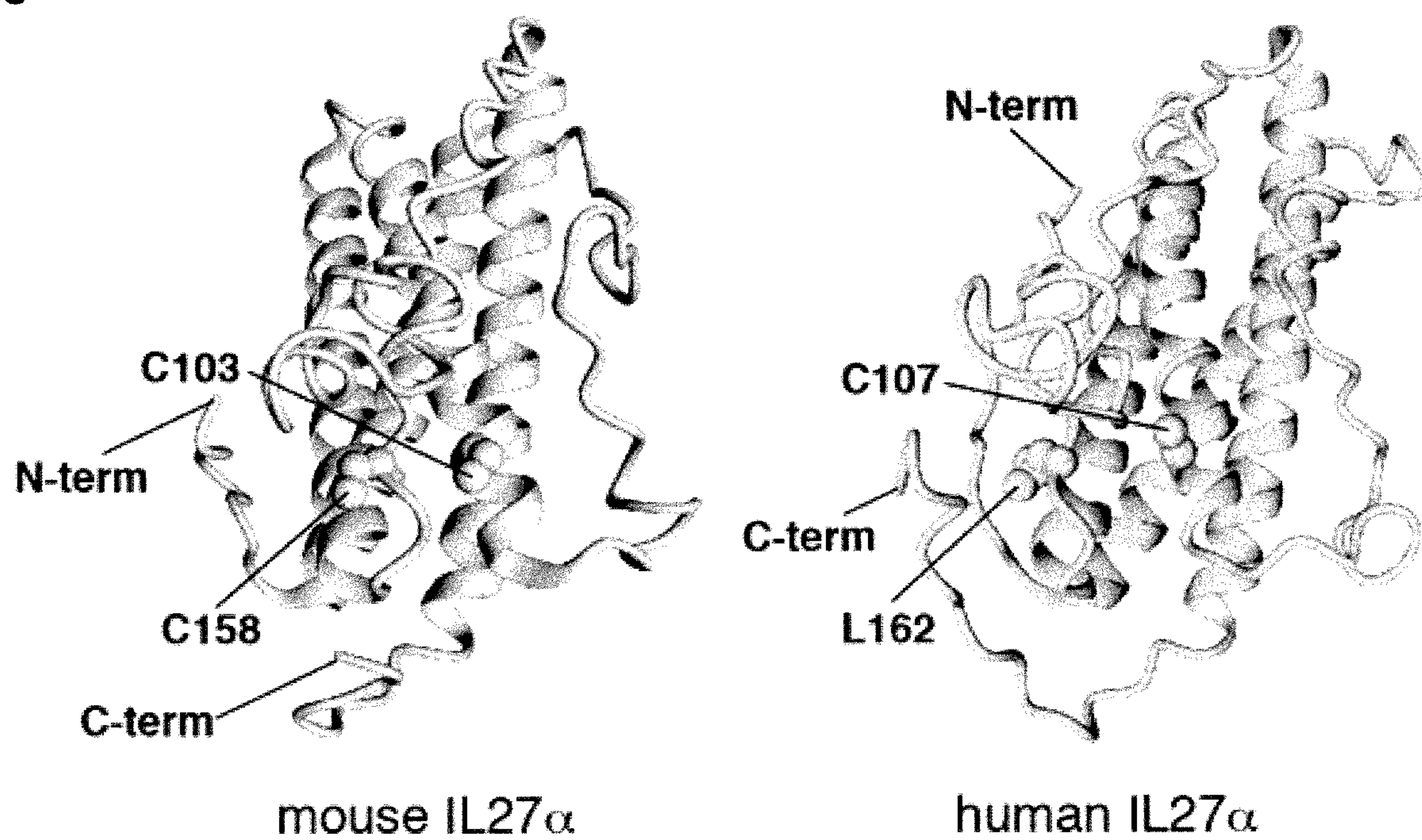
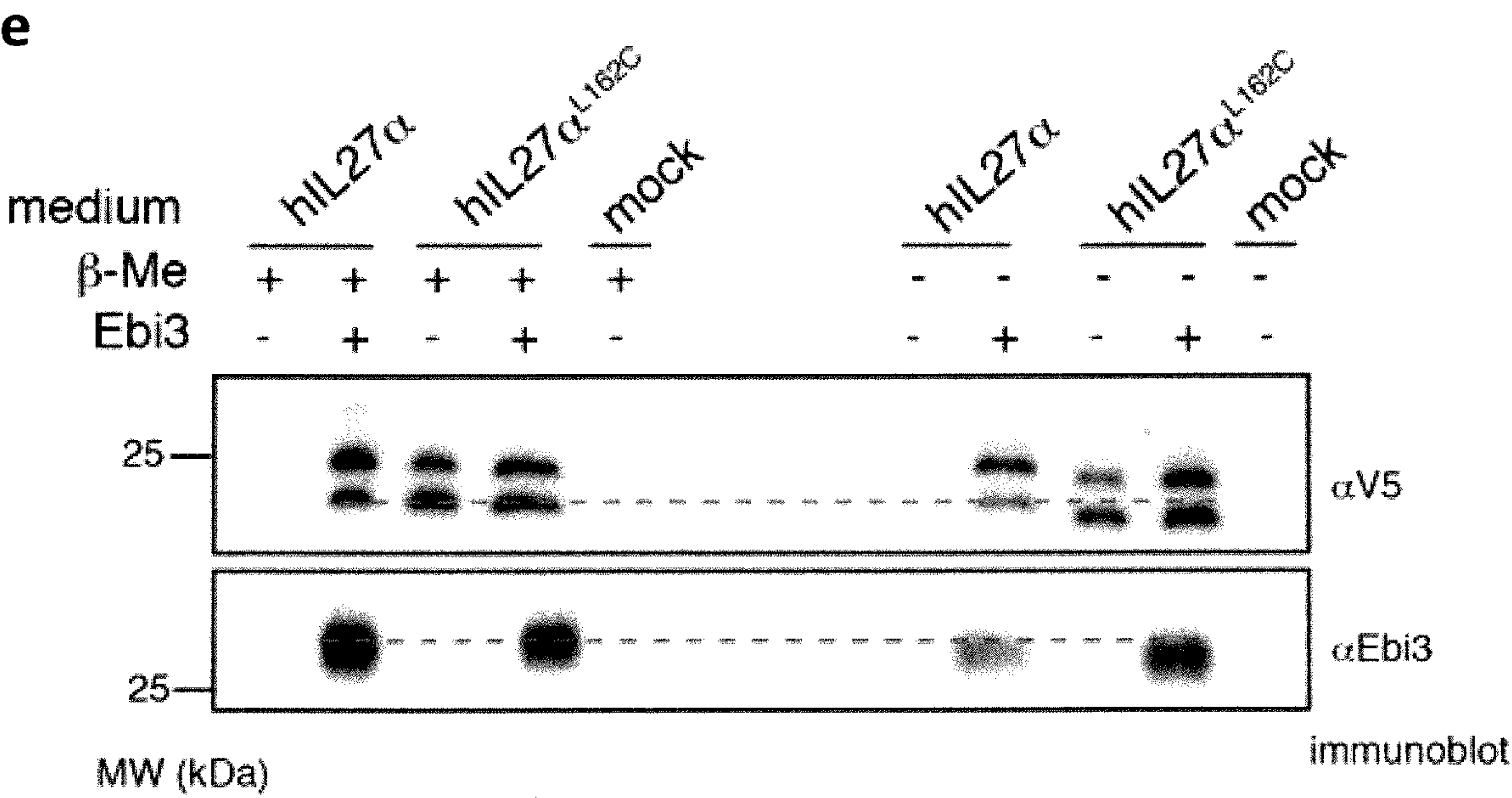


Figure 3 cont'd

d

RMSD= 1.0 Å

Figure 3 cont'd



a

lysate/medium: L M L M L M L M L M L M

HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13

α Hsc70

α V5

α Ebi3

immunoblot

MW (kDa)

70

25

25

b

lysate/medium: L M L M L M L M L M L M

HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13 HL27 α 164-178 +Heb13

α Hsc70

α V5

α Ebi3

immunoblot

MW (kDa)

70

25

25

c

lysate

hIL-27 α

hIL-27 α ^{L162C}

BiP

mock

1 % input

20 % IP

α BiP

α V5

immunoblot

MW (kDa)

