INTERLEUKIN-18 BINDING PROTEINS, THEIR PREPARATION AND USE

Field of the Invention

The present invention relates to interleukin-18 (IL-18) binding protein, hereinafter IL-18BP, capable of binding IL-18. More particularly, this invention relates to a soluble IL-18BP obtainable from body fluids, to soluble IL-18BPs obtainable by expression of suitable DNA vectors in host cells, to virus-encoded homologues of IL-18BP obtainable by expression of suitable DNA vectors in host cells, to vectors expressing the various IL-18BPs, to vectors useful for expression of IL-18BP in humans and other mammals, to antibodies against IL-18BPs, to therapeutic use of said IL-18BPs by modulating and/or blocking IL-18 activity, to therapeutic use of said expression vectors in modulating and/or blocking IL-18 activity and to use of the antibodies.

Background of the Invention

In 1989, an endotoxin-induced serum activity that induced interferon-γ (IFN-γ) obtained from mouse spleen cells was described (27). This serum activity functioned not as a direct inducer of IFN-γ but rather as a co-stimulant together with IL-2 or mitogens. An attempt to purify the activity from post-endotoxin mouse serum revealed an apparently homogeneous 50-55 kDa protein (26). Since other cytokines can act as co-stimulants for IFN-γ production, the failure of neutralizing antibodies to IL-1, IL-4, IL-5, IL-6, or TNF to neutralize the serum activity suggested it was a distinct factor. In 1995, the same scientists demonstrated that the endotoxin-induced co-stimulant for IFN-γ production was present in extracts of livers from mice preconditioned with P. acnes (31). In this model, the hepatic macrophage population (Kupffer cells) expand and in these mice, a low dose of bacterial lipopolysaccharide (LPS), which in non-preconditioned mice is not lethal, becomes lethal. The factor, named IFN-γ -inducing factor (IGIF) and later designated interleukin-18 (IL-18), was purified to homogeneity from 1,200 grams of P. acnes-treated mouse livers. Degenerate oligonucleotides derived from amino acid sequences of purified IL-18 were used to clone a

murine IL-18 cDNA (31). IL-18 is an 18-19 kDa protein of 157 amino acids, which has no obvious similarities to any peptide in the databases. Messenger RNAs for IL-18 and interleukin-12 (IL-12) are readily detected in Kupffer cells and activated macrophages. Recombinant IL-18 induces IFN-gamma more potently than does IL-12, apparently through a separate pathway (31). Similar to the endotoxin-induced serum activity, IL-18 does not induce IFN-γ by itself, but functions primarily as a co-stimulant with mitogens or IL-2. IL-18 enhances T cell proliferation, apparently through an IL-2-dependent pathway, and enhances Th1 cytokine production *in vitro* and exhibits synergism when combined with IL-12 in terms of enhanced IFN-γ production (24).

Neutralizing antibodies to mouse IL-18 were shown to prevent the lethality of low-dose LPS in P. acnes pre-conditioned mice. Others had reported the importance of IFN-γ as a mediator of LPS lethality in pre-conditioned mice. For example, neutralizing anti-IFN-γ antibodies protected mice against Shwartzman-like shock (16), and galactosamine-treated mice deficient in the IFN-γ receptor were resistant to LPS-induced death (7). Hence, it was not unexpected that neutralizing antibodies to murine IL-18 protected P. acnes-preconditioned mice against lethal LPS (31). Anti-murine IL-18 treatment also protected surviving mice against severe hepatic cytotoxicity.

After the murine form was cloned, the human cDNA sequence for IL-18 was reported in 1996 (38). Recombinant human IL-18 exhibits natural IL-18 activity (38). Human recombinant IL-18 is without direct IFN-γ-inducing activity on human T-cells, but acts as a co-stimulant for production of IFN-γ and other T-helper cell-1 (Th1) cytokines (38). To date, IL-18 is thought of primarily as a co-stimulant for Th1 cytokine production (IFN-γ, IL-2 and granulocyte-macrophage colony stimulating factor) (20) and also as a co-stimulant for FAS ligand-mediated cytotoxicity of murine natural killer cell clones (37).

