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# METHOD FOR PREPARING A PHYSIOLOGICALLY ACTIVE IL-18 POLYPEPTIDE

## BACKGROUND OF THE INVENTION

The present invention relates to a process for producing a physiologically active polypeptide, more particularly, to a process for producing active human IL-18.

IL-18, also known as interferon-γ-inducing factor, is a recently discovered novel cytokine. Active IL-18 contains 157 amino acid residues. It has potent biological activities, including induction of interferon-γ-production by T cells and splenocytes, enhancement of the killing activity of NK cells and promotion of the differentiation of naïve $CD4^+$ T cells into Th1 cells. In addition, human IL-18 augments the production of GM-CSF and decreases the production of IL-10. IL-18 has been shown to have greater interferon-γ inducing capabilities than IL-12 and signals through a different receptor and utilizes a distinct signal transduction pathway.

IL-18, the encoding nucleotide sequence, and certain physicochemical chemical properties of the purified protein is known (Ushio, S., *et al.*, 1996, J. Immunology, 156, 4274-4279; Dinarello, C.A., *et al. 1998*, J. Leukocyte Biology, 1998. 63, 658-664).

Kabushiki Kaisha Hayashibara Seibutsu Kayaku Kenkyujo's ("Hayashibara"), U.S. 5,192,324, which corresponds to EP 0692536, published on January 17, 1996, discloses a mouse protein which induces IFN-gamma production by immunocompetent cells, the protein being further characterized as having certain physicochemical properties and a defined partial amino acid sequence. Also disclosed is a protein having a 157 aa sequence, two fragments thereof, DNA (471 bp) encoding the protein, hybridomas, protein purification methods, and methods for detecting the protein.

Hayashibara's U.S. 6,214,584, which corresponds to EP 0712931, published on May 22, 1996, discloses a 157 aa human protein and homologues thereof, DNA encoding the protein, transformants, processes for preparing the protein, monoclonal antibodies against the protein, hybridomas, protein purification methods, methods for detecting the protein, and methods of treatment and/or prevention of malignant tumors, viral diseases, bacterial infectious diseases, and immune diseases.

Incyte Pharmaceuticals, Inc.'s, WO 97/24441, published on July 10, 1997, discloses a 193 amino acid protein corresponding to IL-18 precursor and encoding DNA.

In human cells, polypeptides formed by the expression of genes may be processed by intracellular enzymes to be partially digested and to receive sugar chains. Polypeptides

to be satisfactorily incorporated into pharmaceuticals may be those which were processed similarly as in human cells. It is known that most cytokines are usually produced as precursors with no biological activity, and then processed by intracellular enzymes to be converted into active polypeptides.

The IL-18 polypeptide usually exists in human cells in the form of a precursor of 193 amino acids and no biological activity. The precursor IL-18 is also referred to as Pro-IL-18. One method of producing active IL-18 from its precursor is taught by Hayashibara's U.S. 5,879,942, which corresponds to EP 0819757, published on January 21, 1998. The patent discloses an enzyme or a protein which converts a precursor of IL-18 into active IL-18.

Another method of producing active IL-18 from its precursor is taught by Hayashibara's U.S. Patent No. 5,891,663, which corresponds to EP 0821005, published on January 28, 1998. The patent discloses contacting precursor IL-18 with interleukin-1β-converting enzyme ("ICE"). The teachings of the patents and references are incorporated by reference.

The role of ICE as a mediator of apoptosis and inflammation has been extensively studied in the literature. It is also known that ICE can process precursors of both Interleukin-1 and Interleukin-18 to active forms (Thornberry, NA, et al., 1992, Nature 356, 768-774; Ghayur, T et al., 1997, Nature 386, 619-623).

## SUMMARY OF THE INVENTION

The present invention provides methods for the *in vitro* activation of precursor of human IL-18 (also known as Pro-IL-18) with an activating enzyme comprising, contacting the precursor human IL-18 with an activating enzyme, such as caspase 4 or caspase 5. More specifically, the present invention provides a method by which caspase 4 and caspase 5 act on a precursor of IL-18 to cleave a specific site to produce an active polypeptide that induces IFN-γ production in immunocompetent cells.

The present invention further provides methods for the *in vivo* activation of precursor of human IL-18 comprising co-expressing the protein with an activating protease. More specifically, the present invention provides methods for the *in vivo* activation of IL-18 using proteasese such as, caspase 4, also known as $ICE_{REL}II$, caspase 5, also known as $ICE_{REL}III$, and ubiquitin-specific protease, which act on a precursor of the IL-18 polypeptide to convert it into an active polypeptide that induces IFN-γ production.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

FIG. 1 shows the amino acid sequence of human precursor IL-18 (SEQ ID NO:1)

FIG. 2 shows the nucleic acid sequence encoding full-length human IL-18 (SEQ ID NO:2).

FIG. 3 shows the amino acid sequence of active human IL-18 (SEQ ID NO: 3).

FIG. 4 shows the amino acid sequence of the 6-his tagged N-terminally truncated caspase 4 (SEQ ID NO:4).

FIG. 5 shows the nucleic acid sequence encoding the amino acid sequence of the 6-his tagged N-terminally truncated caspase 4 (SEQ ID NO:5).

FIG. 6 shows the amino acid sequence of the 6-his tagged N-terminally truncated caspase 5 (SEQ ID NO:6).

FIG. 7 shows the nucleic acid sequence encoding the amino acid sequence fo the 6-his tagged N-terminally truncated caspase 5 (SEQ ID NO:7).

FIG. 8 is a schematic diagram of a bicistronic expression cassette contained within pET28-ProIL-18/Casp 4 for co-expressing of Pro-IL-18 and truncated caspase 4 in *E. coli.*

FIG. 9 shows a sequence of Pro-IL-18/Caspase 4 expression cassette within pET28 (SEQ ID NO:8).

FIG. 10 shows the annotated sequence of Pro-IL-18/Caspase 4 expression cassette. Numbering corresponds to the position within the pET28a vector.

FIG. 11 shows Pro-IL-18/Caspase 4 induction.

FIG. 12 is a Schematic diagram of bicistronic expression cassette contained within pET28-Pro-IL18/truncated caspase-5 for co-expression of Pro-IL8 and Caspase-5 in *E. coli.*

FIG 13 shows a sequence of Pro-IL-18/Caspase 5 expression cassette within pET28 (SEQ ID NO:9).