100

70

25

α V5 IP

Relative BiP binding

wt

L162C

hIL-27 α

*

1.0

0.5

0.0

Figure 4 cont'd

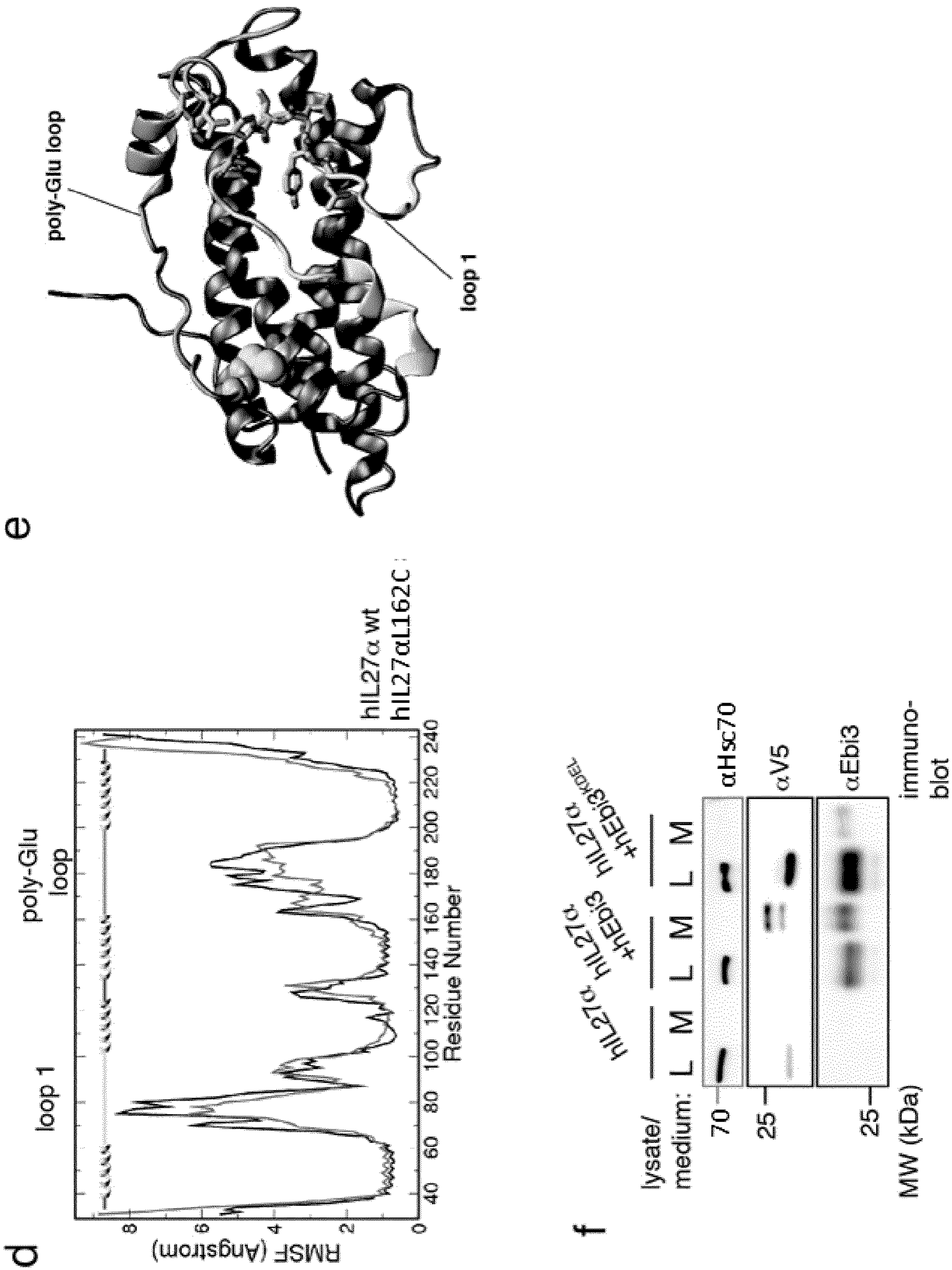


Figure 5

a

CALLORHINCHUS_MILII	-----MAVFFLLLLSLTELVLSAPTD-----PNAI NLSFHQSLN
ALLIGATOR_MISSISSIPPIENSIS	-----MRTL G--LAV-VLSALLG-A--GGSRPP-PPPRWALGLGPEFRSSWK
SARCOPHILUS_HARRISII	-----MFSSIFQGLNLLFSLLLNKAVTCGFPWPRRQPPHGLDMRSEFKISLR
CRITECULUS_GRISEUS	-----MGQVTGGLGWRLSLLLLPLLLVQAGANGFPTG----PLSLQELRREFTVSLY
MUS_MUSCULUS	-----MGQVTGDLGWRLSLLLLPLLLVQAGSWGFP TD----PLSLQELRREFTVSLY
RATTUS_NORVEGICUS	-----MGQVTGGLGWRLSLLLLPLLLMVQ TGSWGFPAD----PLSLQELRREFTVSLY
ORYCTOLAGUS_CUNICULUS	-----MGQTAGNLGWRLSLLLLSLLLV RAGVWGFP RPQS----PQELRREFTVSLH
MACACA_MULATTA	-----MGQTAGNLGWRLSLLLLPLLLVQAGVWGFP RPGRPQLSVQKLQREFTVSLH
HOMO_SAPIENS	MGQT-----AGDLGWRLSLLLLPLLLVQAGVWGFP RPGRPQLSLOELRREFTVSLH
GORILLA_GORILLA_GORILLA	MKDRPEDGPYPQVLAGTNRLSLLLLPLLLVQAGVWGFP RPGRPQLSLOELRREFTVSLH
BOS_TAURUS	-----MGQTAGNLGWRLSLLLLFLLLARAGVWGFP RPGRPPLSLOELQREFKVSLH
SUS_SCROFA	-----MGQMADDLGWRLSLLLLSLL LARAGVWGFP RPGRPPLSLOELQREFKVSLH
ORCINUS_ORCA	-----MGQTAGDLGWRVSLLLSLL LARAGVWGFP RPGRPLRSLOELQREFKVSLH
URSUS_MARITIMUS	-----MGQMAGDLGWRLSLLLLSLL LARAGVWGFP RPGRSPLSLOELQREFKVSLQ
EQUUS_CABALLUS	-----MGQTAGDLGWRLSLLLLSLL LARAGVWGFP RPGRSPLSLOELQREFKVSLH
	: : : : *

Figure 5 cont'd

CALLORHINCHUS MILII	LSRKILQDVQHLLLLKYKQEKIGNPSFEDYNMLGSLPSCQVDYRSWLEQQDEERILLNCR
ALLIGATOR MISSISSIPPIENSIS	LAQKLLVETRELTRDFVLRHLPGVQLQ-LLPLSEQLLPGSLRTRDWLGLTVLARLQGLGA
SARCOPHILUS HARRISII	LARKLLSEIRGIAHLFADTHLVGVSLD-FLPLTEQLPNVTMTFKTWLQLSDPDRICLLSS
CRITECULUS GRISEUS	LARKLLSEAQQGVVHSFAESRLPGVNLD-LLPLGHHLPNVSLTFQAWRHLSLSDPERICFLST
MUS MUSCULUS	LARKLLSEVQGVVHSFAESRLPGVNLD-LLPLGYHLPNVSLTFQAWHHLSDSERICFLAT
RATTUS NORVEGICUS	LARKLLSEVQGVVHSFAESRLPGVNLD-LLPVGHHLPNVSLTFQAWRHLSLSDSERICFLAT
ORYCTOLAGUS CUNICULUS	LARKLLSEVRGQAHRAEAEHLPGVNLD-LLPLGEQFPNVSLTFQVWRQLSDSERICFLSA
MACACA MULATTA	LARKLLSEVRGQAHRAEAEHLPGVNLD-LLPLGEQFPDVSLTFQVWRRLSDLERICFLST
HOMO SAPIENS	LARKLLSEVRGQAHRAEAEHLPGVNLY-LLPLGEQLPDVSLTFQAWRRRLSDPERICFIST
GORILLA GORILLA GORILLA	LARKLLSEVRGQAHRAEAEHLPGVNLY-LLPLGEQLPDVSLTFQAWRRRLSDPERICFIST
BOS TAURUS	LARKLLSEVRVQAHHAESHLPGVNLD-LLPLAEQLPNVSTTFQAWRGLSALSRLDLVME
SUS SCROFA	LARKLLSEVRVQAHRAEAEHLPGVNLD-LLPLGEQLPNVSLNFQAWRGLSDPERICFLSM
ORCINUS ORCA	LSRKLLSEVRVQARDFAEAEHLPGVNLD-LLPLGEQLPNVSLTFQAWRGLSDPERICFLSM
URSUS MARITIMUS	LARKLLSEVRTQAHHAESHLPGVS LD-LLPLGDQLPNVSLTFQAWHSLSDPERICFLSM
EQUUS CABALLUS	LARKLLSEVRAQAHRAEAEHLPGVS LD-LLPLGDQLPNVSMTFQAWRSLSDPERICFLSM
	::: * : : : : : : *