By cloning IL-18 from affected tissues and studying IL-18 gene expression, a close association of this cytokine with an autoimmune disease was found. The non-obese diabetic (NOD) mouse spontaneously develops autoimmune insulitis and diabetes, which can be accelerated and synchronized by a single injection of cyclophosphamide. IL-18 mRNA was demonstrated by reverse transcriptase PCR in NOD mouse pancreas during early stages of insulitis. Levels of IL-18 mRNA increased rapidly after cyclophosphamide treatment and

preceded a rise in IFN-γ mRNA, and subsequently diabetes. Interestingly, these kinetics mimic that of IL-12-p40 mRNA, resulting in a close correlation of individual mRNA levels. Cloning of the IL-18 cDNA from pancreas RNA followed by sequencing revealed identity with the IL-18 sequence cloned from Kupffer cells and in vivo pre-activated macrophages. Also NOD mouse macrophages responded to cyclophosphamide with IL-18 gene expression while macrophages from Balb/c mice treated in parallel did not. Therefore, IL-18 expression is abnormally regulated in autoimmune NOD mice and closely associated with diabetes development (32).

IL-18 plays a potential role in immunoregulation or in inflammation by augmenting the functional activity of Fas ligand on Th1 cells (10). IL-18 is also expressed in the adrenal cortex and therefore might be a secreted neuro-immunomodulator, playing an important role in orchestrating the immune system following a stressful experience (9).

In vivo, IL-18 is formed by cleavage of pro-IL-18, and its endogenous activity appears to account for IFN-γ production in P. acnes and LPS-mediated lethality. Because of its activity, blocking the biological activity of IL-18 in human disease is a therapeutic strategy in many diseases. This can be accomplished using soluble receptors or blocking antibodies to the cell-bound IL-18 receptor.

Cytokine binding proteins (soluble cytokine receptors) correspond to the extracellular ligand binding domains of their respective cell surface cytokine receptors. They are derived either by alternative splicing of a pre-mRNA, common to the cell surface receptor, or by proteolytic cleavage of the cell surface receptor. Such soluble receptors have been described in the past, including among others, the soluble receptors of IL-6 and IFN-γ (30), TNF (11, 12), IL-1 and IL-4 (21), IFN-α/β (28, 29) and others. One cytokine-binding protein, named osteoprotegerin (OPG, also known as osteoclast inhibitory factor - OCIF), a member of the TNFR/Fas family, appears to be the first example of a soluble receptor that exists only as a secreted protein (1, 34, 39).

Summary of the Invention

The present invention provides IL-18 binding proteins (IL-18BPs) and virally encoded IL-18BP homologues (hereinafter, viral IL-18BPs), and fused proteins, muteins, functional derivatives, active fragments and circularly permutated derivatives thereof,

capable of binding to IL-18. The invention also provides a process for isolating IL-18BPs from human fluids, and a process to obtain them by recombinant means.The invention also provides expression vectors of IL-18BPs, suitable for expression of IL-18BP in humans and other mammals. Specific IL-18BPs, virally encoded IL-18BP homologues, fused proteins, muteins, functional derivatives, active fragments and circularly permutated derivatives thereof of the present invention are useful for modulating and/or blocking the biological activities of IL-18.

Replicable expression vehicles containing DNAs suitable for expression of the various IL-18BPs in host cells, host cells transformed herewith and proteins and polypeptides produced by expression of such hosts are also provided.

The invention further provides pharmaceutical compositions consisting of suitable vehicles and IL-18BPs, or viral IL-18BPs, or vectors for expressing same in humans and other mammals, for the treatment of diseases or conditions which require modulation or blocking of IL-18 activity.