FIG. 14 shows the annotated sequence diagram of Pro-IL-18/truncated caspase-5 expression cassette detailing regulatory sequence features and translation of Pro-IL-18 and truncated caspase-5. Numbering corresponds to the positioning within the pET28a vector

FIG. 15 shows Pro-IL-18/Caspase 5 induction.

FIG. 16 shows the amino acid sequence of Ub-IL-18 (SEQ ID NO: 10).

FIG. 17 shows the nucleic acid sequence encoding the amino acid sequence of Ub-IL-18 (SEQ ID NO:11).

FIG. 18 shows the nucleic acid sequence of Ub-IL-18/Ubp-1 expression cassette within the pET28 vector (SEQ ID NO:12).

FIG. 19 shows the annotated sequence of Ub-IL-18/Ubp-1 within the pET28 vector. Numbering corresponds to the position within pET28.

FIG. 20 shows Ub-IL-18 expression and processing by Ubp-1.

FIG. 21 shows IL-18 activity assay using KG-1 (human myelomonocytic cell line) cells and to monitor IFN-γ production (IL-18 expressed in various ways as indicated).

FIG. 22 shows IL-18 activity assay using purified human PBMCs to monitor IFN-γ production (IL-18 expressed in various ways as indicated).

DETAILED DESCRIPTION OF THE INVENTION

Caspase 4 and 5 are members of a family of cysteine proteases that include Interleukin-1β converting enzyme (ICE), which preferentially cleave substrates containing a protease activation motif comprising the amino acid sequences XEYD, wherein X is selected from a group of amino acids consisting of W, L, F, Y, I, V, D, or E ; E is glutamic acid; Y is selected from a group of amino acids consisting of H, I, A, T, S, P or E; and D is aspartic acid (Munday, N.A., *et al.*, 1995, J. Biol. Chemistry, 270, 15870-15876; Talanian, R.V. et al, 1997, J. Biol. Chemistry 272, 9677-82; Thornberry, N.A. et al. 1997 J. Biol. Chemistry 272, 17907-11). The substrate recognition of caspase-5 is thought to be essentially the same for ICE and caspase-4 and distinct from other members of the caspase (Talanian, R.V. et al, 1997, J. Biol. Chemistry 272, 9677-82; Thornberry, N.A. et al. 1997 J. Biol. Chemistry 272, 17907-11). Caspase 4 is disclosed in EP-B-0 754 234. Caspase 5 is disclosed in U.S. 5,552,536 and U.S. 5,760,180.

Ubiquitin-specific proteases are a family of ATP-independent enzymes that can precisely cleave the evolutionarily conserved 76 amino acid ubiquitin peptide from the N-terminus of proteins that are fused to it. These proteases specifically cleave the peptide bond between the carboxyl-terminal amino acid residue of a ubiquitin protein and the α-amino group of any non-ubiquitin protein to which ubiquitin is joined. Ubiquitin-specific proteases from Saccharomyces cerevisiae, Ubp1, Ubp-2, and Ubp-3, for example, are known and can be recombinantly expressed to catalyze deubiquitination reactions that target ubiquitin fusion proteins both *in vivo* and *in vitro* (Baker, RT et al., 1992, J. Biol. Chem. 267: 23364-23375; Baker, RT et al., 1994 J. Biol. Chem. 269: 25381-25386). The specificity of Saccharomyces cerevisiae ubiquitin-specific proteases allows for the precise removal of ubiquitin from any peptide with the exception of those that start with proline. Ubiquitin-specific protease from other species such as mouse Unp and its human homologue Unph, are capable of efficient cleavage even in front of proline (Gilchrist CA et al. 1997, J. Biol. Chem. 272:32280-32285. Thus, virtually any desired N-terminus can be generated through the removal of a precisely fused ubiquitin peptide when combined *in vitro* or co-expressed with ubiquitin-specific proteases. Ubiquitin specific proteases are disclosed in U.S. 5,212,058; U.S. 5,683,904; U.S. 5,391,490; and U.S. 5,494,818.

Any natural and artificially produced caspase 4, caspase 5, or ubiquitin protease can be used in the present invention as long as they produce active polypeptides that induce IFN-γ production in immunocompetent cells independently of their structures, sources and origins.

In human cells, polypeptides formed by the expression of genes may be processed by intracellular enzymes. Intracellular enzymes cleave the precursor proteins, such as Pro-IL-18, into their active form. Polypeptides to be satisfactorily incorporated into pharmaceuticals should receive processing similar to the processing polypeptides receive in human cells. The polypeptides usually exist in human cells in the form of a precursor and no biological activity. It is known that most cytokines, including the IL-18 polypeptide, are usually produced as precursors with no biological activity, and then processed by intracellular enzymes to be converted into active polypeptides.

The precursor of IL-18 as referred to in the present invention exists, for example, in cells which inherently produce the polypeptide, in mammalian host cells, and in a bacterial system, such as *E. coli*, transformed by introducing a DNA, e.g., a DNA with the nucleotide sequence of SEQ ID NO:2, containing a region which encodes the polypeptide. Using such mammalian and bacterial host cells, precursor IL-18 can be co-expressed with proteases to generate active IL-18.

*In Vitro* Cleavage

The present invention provides methods for the *in vitro* activation of a precursor polypeptide, such as the precursor of IL-18 comprising, contacting the precursor polypeptide with an activating enzyme.

In a preferred embodiment, the present invention provides a method for the *in vitro* activation of precursor of human IL-18 comprising, contacting the precursor human IL-18 with caspase 4 or caspase 5.

In a preferred embodiment, the precursor of IL-18 is activated *in vitro* by cleaving with the activating enzyme which recognizes a specific protease activation motif comprising the amino acid sequence *X*E*Y*D, wherein *X* is selected from a group of amino acids consisting of W, L, F, Y, I, V, D or E ; and *Y* is selected from a group of amino acids consisting of of H, I, A, T, S, P or E.

In a further preferred embodiment, the precursor of IL-18 is activated *in vitro* by cleaving the peptide linkage between the aspartic acid 36 and tyrosine 37 in SEQ ID NO:1 with caspase 4 or caspase 5 to produce an active polypeptide that induces IFN-γ production in immunocompetent cells.