Figure 5 cont'd

CALLORHINCHUS_MILII	DLQVFWMHVDTKRVHELQSQDSALLEMEAISLDLRDLISQNSQISALNGSSPDTSTL
ALLIGATOR_MISSISSIPPIENSIS	ALPQYRGALARLGLPG---GDPE-FAQRLQDVWDLRDLAHHVAYQLSVARAHAA-----
SARCOPHILUS_HARRISII	LLGHFQTPLGELEGHQ---GWKGS LRKRLWTAQLDLRDLRSHLHYQMKAIGYSSREDEEA
CRITECULUS_GRISEUS	TLRPPALLEGNGQ---TWTSSERQQLWAMRLDLRDLRHRFRFQVLAAGFNCSAEEEE
MUS_MUSCULUS	TLRPPAMLGGLGTQG---TWTSSEREQLWAMRLDLRDLRHRHLRFQVLAAGFKCSKEEED
RATTUS_NORVEGICUS	TLRPPALLGGLETR---TWTSSEREQLWAMRLDLRDLRHRHLRFQVLAAGFSCSEEEKE
ORYCTOLAGUS_CUNICULUS	ALRPFRLGELGTSQ---PG-----HCLTPGLLLQVLAAGCDLPEQEER
MACACA_MULATTA	TLQPFRLGGLGTQG---RWTNTERMQLWAMRLDLRDLQRHLRFQVLAAGFHLPEEEEE
HOMO_SAPIENS	TLQPFHALLGGLGTQG---RWTNMERMQ--WAMRLDLRDLQRHLRFQVLAAGFNLPPEEEE
GORILLA_GORILLA_GORILLA	TLQPFHALLGGLGTQG---RWTNMERMQLWAMRLDLRDLQRHLRFQVLAAGFNLPPEEEE
BOS_TAURUS	WME--TGVLGMGPPE---SWTSSERMQLQATRLDLRDLQQLHLRFQVLAAGFNLPPE--H
SUS_SCROFA	TLRPFHTLLGGLGSQG---FWTSSERMQ--WAIRLDLRDLQQLHLRFQVLAAGFNLPQEEEE
ORCINUS_ORCA	TLHPFHTLLGGLGSQG---FWTSSERLQLWAMRLDLRDLQQLHLRFQVLAAGFNLPPE--E
URSUS_MARITIMUS	MLRPFHVLGRNGQ---GWTSSERKMLWTVRDLRDLQRHLRFQVLAAGNLNLPPE--E
EQUUS_CABALLUS	TLRPFHALLGGLGSQG---GWTSSERMQLWAMRLDLRDLQRHLHLRFQVLAAGFNLPPE--E
	: : * * . * .

CALLORHINCHUS_MILII	T-----LP-----NDVLNPLYDWHSRLOQYII	FRDLEVLNKNVVRDFTVLKK
ALLIGATOR_MISSISSIPPIENSIS	-----PPPPPPPPAPRAVWRRLOQATAVTLRSLEAVLARAARDFALLRR	
SARCOPHILUS_HARRISII	-----GPEERALRRISLTVRQVSWPQLLRTYQLLRSLSELVLARAVRDFLLLSK	
CRITECULUS_GRISEUS	EEEEEEEEEGKELLGALDGPQKVSSQVSWPQLLYTYQLLHSHSELVLSRAVRDLLLLTLM	
MUS_MUSCULUS	EEEEEEEEEEKKLPLGALGPNQVSSQVSWPQLLYTYQLLHSHSELVLSRAVRDLLLLSL	
RATTUS_NORVEGICUS	EEEEEEEEEGKELLGALGPNQVSSQVSWPQLLYAYQLLHSHSELVLSRAVRDLLLLSL	
ORYCTOLAGUS_CUNICULUS	-----EEKGGLLPGAPGGPSPAWAQLSWPQLLYNYQLLHSHSELVLSRAVRDLLLLSK	
MACACA_MULATTA	E-E-EEEEERKGLLPGALGNASQGPAPQVSWPQLLSTYRLLHSHSELVLSRAVRDLLLLSK	
HOMO_SAPIENS	E-E-EEEEERKGLLPGALGSALQGPAPQVSWPQLLSTYRLLHSHSELVLSRAVRELLLLSK	
GORILLA_GORILLA_GORILLA	E-EEEEEEEEERKGLLPGALGSALQGPAPQVSWPQLLSTYRLLHSHSELVLSRAVRELLLLSQ	
BOS_TAURUS	-----ENEEKGLLPGALGAPLQISAQVSWSRFLYTYRLLHSHLELLLSRTVRDLLLLSR	
SUS_SCROFA	-----ENEAGRELLPGAPGGPSKPAAQVSWPRLLLYTYQLLHSHSELVLSRAMRDFLLLSR	
ORCINUS_ORCA	-----ENEEGEGLLPGALGGPLQMSAQVSWPRLLLYTYQSLHSEIVLSRAVRDLLLLSQ	
URSUS_MARITIMUS	-----N-EERKGLLEWAPGGPSQISAQPSWPQLLYTYQLLHSHSELVLSRAVRDLLLLSQ	
EQUUS_CABALLUS	-----ENЕКGKELLTGAPGSPSQTSVQVSWPQLLYTYQLLHSHSELVLSRAVRDLLLLSQ	
	*	: : * * * : : *

Figure 5 cont'd

CALLORHINCHUS_MILII	H-----	-----
ALLIGATOR_MISSISSIPPIENSIS	LVPAPL-----	-----
SARCOPHILUS_HARRISII	EVAQSQSLAT-----	-----
CRITECULUS_GRISEUS	SPHPDPALGS-----	-----
MUS_MUSCULUS	PRRPGSAWDS-----	-----
RATTUS_NORVEGICUS	PRRPDSACDP-----	-----
ORYCTOLAGUS_CUNICULUS	AGHPVQALGLPTTQPQP	
MACACA_MULATTA	AGHSVWPLGFTLGPQP	
HOMO_SAPIENS	AGHSVWPLGFTLSPQP	
GORILLA_GORILLA_GORILLA	AGHSVWPLGFTSSSPQP	
BOS_TAURUS	AGNSVQALGFTTPSSQP	
SUS_SCROFA	AGNPAPALGFTTPSSPP	
ORCINUS_ORCA	AGNPAQALGFTTPSSQP	
URSUS_MARITIMUS	AGNPAPALGCTSSSSQP	
EQUUS_CABALLUS	AGNPAQALGCTTPSSQP	