The invention further provides antibodies to the IL-18BPs and the viral IL-18BPs, suitable for affinity purification and immunoassays of same.

Description of the Figures

Figure 1 shows SDS-PAGE (sodium dodecyl sulfate polyacrylamide gel electrophoresis) of ligand affinity purified IL-18 binding protein. Crude urinary proteins (concentrated by ultrafiltration of 500 L normal human urine) were loaded on an IL-18-agarose column. The column was washed and bound proteins eluted at pH 2.2. Eluted fractions were neutralized and aliquots were analyzed by SDS-PAGE (10% acrylamide) under non-reducing conditions and silver staining. The lanes are: 1: crude urinary proteins (1.5 μg, loaded on the gel); 2-9: elutions 1-8, respectively, from the IL-18-agarose column; 10: molecular weight markers, in kD, as indicated on the right side. An arrow indicates the band corresponding to IL-18BP.

Figure 2 shows an autoradiogram of SDS-PAGE (7.5 % acrylamide) of complexes consisting of ^{125}I-IL-18 (apparent molecular weight 19 kD), cross-linked to the following

preparations of soluble IL-18 binding protein: Lane 1: Wash of the IL-18 affinity column. Lane 2: Elution 2 of the IL-18 affinity column. Lane 3: Elution 3 of the IL-18 affinity column. Molecular weight markers are indicated on the right side (in kD). An arrow indicates the cross-linked product (58 kD).

Figure 3 shows inhibition of IL-18-induced production of IFN-γ by IL-18BP
(A) Mouse splenocytes were stimulated (24 hr, 37°C) with the indicated combinations of LPS (1 μg/ml) and human IL-18 (5 ng/ml), added either directly, or after pre-mixing (1 h, 37°C) with urinary IL-18BP. The level of muIFN-γ in the culture was determined after 24 hr.
(B) Mouse splenocytes were incubated (24 h) with LPS (1 μg/ml) together with murine IL-18 (10 ng/ml) pre-mixed (1 h, 37°C) with increasing concentrations of human IL-18BP.
(C) Mouse splenocytes were incubated (24 h) with LPS (10 μg/ml) together with increasing concentrations of human IL-18BP.
(D) Mouse splenocytes were incubated (24 h) with Con A (1 μg/ml), together with increasing concentrations of human IL-18BP.
(E) Human KG-1 cells were stimulated with TNF-α (20 ng/ml) and huIL-18 (25 ng/ml), added either alone, or after pre-mixing (1 h, 37°C) with urinary IL-18BP.

Figure 4 shows the sequence of human IL-18BPa cDNA and protein. The signal peptide is underlined.

Figure 5 shows the sequence of human IL-18BPb cDNA and protein. The signal peptide is underlined.

Figure 6 shows the sequence of human IL-18BPc cDNA and protein. The signal peptide is underlined.

Figure 7 shows the sequence of human IL-18BPd cDNA and protein. The signal peptide is underlined.

Figure 8 shows the sequence of human IL-18BP gene. The sequence of a human genomic clone (7.1 kb) was determined and compared with that of the various cDNA clones isolated from 3 cDNA libraries. the common translation start codon is nucleotides 683-685. The NuMA1 gene is located on the negative strand, from nucleotide 3578 to the end.

Figure 9 shows the effect of recombinant IL-18BP on human and mouse IL-18 activity.

His_6-tagged IL-18BPa was transiently expressed in COS7 cells and purified.

(A) Human IL-18 (5 ng/ml) was pre-mixed with either His_6-tagged-IL-18BPa or RPMI and added to mouse spleen cells together with LPS (1 μg/ml). IFN-γ production was measured after 24 h.

(B) Mouse IL-18 (10 ng/ml) was pre-mixed with either His_6-tagged-IL-18BPa or RPMI and added to mouse spleen cells together with LPS (1 μg/ml). IFN-γ production was measured after 24 h.