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Generally, caspase 4 or caspase 5 can be obtained from cells, which inherently produce it, and transformants obtained by applying recombinant DNA technology. Examples of such cells are those which were established from mammal and human cells such as epithelial cells, endothelial cells, interstitial cells, cartilage cells, monocytes, granulocytes, lymphocytes, and established cell lines thereof. Examples of the transformants include transformed microorganisms and animal cells obtained by introducing a DNA encoding caspase 5 into microorganisms and animal cells. Caspase 4 or caspase 5 is prepared by culturing these transformants in conventional culture media used in this field, either treating them with ultrasonics in the form of intact cultures or after separated from the cultures or soaking the transformants in hypotonic solvents, applying to the resulting cell debris or mixtures containing culture supernatants and cell debris the following conventional techniques used for purifying enzymes in this field; salting out, dialysis, filtration, concentration, separatory sedimentation, ion-exchange chromatography, gel filtration chromatography, adsorption chromatography, isoelectric chromatography, hydrophobic chromatography, reverse-phase chromatography, affinity chromatography gel electrophoresis and electrofocusing. Two or more of these purification methods can be used in combination. The DNA encoding caspase 4 (Fig. 5) (SEQ ID NO:5) and caspase 5 (Fig. 7) (SEQ ID NO:7) and transformants which produce caspase 4 and caspase 5 are known in the art. For example, the enzymes may be produced in active form in *E. coli* by expression of N-terminally truncated peptides lacking the pro region, as described (Munday NA et al., 1996, J. Biol. Chem 26:15870-76.)

Cells which produce the precursor polypeptide, such as Pro-IL-18, inherently or those which were transformed to produce the precursor are cultured in nutrient culture media. Preferred culture media include culture media well known in the art, such as Luria-Bertani medium or other rich medium for culturing *E. coli* comprising tryptone and yeast extract.

Caspase 4 or caspase 5, obtained using the above method, is allowed to coexist in the resulting cultures or added to the resulting mixtures or cell debris after disrupting the proliferated cells separated or unseparated from the cultures. The amount of caspase 4 or caspase 5 required is less than the equimolar of the precursor. The caspase 4 or caspase 5 is contacted with the precursor at temperatures and pHs, which allow the caspase 4 or caspase 5 to act on the precursor, usually, the caspase 4 or caspase 5 is allowed to react with the precursor until the desired amount of active polypeptide is formed from the material precursor at temperatures of about 4°-40° C and pHs of about 6-9. The preferred temperature is about 25°C and the preferred pH is about 7.2. Thus, reaction mixtures containing the active polypeptide can be obtained.

The activity of caspase 4 or caspase 5 may be assayed and expressed by units for activity according to the μg processed polypeptide produced per μg caspase 4 or caspase-5 per minute.

*In Vivo* Co-Expression

The present invention further provides methods for the *in vivo* activation of a precursor polypeptide, such as a precursor of IL-18 comprising co-expressing the protein with an activating protease. More specifically, the present invention provides methods for the *in vivo* activation of IL-18 comprising the bicistronic co-expression of polypetides, such as IL-18, with proteasese such as, caspase 4, also known as $ICE_{REL}II$, caspase 5, also known as $ICE_{REL}III$, and ubiquitin.

In a preferred embodiment, human caspase 4, also known as $ICE_{REL}II$, is co-expressed bicistronically with human Pro-IL-18 to allow for the *in vivo* processing of Pro-IL-18 into active IL-18.

In another preferred embodiment, truncated human caspase 4 (SEQ ID NO. 4), is co-expressed bicistronically with human Pro-IL-18 to allow for the *in vivo* processing of Pro-IL-18 (SEQ ID NO:1) into active IL-18 (SEQ ID NO:3).

In another preferred embodiment, human caspase 5, also known as $ICE_{REL}III$, is co-expressed bicistronically with human Pro-IL-18 to allow for the *in vivo* processing of Pro-IL-18 into active IL-18 (SEQ ID NO:3).

In yet another preferred embodiment, ubiquitin protease 1 (Ubp-1) is co-expressed bicistronically with Ubiquitin-IL-18 (Ubp-IL-18) for the *in vivo* processing of Ub-IL-18 into active IL-18.

In yet another preferred embodiment, ubiquitin protease 1 (Ubp-1) is co-expressed bicistronically with Ubiquitin-IL-18 (Ubp-IL-18) for the *in vivo* processing of UB-IL-18 (SEQ ID NO:9) into active IL-18 (SEQ ID NO. 3).

In the most preferred embodiment, truncated human caspase 5 (SEQ ID NO. 5), is co-expressed bicistronically with human Pro-IL-18 to allow for the *in vivo* processing of Pro-IL-18 (SEQ ID NO:1) into active IL-18 (SEQ ID NO:3).

A DNA encoding caspase 4 or caspase 5 and a DNA encoding a precursor of the polypeptide are both introduced into an appropriate bacterial or mammalian host cell to transform it. In this case, caspase 4 or caspase 5, formed by the DNA expression, acts on a precursor of the polypeptide, formed by the DNA expression in the same transformant, to form an active polypeptide (Figures 11 and 15). Preferred host cells are epidermal-, interstitial-, neuroblast-, hematopoietic-cell lines, which are derived from humans, monkeys,

mice and hamsters and used conventionally as hosts, such as 3T3 cells including 3T3-Swiss albino cells (ATCC CCL 92), C1271 cells (ATCC CRL 1616), CHO cells including CHO-K1 cells (ATCC CCL 61), CV-1 cells (ATCC CCL 70), COS cells including COS-1 cells (ATCC CCL 1650), HeLa cells (ATCC CCL 2), MOP cells including MOP-8 cells (ATCC CRL 1709) and mutants thereof. Most preferred host cells are *E. coli*. The most preferred method is of introducing DNA encoding caspase 4 or 5 and a DNA encoding a precursor of the polypeptide into *E. coli* is chemical transformation with rubidium chloride, which is well known in the art. Methods to introduce a DNA encoding caspase 4 or caspase 5 and a DNA encoding a precursor of the polypeptide into mammalian host cells include conventional DEAE-dextran method, phosphoric acid-calcium method, electroporation, lipofection, microinjection, and virus-infection method using retrovirus, Adenovirus, herpesvirus and vaccinia virus. In this case, vectors such as pCD, pcDL-SRα, pKY4, pCDM8, pCEV4, pME18S and pSV2-gpt, including appropriate promoters, enhancers, replication origins, termination sites, splicing sequences, polyadenylation sequences and/or selection markers can be used following standard techniques described in Ausubel FM et al., 1994 Current Protocols in Molecular Biology, New York: Greene Publishing Assoc. and Wiley Interscience. Clones, which were observed by immunological detection to produce an activated polypeptide, were selected by choosing the desired clone from transformants after culturing in nutrient culture media. Cultures containing the active polypeptide can be obtained by culturing the cloned transformant with conventional nutrient culture used in this field. As for cells which inherently produce a precursor of the polypeptide and other cells which were transformed to produce the polypeptide, they may produce the precursor along with activating enzymes, which activate the polypeptide, such as caspase 4, caspase 5, and ubiquitin. Recombinant DNA technologies using mammalian host cells are disclosed in detail in Glutzman, Cell, 23:175 (1981) Mullingan, PNAS78:2072 (1981). Recombinant DNA technologies using bacterial host cells are described in Protein Expression:A Practical Approach, S.J. Higgins and B.D. Hames eds. 1999, New York, Oxford University Press.