Figure 5 cont'd

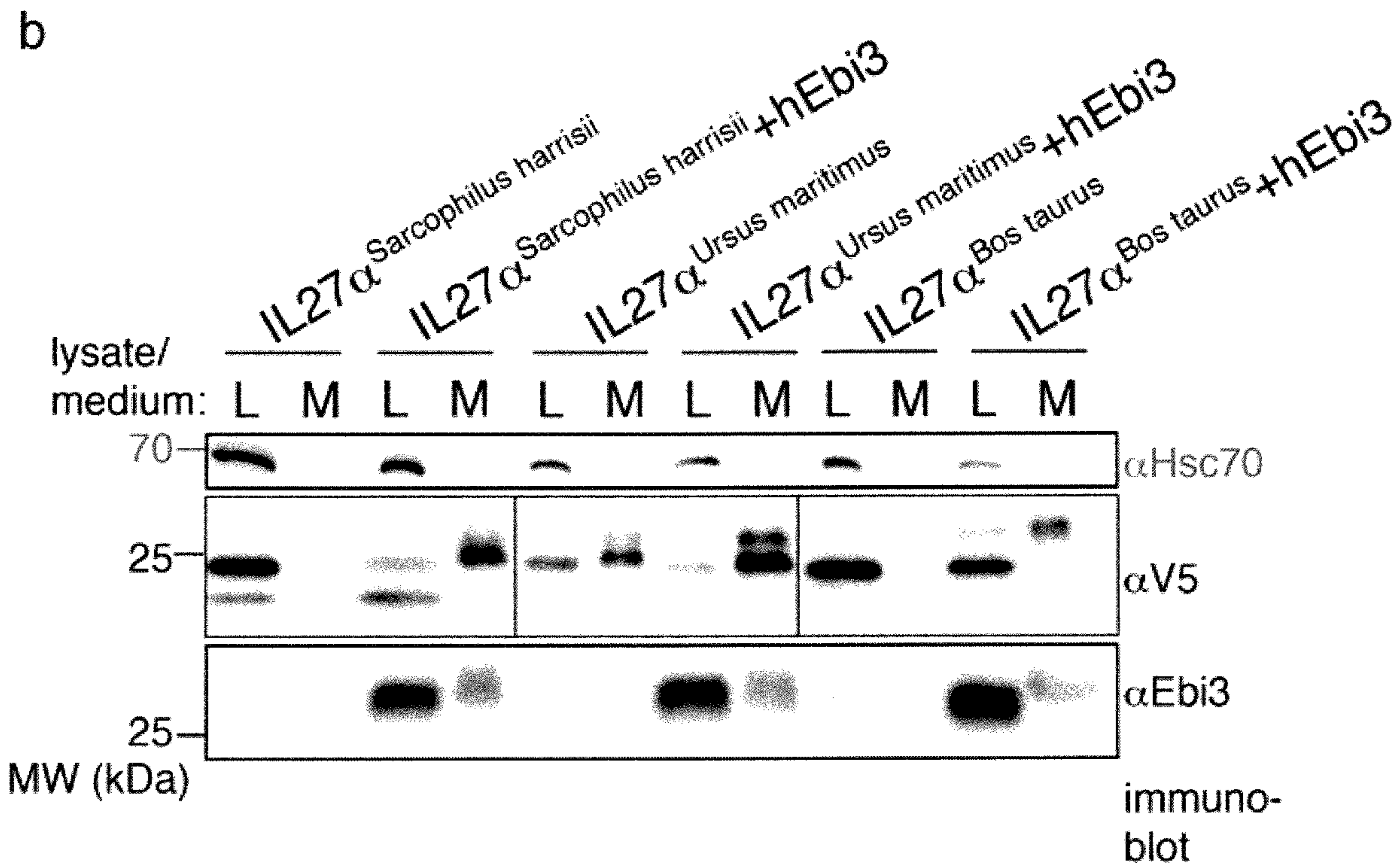


Figure 5 cont'd

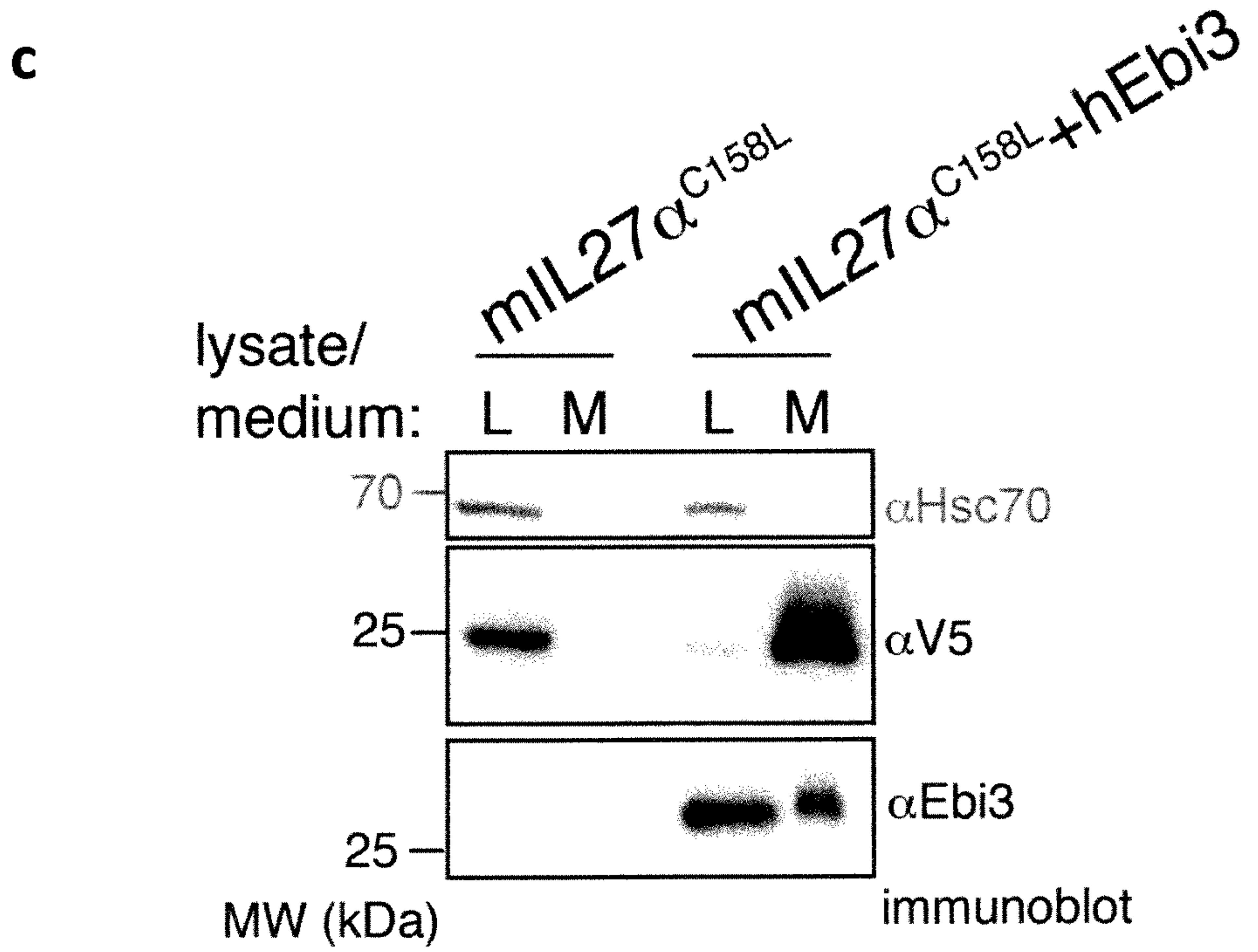


Figure 6

correct isotype controls

medium:	1 % input								15 % IP				
mIL27 α	+	-	-	-	+	-	-	-	+	+	-	-	-
mIL27 α^{C158L}	-	+	-	-	-	+	-	-	-	-	+	+	-
hEbi3	+	+	+	-	+	+	+	-	+	+	+	+	+
mock	-	-	-	+	-	-	-	+	-	-	-	-	-