(C) Human IL-18 (25 ng/ml) was pre-mixed with either COS7-IL-18BPa or RPMI and added to Human PBMC in the presence of IL-12 (10 ng/ml).

(D) Human IL-18 (25 ng/ml) was pre-mixed with either COS7-IL-18BPa or RPMI and added to Human KG-1 cells in the presence of TNF-α (20 ng/ml).

Detailed Description of the Invention

The present invention relates to various IL-18BPs and viral IL-18BPs which bind to IL-18. Such IL-18BPs may be capable of modulating and/or blocking the biological activities of IL-18. The term, "IL-18BPs and viral IL-18BPs," includes the mature protein (without the signal sequence), the protein comprising signal sequences, muteins of IL-18BPs and viral IL-18BPs, derivatives of IL-18BPs and viral IL-18BPs and truncated forms of IL-18BPs and viral IL-18BPs and salts thereof.

The invention further relates to replicable expression vehicles, suitable for expression of various IL-18BPs or viral IL-18BPs in host cells and host bacteria. The invention further relates to expression vectors, suitable for expression of various IL-18BPs or viral IL-18BPs in humans and in other mammals.

The invention further relates to DNAs coding for various IL-18BPs, viral IL-18BPs, muteins, fused proteins, functional derivatives, active fractions and mixtures thereof. Said DNA may be a genomic DNA, a cDNA, a synthetic DNA, a PCR product or combinations thereof. These DNAs may be inserted into replicable expression vehicles for expression of various IL-18BPs and viral IL-18BPs in host cells, according to the invention. DNAs capable of hybridizing to the above DNAs under stringent conditions and encoding proteins or polypeptides which are also capable of binding IL-18 are also included in the present invention.

One such DNA encodes an IL-18BP including the amino acid sequence of SEQ ID NO:10 and provided with a stop codon at its 3' end.

The expression vectors, suitable for expression of various IL-18BPs or viral IL-18BPs in humans and in other mammals, i.e. for gene therapy, may be viral vectors or other types of vectors in which an IL-18BP gene or an IL-18BP cDNA or a DNA encoding a viral IL-18BP was inserted in a way that enables efficient expression of an IL-18BP or a viral IL-18BP in humans and other mammals. DNA molecules hybridizing to the above DNAs under stringent conditions and encoding proteins or polypeptides which are capable of binding IL-18, are also included in the present invention.

Isolation of IL-18BP may be carried out in accordance with the invention, *e.g.* by passing a human fluid, such as urine or serum, through a chromatographic column to which IL-18 is coupled, and thereafter, eluting the bound IL-18BP.

The various IL-18BPs and viral IL-18BPs can also be prepared by recombinant means, *i.e.* by expressing IL-18BP in a suitable host, after operatively linking promoters, expression enhancers, regulatory sequences, etc., suitable for the particular host employed which e.g. allow expression in the correct orientation.

The various IL-18BPs and viral IL-18BPs and vectors for expressing IL-18Bp in humans and other mammals may be employed in the treatment and alleviation of conditions in which IL-18 is involved or caused by an excess of exogenously administered or endogenously produced IL-18. Such conditions are, e.g., autoimmune diseases, type I diabetes, rheumatoid arthritis, graft rejections, inflammatory bowel disease, sepsis, multiple sclerosis, ischemic heart diseases (including heart attacks), ischemic brain injury, chronic hepatitis, psoriasis, chronic pancreatitis, acute pancreatitis and the like.

According to the present invention, IL-18BP was isolated from normal human urine by one chromatographic step. A preparation of crude human urinary proteins concentrated from 500l of normal human urine was loaded on a column consisting of human IL-18 bound to agarose. The column was washed and bound proteins were eluted at low pH. Eluted fractions were neutralized and aliquots were analyzed by SDS-PAGE (10% acrylamide) under non-reducing conditions and silver staining. A protein band of ~40 kD was specifically obtained in the eluted fractions (Fig. 1).