While the resulting reaction mixtures and cultures containing an active IL-18 polypeptide can be used intact as an IFN-γ inducer, in a preferred embodiment, cells in the cultures are disrupted by ultrasonics, cell lysis enzymes and/or surfactants, followed by separating the polypeptide from the resulting cells and cell debris by filtration, centrifugation, etc., following standard industry procedures described in Protein Purification:Principles and Practice, Cantor, C.R. ed. 1993, New York, Spinger-Verlag. The polypeptide free of cells and cell debris may be purified by conventional purification methods used to purify biologically active substances in this field, for example, salting out, dialysis, filtration, concentration, separatory sedimentation, ion-exchange chromatography,

gel filtration chromatography, adsorption chromatography, isoelectric chromatography, hydrophobic chromatography, reverse-phase chromatography, affinity chromatography, gel electrophoresis and electrofocusing. If necessary, two or more of these purification methods can be used in combination. The resulting purified polypeptide can be concentrated and lyophilized into a liquid or solid product to meet their final uses.

The bicistronic expression cassettes of the present invention are versatile vectors which can be used for the *in vivo* processing of virtually any peptide containing the appropriate caspase 4/caspase 5 or ubiquitinase cleavage recognition sites as have been previously described (Tobias, J.W. et al., *Journal of Biological Chemistry,* 1991. 266(18): p.12021.12028; Talanian, R.V. et al., *Journal of Biological Chemistry,* 1997. 272(15): p.9677-9682). Bicistronic expression offers advantages over other co-expression strategies because both genes are tied to the same transcription unit, ensuring consistent expression of both genes over time. This is in contrast to dual plasmid systems where one plasmid can be lost over time, or single plasmid dual promoter systems where expression may vary from each promoter from one experiment to the next. In particular, the bicistronic expression systems described here are ideally suited for the *in vivo* activation of enzymes, cytokines, growth factors, and other proteolytically activatable proteins, thereby enabling large-scale production of such proteins from cells in a single step and eliminating the need for a separate *in vitro* activation step.

Activating proteases, caspase 4 (Ala105 to Asn377) or caspase 5 (Ile146 to Asn418), were subcloned as N-terminal 6-His fusions immediately following the Pro-IL-18 sequence in order to generate a transcriptional fusion of the two genes. A T7 terminator sequence is located downstream of the caspase-4 sequence for translational termination of the bicistronic transcription unit. A small intergenic region including a defective Shine-Dalgarno sequence was also added to permit only minimal translation initiation from the caspase-4 sequence (Figures 10, and 14). Other regulatory regions include a 25 basepair lac operator sequence located immediately downstream of the 17 basepair promoter region which is bound by lac repressor encoded by a copy of the *lac-I* gene located on the plasmid, thereby suppressing basal transcription in the absence of T7 RNA polymerase. The resultant plasmids designated ProIL18/Casp4 and ProIL18/Casp5 were then separately transfected into *E. coli* BL21 (DE3) strain that contains an inducible chromosomal copy of the T7 polymerase gene.

The transcription of the bicistronic cassette is under the direction of the T7 promoter, which is controlled by the phage T7 RNA polymerase protein, encoded from a lysogenic copy of the T7 RNA polymerase gene. This chromosomal copy of T7 polymerase is itself under lacUV5 promoter control, inducible by the addition of isopropyl-1-thio-b-D-

galactopyranoside. Induction leads to the coordinate transcription and translation of Pro-IL-18 and His-caspase-4 or His-caspase-5. Nascently translated caspase-4 or caspase-5 is autoprocessed to an active species, which initiates the proteolytic activation ProIL-18. Both the translated precursor IL-18 as well as the post-translationally activated IL-18 are mainly soluble inside *E. coli*. Mature active IL-18 containing an N-terminal tyrosine is purified directly from bacterial cell lysates following induction by conventional chromatography methods. Cleavage to mature IL-18 with caspase-4 is complete by 4 hours at 37°C or by 18 hours at 29°C (Figure 11) and cleavage to mature IL-18 with caspase-5 is complete by 18 hours at 29°C (Figure 15).

In the most preferred embodiment, the present invention uses a truncated caspase 4, as shown in FIG. 4 (SEQ ID NO:4 and SEQ ID NO:5), or truncated caspase 5 as shown in FIG. 5 (SEQ ID NO: 6 and SEQ ID NO: 7). Truncation of caspase 4 and caspase 5 is disclosed in Munday, N.A., *et al.*, 1995, J. Biol. Chemistry, **270**, 15870-15876.

The present invention further provides a method for creating an active polypeptide by co-expression of a ubiquitin-specific protease with an N-terminal ubiquitin IL-18 fusion (precursor) which is converted to active IL-18 by the ubiquitin c-terminal hydrolase activity. A 76 amino acid ubiquitin protein containing an authentic N-terminal tyrosine is fused to the mature N-terminus of human IL-18 and coexpressed with a ubiquitin-specific protease in *E. coli* for example as shown in SEQ ID NO:10 and SEQ ID NO:11. Ubiquitin is a highly conserved 76-residue protein found in eucaryotic cells that function to mark proteins for degradation (Baker, R.T., Current Opinion in Biotechnology, 1996. 7(5): p. 541-6). Ubiquitin is specifically cleaved from proteins by the action of ubiquitin-specific proteases that are endogenously expressed in eucaryotic cells but which are absent in bacteria. The co-expression of ubiquitin fused proteins with ubiquitin-specific proteaese in E .coli also leads to the efficient removal of ubiquitin (Baker, R.T. et al., Journal of Biological Chemistry, 1992. 267(32): p. 23364-75) (Figure 20). In addition, most of these deubiquitinating enzymes are capable of cleaving in front of virtually any amino acid with the exception of proline. Thus, cleavage of ubiquitin from mature IL-18 is possible despite the presence of the large aromatic tyrosine residue in the P1' position.