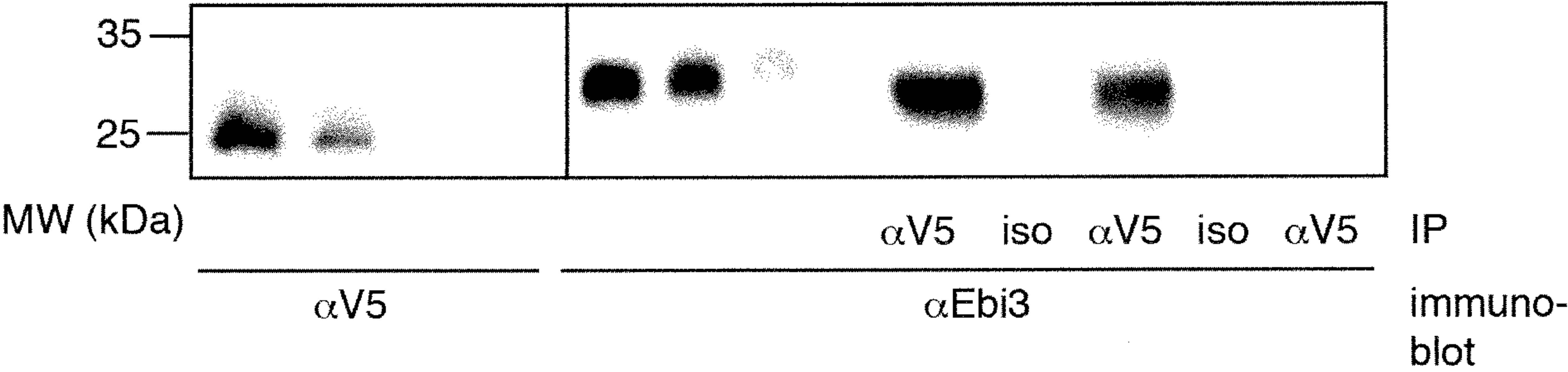


Figure 7

a

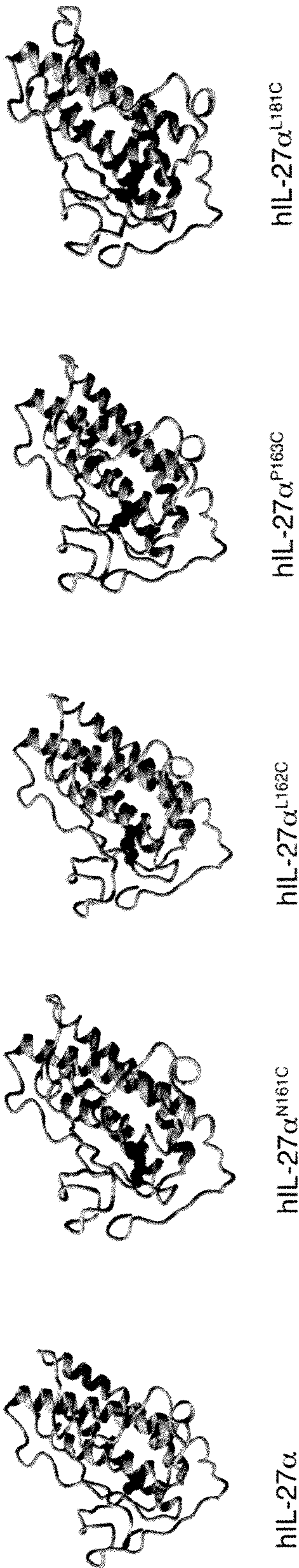
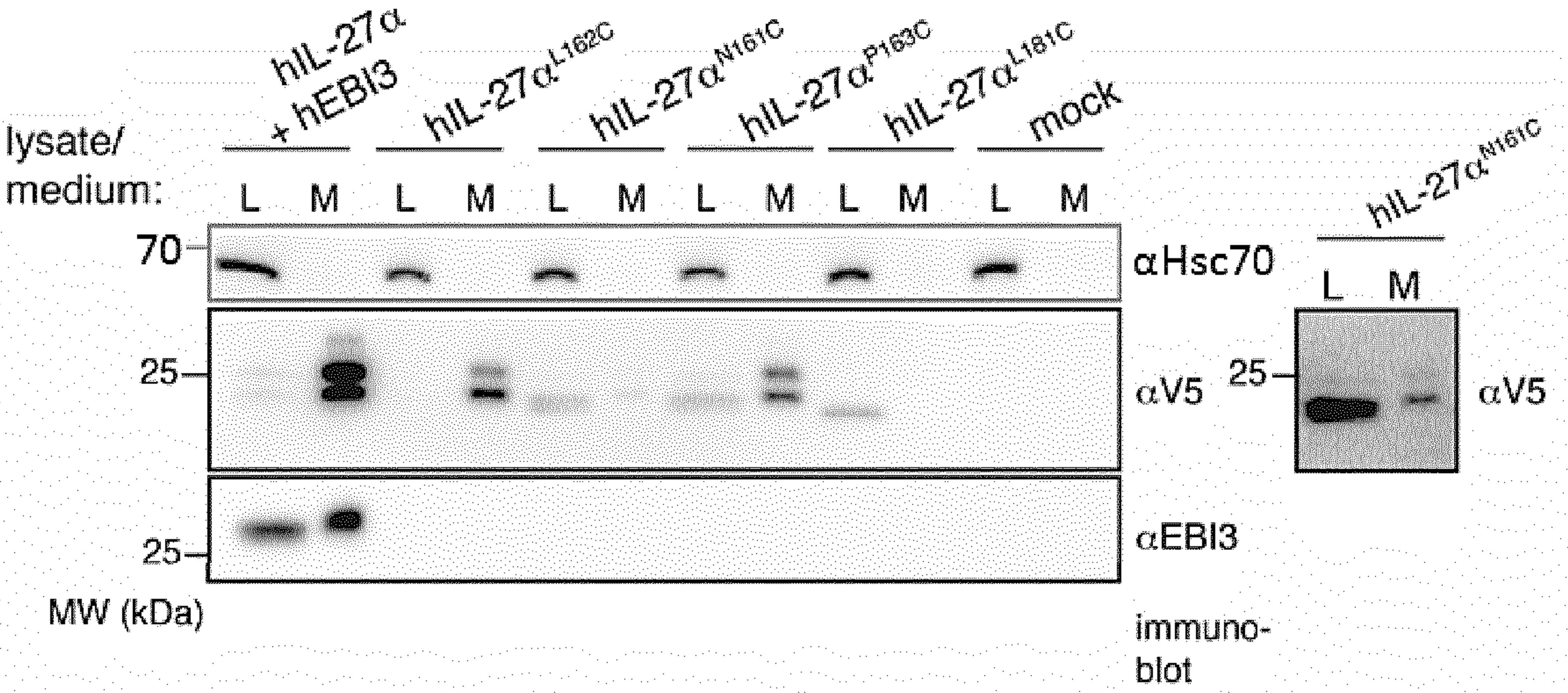