The ~40 kD protein obtained in the first step was identified as an IL-18 binding protein by its ability to specifically cross-link with ^{125}I-IL-18 (Fig. 2). The ~40 kD protein was further characterized by N-terminal protein sequence analysis. Aliquots from the eluted protein were subjected to SDS-PAGE, electroblotted to a PVDF membrane and subjected to protein microsequence analysis. Similarly, aliquots from the eluted protein were subjected to direct protein microsequence analysis. In both cases, two polypeptide sequences were obtained. A major sequence and a minor sequence, the latter corresponding to a fragment of human defensin (accession number p11398), starting at amino acid 65. Subtraction of the known defensin sequence provided the following sequence:

T-P-V-S-Q-Q-x-x-x-A-A-A

1 . . . 5 . . . .10 . .

wherein x represents a yet undetermined amino acid.

In order to obtain a longer and more accurate sequence and in order to identify potential cysteine residues, an aliquot of the eluted fraction was reduced with DTT under denaturing conditions, reacted with 4-vinyl pyridine, desalted by a micro-ultrafiltration device (Ultrafree, cutoff 10,000 Da, Millipore) and subjected to protein microsequence analysis. After sequencing cycle No. 1 the residual protein was reacted with o-phtalaldehyde to block all N-terminal polypeptides other than Pro and sequencing was then resumed. In this way the following single protein sequence was obtained:

TPVSQXXXAA XASVRSTKDP CPSQPPVFPA AKQCPALEVT

1 10 20 30 40

(T=Thr; P=Pro; V=Val; S=Ser; Q=Gln; X=Unknown; A=Ala; R=Arg; K=Lys; D=Asp; C=Cys; F=Phe; L=Leu; E=Glu)

The resulting sequence is significantly different from that of any other known protein, as determined by searching protein databases. However, searching the database of The Institute of Genomic Research (TIGR) (HTTP://www.ncbi.nlm.nih.gov) by the tblastn search program provided a cDNA file, denoted THC123801, whose open reading frame (218 codons), when translated, contains a sequence highly homologous to that of the N-terminal sequence of IL-18BP. The homology is hereby shown:

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1 .......TPVSQXXXAAXASVRSTKDPCPSQPPVFPAAKQCPALEVT... 40
             | | |   ||||||||||||||||||||||||||||||||
  51 VTLLVRATXVXQTTTAATASVRSTKDPCPSQPPVFPAAKQCPALEVTWPE 100
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(The upper sequence (1-40) is that of the IL-18BP isolated according to the invention; the lower sequence (51-100) is deduced by translation of the cDNA of TIGR file THC123801).

The cDNA sequence identified as THC123801 is, however, only an EST (expressed sequence tag), i.e. a randomly selected cDNA clone. It has never been analyzed whether this EST contains an open reading frame, whether a protein is expressed from the gene corresponding to the EST or from the EST itself, nor has any function of a protein encoded by THC123801 ever been identified. No information was available at all that THC123801 contains an open reading frame coding for an IL-18BP.

The affinity-purified urinary IL-18BP retained the ability to bind its labeled ligand (^{125}I-IL-18), and following covalent cross-linking, a complex of molecular weight 58 kD was formed. The molecular weight of this complex corresponded to a 1:1 ratio of the ~40 kD IL-18BP and the 19 kD IL-18 (Fig. 2).

The affinity-purified urinary IL-18BP blocked the biological activity of human as well as mouse IL-18. Thus when IL-18BP was added to either human or mouse IL-18 it blocked the ability of IL-18 to induce the production of interferon-γ when added together with lipopolysaccharide (LPS) to cultures of mouse spleen cells (Fig. 3).