The co-expression of Ubiquitin-IL-18 (Ub-IL-18) and Ubiquitin protease-1(Ubp-1) (Tobias, J.W. et al., *Journal of Biological Chemistry*, 1991. 266(18): p.12021.12028) is accomplished through the bicistronic expression of the two genes under inducible T7 promoter control. Mature IL-18 is expressed as an N-terminal fusion with the evolutionarily conserved 76 amino acid ubiquitin peptide. The Ub-IL-18 cDNA is subcloned under the control of the T7 RNA polymerase promoter within pET28a vector. Subsequently, the

cDNA encoding full-length ubiquitin-specific protease is subcloned downstream preceding the T7 terminator sequence (Figure 19). Both Ub-IL-18 and Ubiquitin-specific protease cDNA's are transcribed into a single mRNA transcript from which Ub-IL-18 and Ubiquitin-specific protease proteins are separately translated.

As described above, the active human IL-18 polypeptide, obtained by the present methods has an activity of inducing the production of IFN-γ as a useful biologically active substance, stimilates the production of IFNg from KG-1 (human myelomonocytic cell line) cells Figure 21 and purified human PBMCs (Figure 22).

All publications and patents are hereby incorporated by reference. The following examples further explain but do not limit the present invention:

EXAMPLE 1 - Preparation of precursor IL-18 (pro-IL-18)

Human-precursor IL-18 was expressed as an N-terminal hexa-histidine tagged fusion in *E. coli*. The expression plasmid, ProEx-hIL18, was derived from a vector, pPROEX-1 (Life Technologies) containing the Trc promoter and IacIq for inducible expression with isopropyl-1-thio-β-D-galactopyranoside (IPTG). In order to construct the recombinant expression vector, a DNA fragment containing the entire caspase 5 precursor gene was PCR amplified from a cDNA clone, tailing 5' with *Nde* I and 3' with *Bam* HI restriction endonuclease sites. The amplified product was subcloned between these two restriction sites in pPROEX-, thus generating an in frame N-terminal fusion with the hexa-histidine coding sequence present in the vector.

The resultant plasmid was expressed in DH10B host cells following induction with 1mM IPTG for 5 hours at 37°C. Recombinant protein was harvested from cell pellets obtained following centrifugation of the induced cultures.

EXAMPLE 2- Purification of pro-IL-18

1.5 kg of E coli cells expressing pro-IL-18 as described in EXAMPLE 1 was suspended in 3.6 L lysis Buffer C (50 mM Tris HCl, 10 mM BME, 0.5 M NaCl, 5 % glycerol, 1 ug/ml pepstatin A, 1 ug/ml leupepsin, 0.4 mM AEBSF), lysed by two passes through Microfluidics at 12,000 psi, centrifuged at 28,000 xg, and 3.7 L supernatant were collected. 600 ml of NiNTA agarose preequilibrated with Buffer C containing 5 mM imidazole (Buffer D) was added to the supernatant and incubated the slurry for one hour to capture pro-IL-18. The slurry was centrifuged at low speed (3,000 rpm), the supernatant was decanted, and the slurry was packed in a column. The column was washed with Buffer D and pro-IL-18 was eluted with 300 mM imidazole in Buffer C. The pool was dialyzed in Buffer E (25 mM

HEPES, 10 mM BME, pH 8.0) and applied to DEAE ToyoPearl 650M column equilibrated with the same buffer. The column was eluted with a linear gradient of 0 to 0.5 M NaCl in Buffer E. The pool contained 650 mg of >90 % pure pro-IL-18.

EXAMPLE 3 - Preparation of Caspase 4

Human caspase-4 was also expressed as an N-terminal Hexa-histindine tagged fusion in *E. coli*. The expression plasmid, pET16b-caspase 4, was derived from a vector pET16b (Novagen) containing the phage T7 promoter. The recombinant vector was constructed by PCR amplification of the caspase-4 active domain (amino acids Ile146 to Asn418) incorporating a hexa-histidine coding sequence at the N-terminus and tailing with *Nco* I and *Xho* I restriction endonuclease sites. The resultant PCR product was then subcloned between these two restriction sites to generate the N-terminal Hexa Histidine-Caspase 4 fusion vector.

The resultant plasmid was transformed into the lysogenic BL21 DE3 *E. coli* strain containing a chromosomal copy of T7 RNA polymerase under lacUV5 promoter control enabling inducible expression of caspase 4 following induction with 1mM IPTG. Active protein was purified from cell pellets isolated following induction at 37°C for 3 hours.

EXAMPLE 4 - Purification of Caspase 4

When *E. coli* cells expressing N-terminal hexa-His tagged human caspase 4 described in Example 2 are lysed, caspase 4 activity can be detected in the lysate supernatant. When the protein is captured on NiNTA agarose beads from the supernatant, both p10 and p20 are recovered. This indicates that caspase 4 protease domain is activated during cell culture through autocleavage at the junction of p10 and p20 and remains as a soluble noncovalent heterodimer. With this information, hexa-His tagged p20/p10 heterodimer can be purified. The entire process is carried out at 4°C to avoid any further breakdown of the molecule.

Approximately 400 g of *wet E. coli* cell pellet was suspended in 1.6 L of lysis buffer containing 25 mM HEPES, 0.1% CHAPS, 500 mM NaCl, 10 mM beta mercaptoethanol (BME) at pH 7.4, and 10% glycerol (Buffer A) and lysed by two passes through Microfluidics at 12,000 psi. The lysate was centrifuged at 30,000xg for one hour and lysate supernatant, 1.7 L, was recovered. NiNTA agarose, 150 ml, which was preequilibrated with lysis buffer containing 5 mM imidazole, was added to the lysate supernatant, the suspension was adjusted to pH 8.0 with 2 N NaOH, and caspase 4 was batch-absorbed for one hour. NiNTA agarose was packed in the column, washed with 5 mM and 25 mM imidazole in Buffer A sequentially to remove impurities, and caspase 5 was eluted with 300 mM imidazole in Buffer A. The protein was dialyzed against Buffer B (25 mM HEPES, 0.1% CHAPS, 10%

glycerol, 10mM BME, pH 8.0) and applied to DEAE ToyoPearl 650M column preequilibrated with the same buffer. Caspase 4 was eluted from the column with 100 mM NaCl in the same buffer. Fractions displaying highest specific activity of caspase 4 using fluorescent peptide substrate, LEED-AMC, were pooled.