Figure 7 cont'd

b



C

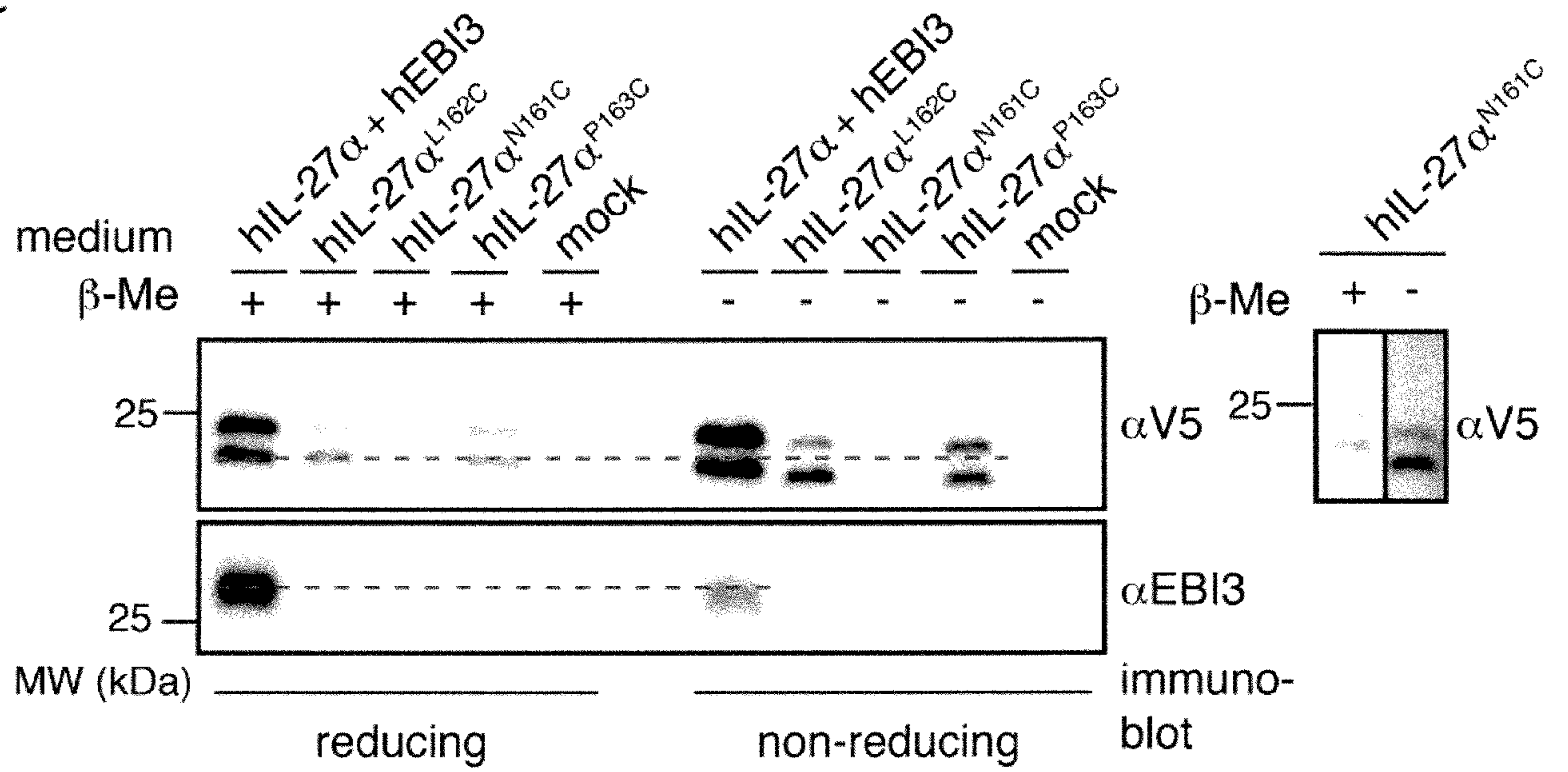
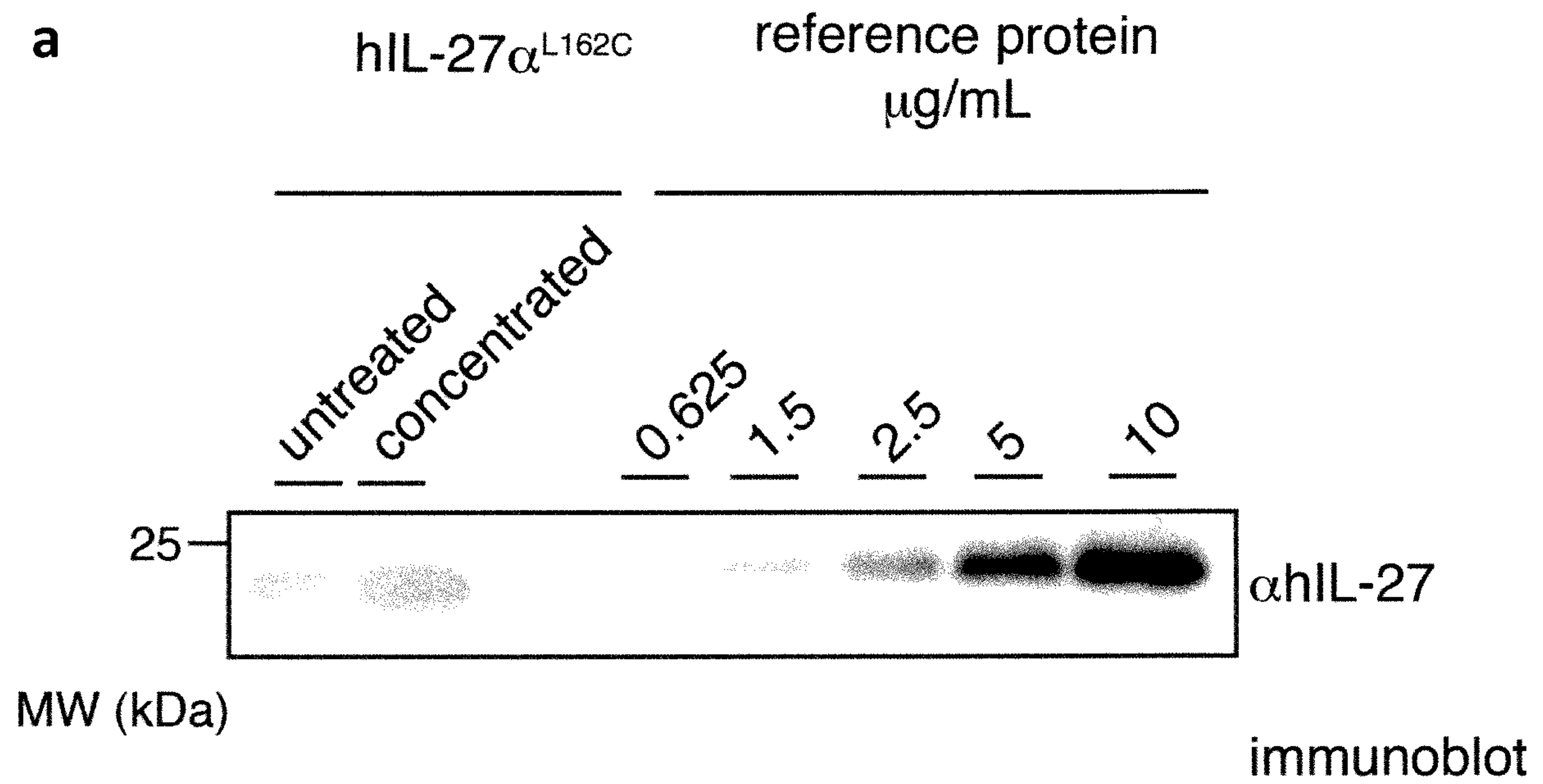


Figure 8



hIL-27 α ^{L162C}

reference protein
μg/mL

untreated
concentrated

0.625

15

2.5

5

10

25.

α hIL-27

MW (kDa)