For the purpose of the present description the expression "biological activity of IL-18" refers inter alia to at least one of the following biological properties :

(i) induction of IFN-γ, primarily as a co-stimulant with mitogens, IL-1, IL-12, TNF-α, LPS in various cell types, such as mononuclear cells, murine

splenocytes, human peripheral blood mononuclear cells, the human KG-1 cell line and T-cells,

(ii) enhancement of T-cell proliferation,

(iii) enhancement of Th-1 cytokine production *in vitro*, primarily as a co-stimulant,

(iv) synergism with IL-12 in terms of enhanced IFN-γ production, co-stimulatory action for production of IFN-γ and other T-helper cell-1 cytokines,

(v) co-stimulatory action for FAS ligand-mediated cytotoxicity of murine natural killer cell clones,

(vi) induction of the activation of NF-κB in human KG-1 cells, probably by inducing the formation of the 50 NF-κB homodimer and the p65/p50 NF-κB heterodimer,

(vii) induction of IL-8.

As used herein, the expression "binding to IL-18" means the capability of IL-18BP to bind IL-18, e.g. as evidenced by its binding to labeled IL-18 when affinity purified as in Example 2 herein.

As used herein, the expression "modulating the activity of IL-18" means the capability of IL-18BP to modulate any IL-18 activity other than blocking, e.g. partial inhibition, enhancement, or the like.

As used herein, the expression "blocking the activity of IL-18" refers to the activity of IL-18BP to block at least one of the above exemplified biological activities of IL-18. The IL-18 blocking activity of IL-18BP is exemplified by the ability of IL-18BP to block the IL-18 associated IFN-γ expression in murine splenocytes. As it will be shown below in more detail, the modulating or blocking activity of IL-18BP is in part due to the fact that IL-18BP inhibits the activation of NF-κB by IL-18. Furthermore, IL-18BP blocks at least one of the following activities of IL-18, namely induction of IFN-γ in human and mouse cells, induction of IL-8 and activation of NF-κB.

A DNA probe for screening cDNA libraries was prepared by reverse-transcription PCR with specific sense and antisense primers and RNA from the human Jurkat T cells with primers from the TIGR sequence. The resulting PCR product was confirmed by DNA

sequence analysis. This PCR product was labeled with ^{32}[P] and used as a probe for screening of four human cDNA libraries, derived from peripheral blood monocytes, from the Jurkat T-cell line, from PBMC and from human spleen. The various independent cDNA clones corresponded to four IL-18BP splice variants (SEQ ID NO:1, 3, 5 and 7). All splice variants coded for putative soluble secreted proteins. The most abundant one (IL-18BPa) had an open reading frame of 192 codons, coding for a signal peptide herein sometimes referred to as a "leader sequence" of 28 amino acid residues followed by a mature putative IL-18BPa, whose first 40 residues matched perfectly with the N-terminal protein sequence of the urinary IL-18BP (SEQ ID NO:2). The position of the cysteine residues suggested that this polypeptide belongs to the immunoglobulin (Ig) super-family. Interestingly, each of the four Gln residues within mature IL-18BPa was a potential N-glycosylation site. The three other variants of IL-18BP were less abundant than IL-18BPa. They included a shorter 1 kb IL-18BPb cDNA, coding for a signal peptide of 28 amino acid residues followed by a mature protein of 85 amino acid residues (SEQ ID NO:4). A third variant, IL-18BPc was represented by a 2.3 kb cDNA, coding for a signal peptide of 28 amino acid residues followed by a mature IL-18BP of 169 amino acid residues (SEQ ID NO:6). The fourth variant, IL-18BPd, coded for a signal peptide of 28 amino acid residues followed by a mature IL-18BP of 133 amino acid residues (SEQ ID NO:8).

To further study the possible existence of additional IL-18BP splice variants, a human genomic library was screened with a probe corresponding to full length IL-18BP cDNA. Five genomic clones, differing in length, were identified in this library. These clones were subjected to DNA sequence analysis with external and internal primers. Altogether, a 7.8 kb sequence was assembled from these clones (SEQ ID NO:9). No exon coding for a trans-membrane (TM) receptor was identified within the 7.8 kb sequence. All variants shared a common translation start site, coded for the same signal peptide of 28 amino acid residues and soluble mature proteins of varying sizes and C-terminal sequences. The IL-18BP locus contains an additional gene, coding for the nuclear mitotic apparatus protein 1 (NUMA1), positioned at the minus strand. This finding localizes the IL-18BP gene to human chromosome 11q13 (36).