EXAMPLE 5 - *In vitro* activation and preparation of polypeptide

Pro-IL-18 purified as described in Example 2 was incubated with Caspase 4 at 1:500 w/w ratio for 3 hours at room temperature. The cleavage reaction of prodomain was completed >90 % according to SDS-PAGE analysis. To the reaction mixture, 140 ml of NiNTA agarose in Buffer D was added, incubated for one hour, and poured to sintered glass funnel to recover unbound material containing mainly mature IL-18. Small amounts of remaining pro-IL-18, prodomain, caspase 4, and other impurities were bound to NINTA agarose. The unbound solution was adjusted to 25 mM DTT, incubated for one hour to complete reduction reaction, adjusted the pH of the solution to 6.0 by adding 2 M phosphoric acid, and concentrated to 86 ml using YM10 membrane. The concentrated sample was applied to Superdex 75 column equilibrated with 10mM NaPhosphate pH 6.0 containing 0.1M NaCl. Pooled fractions contained 560 mg of mature IL-18.

EXAMPLE 6 - *In vivo* activation and preparation of polypeptide

Activation of IL-18 can also be achieved *in vivo* through the simultaneous expression of human precursor IL-18 and caspase-4. Pro-IL-18 is co-expressed bicistronically in *E. coli* from a single transcript with human caspase-4 within the expression plasmid, pET28-Pro-IL-18/Casp4 (Figures 5 and 6). The human pro-IL-18 gene is subcloned into pET28a (Novagen) under the control of the T7 promoter including an efficient Shine-Dalgarno sequence for optimal translation initiation from the Pro-IL-18 sequence (Figure 8). The caspase 4 gene (Ile146 to Asn418) was subcloned immediately after the Pro-IL-18 sequence including a defective Shine-Dalgarno sequence, permitting minimal translation initiation from the caspase 4 sequence. A T7 terminator sequence was included for translational termination following the bicistronic transcription unit. The resultant construct was then transfected into a BL21(DE3) host containing an inducible chromosomal copy of the T7 polymerase gene. Induction of this construct in this host with 1mM IPTG resulted in the coordinate transcription and translation of pro-IL-18 and pro-caspase 4. Nascently translated pro-caspase 4 is autoprocessed to an active species which initiates the proteolytic activation of pro-IL-18. Figure 8 shows a time course of IL-18 activation over 18 hours at 29°C following 1mM IPTG induction (0-18 hours).

EXAMPLE 7 – *In vivo* activation of caspase 4

The *in vivo* activation of Caspase-4 is described in (Munday, N.A., *et al.*, 1995, J. Biol. Chemistry, 270, 15870-15876). Expression of a truncated form of caspase-4 beginning at Ala 59, lacking the proregion in *E. coli*, leads to self-activation by cleavage into P10 and P20 subunits which assemble into an active enzyme heterodimer. The delay in caspase –4 activation is translated into a delay in the cleavage and activation of Pro-IL-18 to mature IL-18 (Figure 9). This enables accumulation of the more stable Pro-IL-18 prior to its cleavage to mature IL-18 which is less stable in cells.

EXAMPLE 8 - Purification of human IL-18 coexpressed with Caspase 4

66 g of *E. coli* cells expressing IL-18 as described in Example 6 were suspended in 130 ml of 0.1 M HEPES pH 7.5 containing 1 mM EDTA and 10 mM DTT (entire process was performed at 4°C and in the presence of 10 mM DTT except the last step to maintain free SH) and lysed at 15,000 psi by two passes using Microfluidics. The lysate (230 ml) was centrifuged at 34,000 xg for 30 min. The supernatant (200 ml) was diluted to 1 L with 25 mM HEPES pH 7.0 and flowed through two columns in tandem, ToyoPearl SP 650M and ToyoPearl DEAE 650M. Much of the impurities derived from *E. coli* cells were bound to the columns. The flow-through material was adjusted to pH 9.5 with 25 mM bistris propane, diluted to 2 L and applied to Source 15Q column equilibrated with 25 mM bistris propane HCl pH 9.5. The column was eluted with a linear gradient of 0 to 0.5 M NaCl in the same buffer. Fractions containing IL-18 were identified using Vydac C4 RP-HPLC and pooled (250 ml). The pool was concentrated to 50 ml using YM10 membrane and applied to Superdex 75 column which was preequilibrated with 10 mM NaPO4 pH 6.0 containing 1 mM EDTA and 0.15 M NaCl (no DTT for *in vivo* use).

EXAMPLE 9 - Preparation of truncated caspase 5

Human truncated caspase 5 was also expressed as an N-terminal Hexa-histindine tagged fusion in *E. coli*. The expression plasmid, pET16b- truncated caspase 5, was derived from a vector pET16b (Novagen) containing the phage T7 promoter. The recombinant vector was constructed by PCR amplification of the truncated caspase 5 active domain (amino acids Ile146 to Asn418) incorporating a hexa-histidine coding sequence at the N-terminus and tailing with *Nco* I and *Xho* I restriction endonuclease sites. The resultant PCR product was then subcloned between these two restriction sites to generate the N-terminal Hexa Histidine- truncated caspase 5 fusion vector.

The resultant plasmid was transformed into the lysogenic BL21 DE3 *E. coli* strain containing a chromosomal copy of T7 RNA polymerase under lacUV5 promoter control enabling inducible expression of truncated caspase 5 following induction with 1mM IPTG. Active protein was purified from cell pellets isolated following induction at 37°C for 3 hours.

EXAMPLE 10 - Purification of truncated caspase 5

When *E. coli* cells expressing N-terminal hexa-His tagged human truncated caspase 5 described in EXAMPLE 9 are lysed, truncated caspase 5 activity can be detected in the lysate supernatant. When the protein is captured on NiNTA agarose beads from the supernatant, both p10 and p20 are recovered. This indicates that truncated caspase 5 protease domain is activated during cell culture through autocleavage at the junction of p10 and p20 and remains as a soluble noncovalent heterodimer. With this information, hexa-His tagged p20/p10 heterodimer can be purified. The entire process is carried out at 4°C to avoid any further breakdown of the molecule.