immunoblot

Figure 8 cont'd

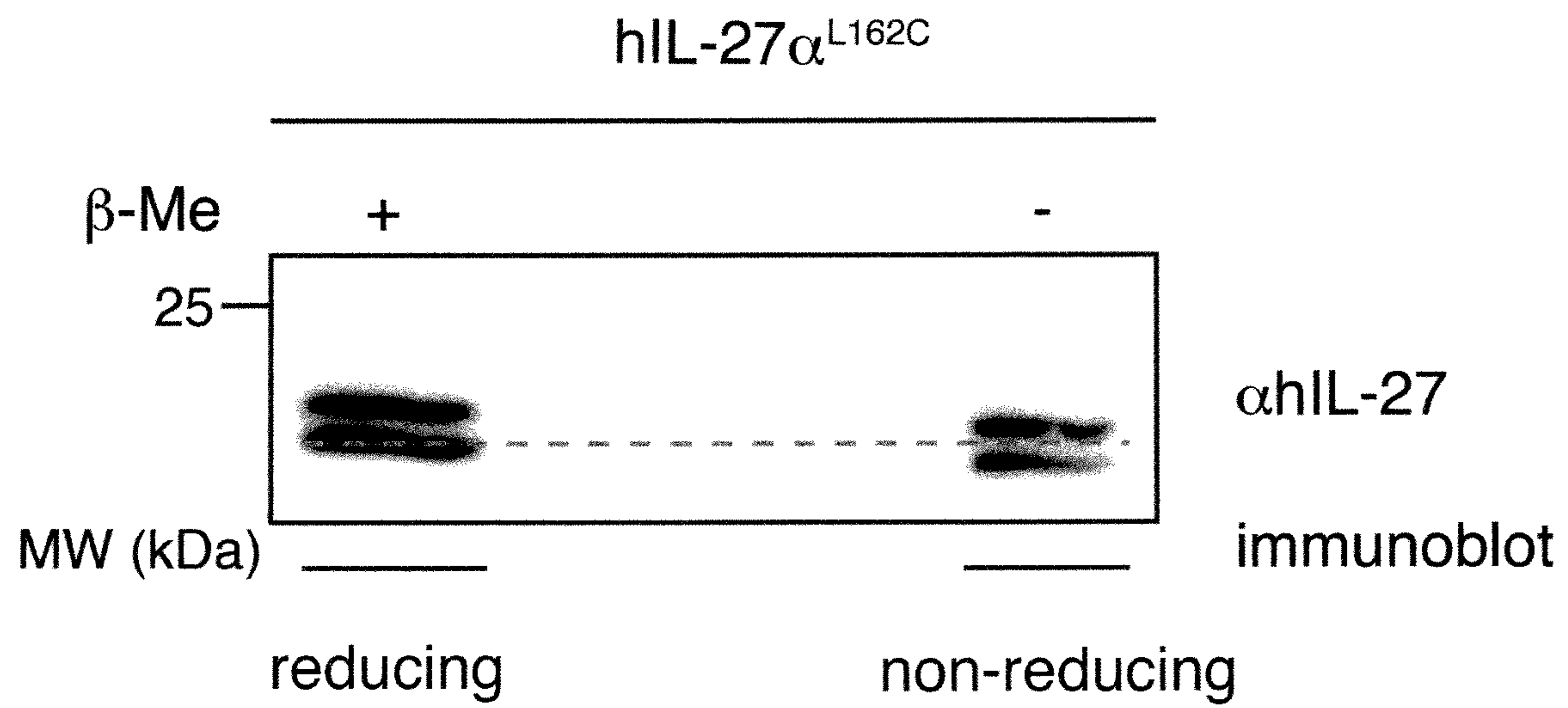
b

Figure 9

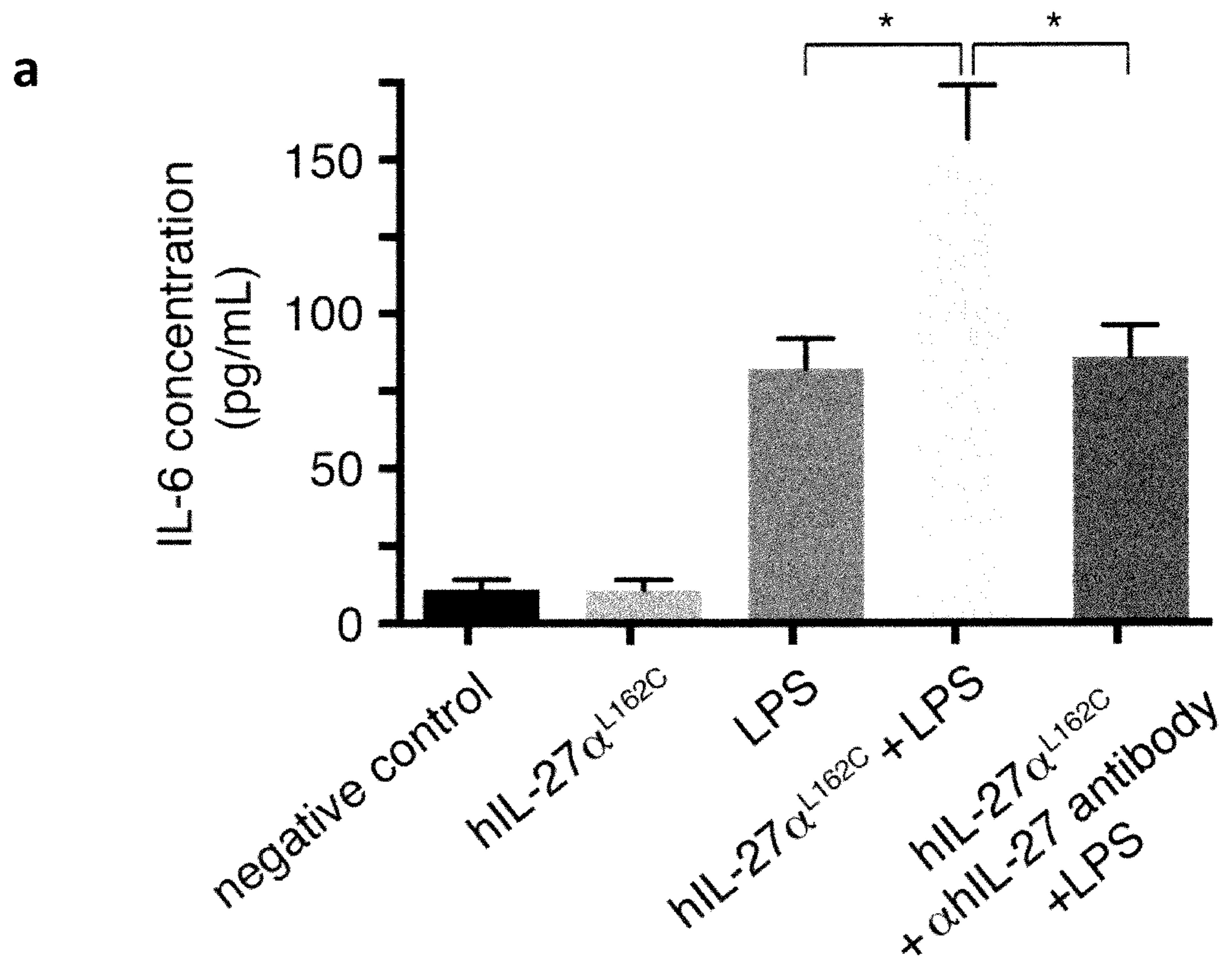


Figure 9 cont'd

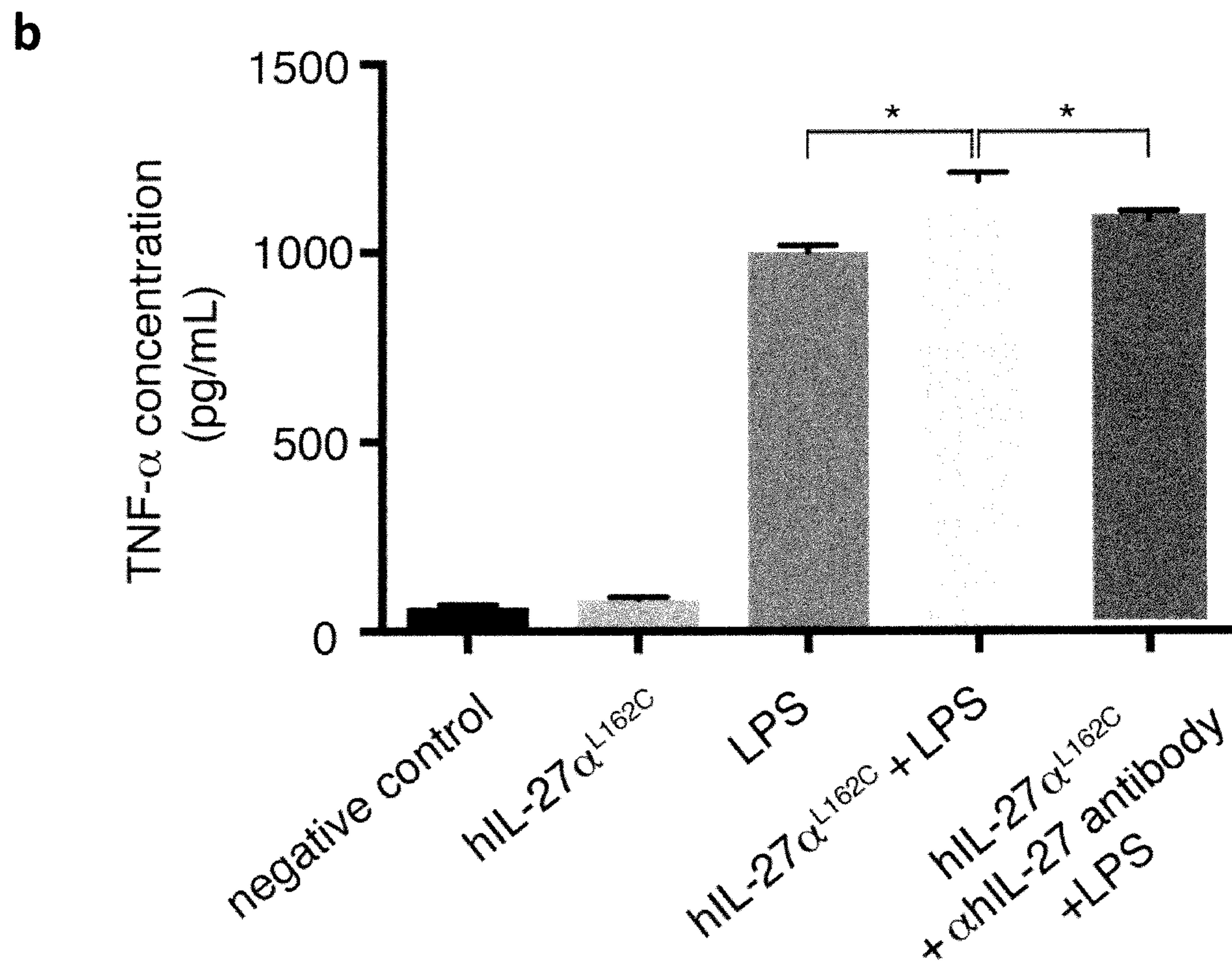


Figure 10

a

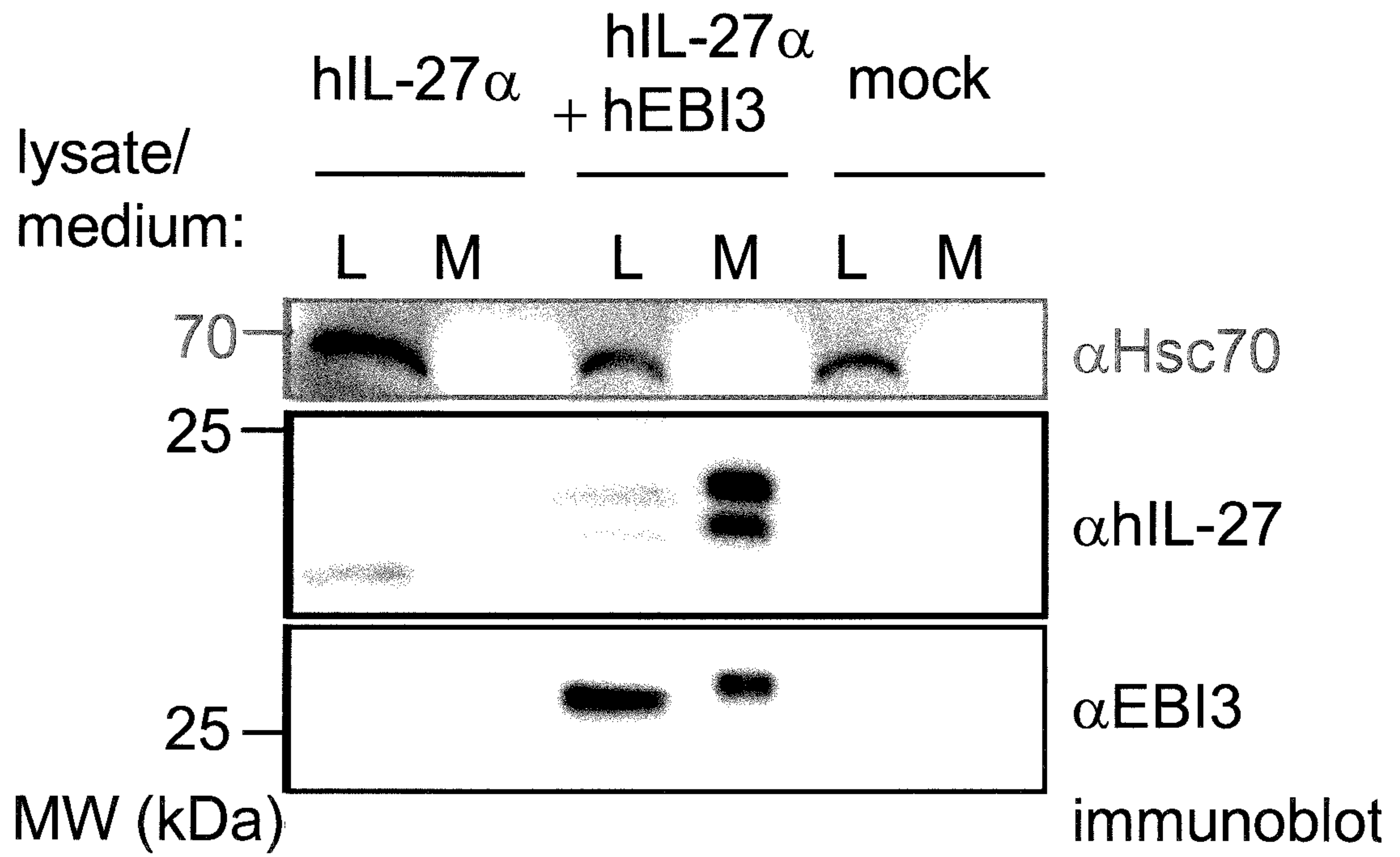


Figure 10 cont'd

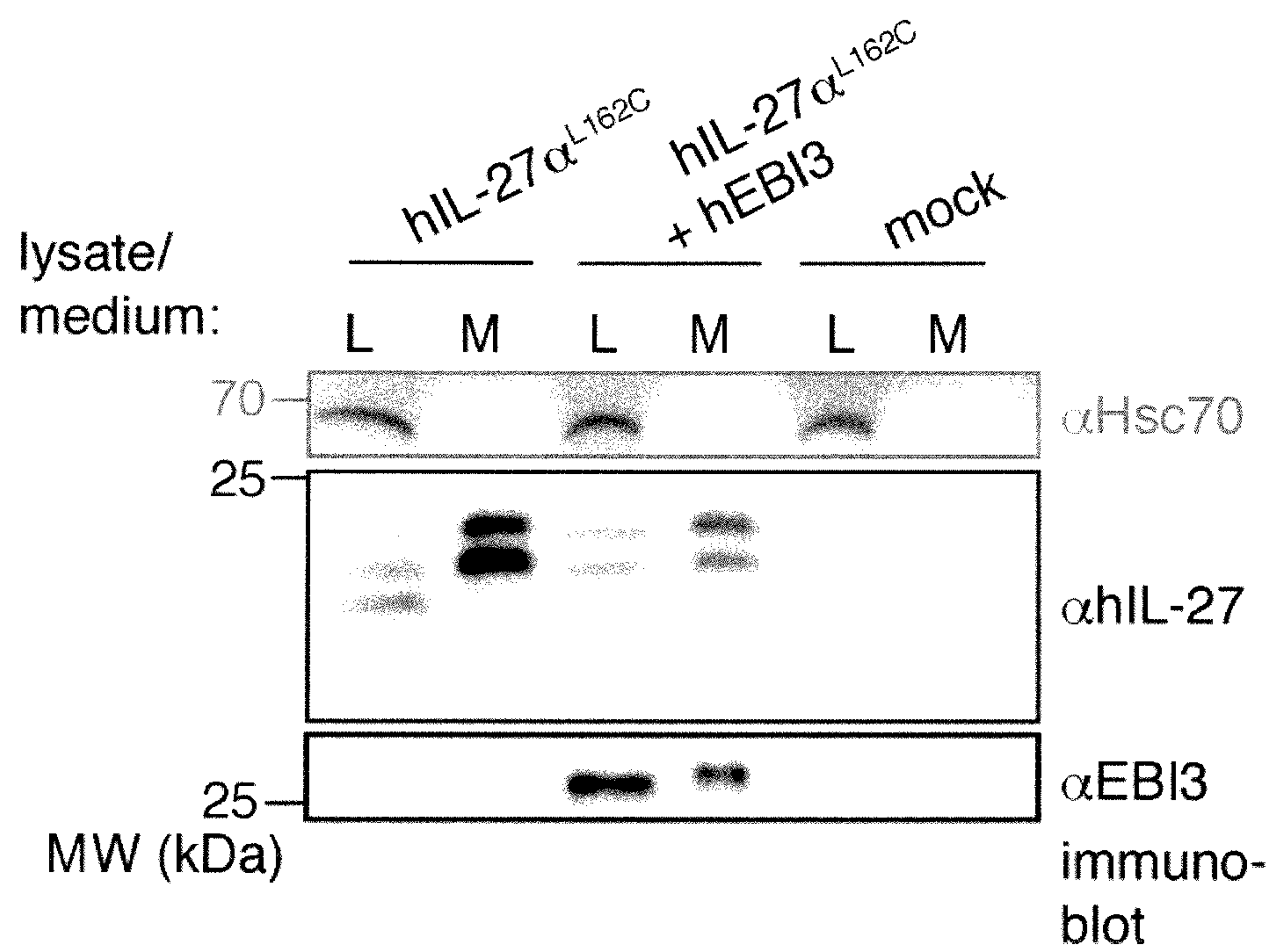
b

Figure 11

ER import sequence

human MTPQLLLALVLWASCPPCSKRKGPAAALTLPVQC CRASRYPIAVDC SWTLPPAPNSTSPV 60
murine MSKLLFLSLALWASRSPGYTE-TALVALSQPRVQC CHASRYPVAVDC SWTPLQAPNSTRST 59

::*:*:* * . ** : ***** :***** *

human SFIATYRLGMAARGHWPCLQQTPTSTSC ITTDVQLFSMAPYVLNVTA VHPWGSSSFVP 120
murine SFIATYRLGVATQQSQPCLQRSPOASRC TIPDVHLFSTVPYMLNVTA VHPGGASSSLLA 119

*****:*:*:* * * * * * :***** *:*:*:*:

human FITEHIIKPDPPEGVRLSPLAERQLQVQWEPPGSWPFEI FSLKYWI RYKRQGAARFHRV 180
murine FVAERI IKPDPEGVRLRTA-GQR LQVLWHPPASWPFDFISLKYRLRYRRRGASHFRQV 178

::*:*:****** :*** * *.***** :***:*:*:*:

human GPIEATSFILRAVRPRARYYVQVAAQDLTDYGELSDWSLPATA TMSLGK- 229
murine GPIEATTFTLRNSKPHAKYC IQVSAQDLTDYCKPSDWSLPQGVE SAPHKP 228

*****:* * * :*:~* :*****~* :*****~* *