An homology search was done with the complete protein sequence of IL-18BPa and the GenPept database (HTTP://www.ncbi.nlm.nih.gov), using the Smith Watermann

algorithm. It was found that homologues of IL-18BP are expressed in several Poxviruses as secreted proteins of a previously unknown function. It was previously reported that viruses code for various cytokine receptors and that such virally encoded molecules serve as decoy receptors that inhibit immune responses by neutralizing their corresponding cytokine (reviewed by Spriggs, MK, 1994, Curr. Opin. Immunol., 6, 526-529). Therefore the invention further relates to virally encoded homologues of IL-18BP that may also serve as blockers or modulators of the biological activity of IL-18. Examples of virus-encoded homologues of IL-18BP are provided in Table 1.

According to the present invention the virus encoded homologue of IL-18BP may be expressed in a prokaryotic or eukaryotic host. As used herein, the expression "virus encoded homologue IL-18BP" refers to a similarity of at least 50% in a sequence of at least 70 amino acid residues. More preferably, it has at least 50%, at least 60%, at least 70%, at least 80% or, most preferably, at least 90% similarity thereto in a sequence of 100 amino acid residues.

Table 1. Virus-encoded proteins, showing high homology to human IL-18BP

GenPept sequence	Virus type
MCU60315_54	U60315 Molluscum contagiosum virus subtype 1
MCU60315_53	U60315 Molluscum contagiosum virus subtype 1
SWPHLSB_12	L22013 Swinepox virus
CV41KBPL_14	Cowpox virus
VVCGAA_5	Variola virus
U01161_3 174	Ectromelia virus (mouse Poxvirus)
VVU18340_6	Variola virus
VVU18338_7	Variola virus
VVU18337_7	Variola virus
VARCG_7 173	Variola major virus
MCU60315_51	Molluscum contagiosum virus
HNABV_1	New Hepatitis non-A, non-B associated virus

IL-18BPa was expressed in monkey COS7 cells. For this purpose, the cDNA of IL-18BPa was inserted into the mammalian expression vector pEF-BOS. A cassette coding for an $(His)_6$ sequence was added to the 3'-end of the IL-18BP ORFs in frame, in order to facilitate purification of the recombinant protein. COS7 cells were transiently transfected with the expression vector and serum-free medium of these cells (150 ml) was concentrated and purified by metal chelate chromatography. IL-18BPa ran as a single band upon SDS-PAGE with silver staining under reducing and non-reducing conditions and had the same apparent molecular mass as that of the urinary IL-18BP. Protein sequence analysis of this preparation revealed the same N-terminal sequence as that of the urinary IL-18BP. Immunoblot analysis of IL-18BPa with antibodies raised against the urinary IL-18BP revealed the same molecular mass band as that of the urinary protein. Furthermore, using immunoprecipitation followed by SDS-PAGE and autoradiography, IL-18BPa was able to displace urinary ^{125}I-IL-18BP from binding to the antibody. Therefore, IL-18BPa corresponds structurally to the IL-18BP isolated from urine.

Crude and purified IL-18BPa were tested for their ability to inhibit the biological activity of IL-18. IL-18BPa inhibited the activity of human and mouse IL-18 in murine splenocytes, PBMC and the human KG-1 cell line (Fig. 9). These results confirm the identity of IL-18BPa cDNA as the one coding for a biologically active IL-18BP.

The invention further relates to muteins and fragments of IL-18BPs and viral IL-18BPs and to fused proteins consisting of wild type IL-18BPs and viral IL-18BPs or their muteins or their fragments, fused to another polypeptide or protein and being capable of binding IL-18 or its homologues.