Approximately 400 g of *wet E. coli* cell pellet was suspended in 1.6 L of lysis buffer containing 25 mM HEPES, 0.1% CHAPS, 500 mM NaCl, 10 mM beta mercaptoethanol (BME) at pH 7.4, and 10% glycerol (Buffer A) and lysed by two passes through Microfluidics at 12,000 psi. The lysate was centrifuged at 30,000xg for one hour and lysate supernatant, 1.7 L, was recovered. NiNTA agarose, 150 ml, which was preequilibrated with lysis buffer containing 5 mM imidazole, was added to the lysate supernatant, the suspension was adjusted to pH 8.0 with 2 N NaOH, and caspase 5 was batch-absorbed for one hour. NiNTA agarose was packed in the column, washed with 5 mM and 25 mM imidazole in Buffer A sequentially to remove impurities, and caspase 5 was eluted with 300 mM imidazole in Buffer A. The protein was dialyzed against Buffer B (25 mM HEPES, 0.1% CHAPS, 10% glycerol, 10mM BME, pH 8.0) and applied to DEAE ToyoPearl 650M column preequilibrated with the same buffer. The truncated caspase 5 was eluted from the column with 100 mM NaCl in the same buffer. Fractions displaying highest specific activity of truncated caspase 5 using fluorescent peptide substrate, LEED-AMC, were pooled.

EXAMPLE 11 - *In vitro* activation and preparation of polypeptide

Pro-IL-18 prepared and purified as described in Examples 1 and 2 was incubated with truncated caspase 5 at 1:500 w/w ratio for 3 hours at room temperature. The cleavage reaction of prodomain was completed >90 % according to SDS-PAGE analysis. To the reaction mixture, 140 ml of NiNTA agarose in Buffer D was added, incubated for one hour, and poured to sintered glass funnel to recover unbound material containing mainly mature

IL-18. Small amounts of remaining pro-IL-18, prodomain, truncated caspase 5, and other impurities were bound to NINTA agarose. The unbound solution was adjusted to 25 mM DTT, incubated for one hour to complete reduction reaction, adjusted the pH of the solution to 6.0 by adding 2 M phosphoric acid, and concentrated to 86 ml using YM10 membrane. The concentrated sample was applied to Superdex 75 column equilibrated with 10mM NaPhosphate pH 6.0 containing 0.1M NaCl. Pooled fractions contained 560 mg of mature IL-18.

EXAMPLE 12 - *In vivo* activation and preparation of polypeptide

Activation of IL-18 can also be achieved *in vivo* through the simultaneous expression of human precursor IL-18 and truncated caspase 5. Pro-IL-18 was co-expressed bicistronically in *E. coli* from a single transcript with human truncated caspase 5 within the expression plasmid, pET28-ProIL18/Casp5 (Figure 9). The human pro-IL-18 gene is subcloned into pET28a (Novagen) under the control of the T7 promoter including an efficient Shine-Dalgarno sequence for optimal translation initiation from the Pro-IL-18 sequence (Figure 10). The truncated caspase 5 gene (Ile146 to Asn418) was subcloned immediately after the Pro-IL-18 sequence including a defective Shine-Dalgarno sequence, permitting minimal translation initiation from the truncated caspase 5 sequence. A T7 terminator sequence was included for translational termination following the bicistronic transcription unit. The resultant construct was then transfected into a BL21(DE3) host containing an inducible chromosomal copy of the T7 polymerase gene. Induction of this construct in this host with 1mM IPTG resulted in the coordinate transcription and translation of pro-IL-18 and pro-caspase 5. Nascently translated pro-caspase 5 is autoprocessed to an active species which initiates the proteolytic activation of pro-IL-18.

EXAMPLE 13 - Purification of human IL-18 coexpressed with truncated caspase 5

66 g of *E. coli* cells expressing IL-18 as described in Example 12 were suspended in 130 ml of 0.1 M HEPES pH 7.5 containing 1 mM EDTA and 10 mM DTT (entire process was performed at 4°C and in the presence of 10 mM DTT except the last step to maintain free SH) and lysed at 15,000 psi by two passes using Microfluidics. The lysate (230 ml) was centrifuged at 34,000 xg for 30 min. The supernatant (200 ml) was diluted to 1 L with 25 mM HEPES pH 7.0 and flowed through two columns in tandem, ToyoPearl SP 650M and ToyoPearl DEAE 650M. Much of the impurities derived from *E. coli* cells were bound to the columns. The flow-through material was adjusted to pH 9.5 with 25 mM bistris propane, diluted to 2 L and applied to Source 15Q column equilibrated with 25 mM bistris propane HCl pH 9.5. The column was eluted with a linear gradient of 0 to 0.5 M NaCl in

the same buffer. Fractions containing IL-18 were identified using Vydac C4 RP-HPLC and pooled (250 ml). The pool was concentrated to 50 ml using YM10 membrane and applied to Superdex 75 column which was preequilibrated with 10 mM NaPO4 pH 6.0 containing 1 mM EDTA and 0.15 M NaCl (no DTT for *in vivo* use).

EXAMPLE 14 - Preparation of Ubiquitin/Pro-IL-18/Ubp1

The 76 amino acid ubiquitin coding sequence is fused in frame with the start of mature human IL-18 through blunt end ligation such that the first tyrosine codon of mature IL-18 immediately follows the glycine 76 codon of ubiquitin. The gene fusion is then subcloned into a pET vector under the control of the T7 promoter including an efficient Shine-Dalgarno sequence for optimal translation initiation from the ubiquitin-IL-18 gene sequence. The full-length Ubp-1 gene is then subcloned immediately following IL-18 including a defective Shine-Dalgarno sequence for minimal translation of Ubp-1. Fig. 11 depicts the sequence of UbIL-18/Ubp-1 expression cassette within pET28. Fig. 13 depicts the annotated sequence of UbIL-18/Ubp-1 within pET28. Numbering corresponds to the position within pET28.

EXAMPLE 15 - *In vivo* activation and preparation of IL-18

The construct of Example 14 was then transfected into a BL21(DE3) host. Induction with 1mM IPTG resulted in the coordinate transcription and translation of Ubiquitin-IL-18 and Ubp-1. The enzymatic action of Ubp-1 led to the efficient processing of Ub-IL-18 to mature active IL-18 which can then be directly purified from *E. coli* lysates by conventional methods. Figure 16 illustrates the time course of IL-18 expression and processing at 30°C and 37°C following induction with 1 mM IPTG. The top arrow indicates the portion of unprocessed UB-IL-18 in Lane 1. Bottom arrow indicates the portion of processed IL-18 in Lane 3. (Western blot detection using anti-IL-18 antisera.)

EXAMPLE 16 - Purification of human IL-18 coexpressed with Ubiquitin

66 g of *E. coli* cells expressing IL-18 as described in Example 15 were suspended in 130 ml of 0.1 M HEPES pH 7.5 containing 1 mM EDTA and 10 mM DTT (entire process was performed at 4°C and in the presence of 10 mM DTT except the last step to maintain free SH) and lysed at 15,000 psi by two passes using Microfluidics. The lysate (230 ml) was centrifuged at 34,000 xg for 30 min. The supernatant (200 ml) was diluted to 1 L with 25 mM HEPES pH 7.0 and flowed through two columns in tandem, ToyoPearl SP 650M and ToyoPearl DEAE 650M. Much of the impurities derived from *E. coli* cells were bound to the columns. The flow-through material was adjusted to pH 9.5 with 25 mM bistris

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propane, diluted to 2 L and applied to Source 15Q column equilibrated with 25 mM bistris propane HCl pH 9.5. The column was eluted with a linear gradient of 0 to 0.5 M NaCl in the same buffer. Fractions containing IL-18 were identified using Vydac C4 RP-HPLC and pooled (250 ml). The pool was concentrated to 50 ml using YM10 membrane and applied to Superdex 75 column which was preequilibrated with 10 mM NaPO4 pH 6.0 containing 1 mM EDTA and 0.15 M NaCl (no DTT for *in vivo* use).

While there has been described what is at present considered to be the preferred embodiments of the invention, it will be understood the various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

We claim:

1. A method for producing an active IL-18 polypeptide from a precursor IL-18 polypeptide, comprising:

(i) containing caspase 4 with a precursor IL-18 polypeptide; and

(ii) purifying the active IL-18 polypeptide.

2. A method for producing an active IL-18 polypeptide from a precursor IL-18 polypeptide, comprising:

(i) containing caspase 5 with the precursor IL-18 polypeptide; and

(ii) purifying the active IL-18 polypeptide.

3. The method of claim 1 wherein the precursor IL-18 polypeptide is a human Il-18 polypeptide.

4. The method of claim 2 wherein the precursor IL-18 polypeptide is a human Il-18 polypeptide.

5. A method for producing an active human IL-18 polypeptide comprising:

(i) contacting caspase 4 with a human precursor IL-18 polypeptide to convert said precursor polypeptide into the active human IL-18 polypeptide, said precursor IL-18 polypeptide comprising the amino acid sequence of SEQ ID NO:1, or a portion thereof, which maintains the aspartic acid 36 and tyrosine 37 residues in the amino sequence of SEQ ID NO:1 as an N-terminal sequence; and

(ii) purifying the active human IL-18 polypeptide.

6. A method for producing an active human IL-18 polypeptide comprising:

(i) contacting caspase 5 with a human precursor IL-18 polypeptide to convert said precursor polypeptide into the active human IL-18 polypeptide, said precursor IL-18 polypeptide comprising the amino acid sequence of SEQ ID NO:1, or a portion thereof, which maintains the aspartic acid 36 and tyrosine 37 residues in the amino sequence of SEQ ID NO:1 as an N-terminal sequence; and

(ii) purifying the active IL-18 polypeptide.

7. The method for producing an active human IL-18 polypeptide of claim 5, wherein the active human IL-18 polypeptide is a polypeptide having the amino acid sequence of SEQ ID NO:3.

8. The method for producing an active human IL-18 polypeptide of claim 6, wherein the active human IL-18 polypeptide is a polypeptide having the amino acid sequence of SEQ ID NO:3.

9. A method for producing an active polypeptide from a precursor polypeptide, comprising:

(i) co-expressing bicistronically caspase 4 with the precursor polypeptide; and

(ii) purifying the active polypeptide.

10. A method for producing an active polypeptide from a precursor polypeptide, comprising:

(i) co-expressing bicistronically caspase 5 with the prescursor polypeptide; and

(ii) purifying the active polypeptide.

11. A method for producing active IL-18 polypeptide from a precursor IL-18 polypeptide, comprising:

(i) co-expressing bicistronically ubiquitinase with a ubiquitin/IL-18 fusion; and

(ii) purifying the active IL-18 polypeptide.

12. A method for producing an active IL-18 polypeptide from a precursor polypeptide, comprising:

(i) co-expressing bicistronically caspase 4 with the precursor IL-18 polypeptide; and

(ii) purifying the active IL-18 polypeptide.

13. A method for producing an active IL-18 polypeptide from a precursor IL-18 polypeptide, comprising:

(i) co-expressing bicistronically caspase 5 with the precursor IL-18 polypeptide; and

(ii) purifying the active IL-18 polypeptide.

14. The method of claim 11, wherein the precursor IL-18 polypeptide is a human precursor IL-18 polypeptide.

15. The method of claim 12, wherein the precursor IL-18 polypeptide is a human precursor IL-18 polypeptide.

16. The method of claim 13, wherein the precursor IL-18 polypeptide is a human precursor IL-18 polypeptide.

17. The method claim 14, wherein the active human IL-18 polypeptide is a polypeptide having the amino acid sequence of SEQ ID NO:3.

18. The method claim 15, wherein the active human IL-18 polypeptide is a polypeptide having the amino acid sequence of SEQ ID NO:3.

19. The method claim 16, wherein the active human IL-18 polypeptide is a polypeptide having the amino acid sequence of SEQ ID NO:3.

20. A method for producing active human IL-18 polypeptide from precursor human IL-18 polypeptide, comprising:

(i) co-expressing bicistronically ubiquitinase with a ubiquitin/IL-18 having the amino acid sequence of SEQ ID NO:10; and

(ii) purifying the active human IL-18 polypeptide.

21. A method for producing an active human IL-18 polypeptide from a human precursor IL-18 polypeptide, comprising:

(i) co-expressing bicistronically caspase 4, having the amino acid sequence of SEQ ID NO:4, with the human precursor IL-18 polypeptide; and

(ii) purifying the active IL-18 polypeptide.

22. A method for producing an active human IL-18 polypeptide from a human precursor IL-18 polypeptide, comprising:

(i) co-expressing bicistronically caspase 5, having the amino acid sequence of SEQ ID NO:6, with the human precursor IL-18 polypeptide; and

(ii) purifying the active IL-18 polypeptide.