As used herein the term "muteins" refers to analogs of an IL-18BP, or analogs of a viral IL-18BP, in which one or more of the amino acid residues of a natural IL-18BP or viral IL-18BP are replaced by different amino acid residues, or are deleted, or one or more amino acid residues are added to the natural sequence of an IL-18BP, or a viral IL-18BP, without changing considerably the capability of the resulting products as compared with the wild type IL-18BP or viral IL-18BP to bind to IL-18. These muteins are prepared by known synthesis and/or by site-directed mutagenesis techniques, or any other known technique suitable therefor.

Any such mutein preferably has a sequence of amino acids sufficiently duplicative of that of an IL-18BP, or sufficiently duplicative of a viral IL-18BP, such as to have substantially similar activity to IL-18BP. One activity of IL-18BP is its capability of binding IL-18. As long as the mutein has substantial binding activity to IL-18, it can be used in the purification of IL-18, such as by means of affinity chromatography, and thus can be considered to have substantially similar activity to IL-18BP. Thus, it can be determined whether any given mutein has substantially the same activity as IL-18BP by means of routine experimentation comprising subjecting such a mutein, *e.g.*, to a simple sandwich competition assay to determine whether or not it binds to an appropriately labeled IL-18, such as radioimmunoassay or ELISA assay.

In a preferred embodiment, any such mutein has at least 40% identity or homology with the sequence of either an IL-18BP or a virally-encoded IL-18BP homologue. More preferably, it has at least 50%, at least 60%, at least 70%, at least 80% or, most preferably, at least 90% identity or homology thereto.

Muteins of IL-18BP polypeptides or muteins of viral IL-18BPs, which can be used in accordance with the present invention, or nucleic acid coding therefor, include a finite set of substantially corresponding sequences as substitution peptides or polynucleotides which can be routinely obtained by one of ordinary skill in the art, without undue experimentation, based on the teachings and guidance presented herein. For a detailed description of protein chemistry and structure, see Schulz, G.E. et al., *Principles of Protein Structure*, Springer-Verlag, New York, 1978; and Creighton, T.E., *Proteins: Structure and Molecular Properties*, W.H. Freeman & Co., San Francisco, 1983, which are hereby incorporated by reference. For a presentation of nucleotide sequence substitutions, such as codon preferences, see Ausubel et al, *supra*, at §§ A.1.1-A.1.24, and Sambrook et al, *supra*, at Appendices C and D.

Preferred changes for muteins in accordance with the present invention are what are known as "conservative" substitutions. Conservative amino acid substitutions of IL-18BP polypeptides or proteins or viral IL-18BPs, may include synonymous amino acids within a group which have sufficiently similar physicochemical properties that substitution between members of the group will preserve the biological function of the molecule, Grantham, Science, Vol. 185, pp. 862-864 (1974). It is clear that insertions and deletions of amino acids

may also be made in the above-defined sequences without altering their function, particularly if the insertions or deletions only involve a few amino acids, *e.g.*, under thirty, and preferably under ten, and do not remove or displace amino acids which are critical to a functional conformation, *e.g.*, cysteine residues, Anfinsen, "Principles That Govern The Folding of Protein Chains", Science, Vol. 181, pp. 223-230 (1973). Proteins and muteins produced by such deletions and/or insertions come within the purview of the present invention.

However, cysteine residues which are not required for biological activity may be replaced with other residues, e.g. in order to avoid the formation of undesired intramolecular or intermolecular disulfide bridges which may cause a reduction in the activity of the IL-18BPs.

Preferably, the synonymous amino acid groups are those defined in Table I. More preferably, the synonymous amino acid groups are those defined in Table II; and most preferably the synonymous amino acid groups are those defined in Table III.

TABLE I

Preferred Groups of Synonymous Amino Acids

Amino Acid	Synonymous Group
Ser	Ser, Thr, Gly, Asn
Arg	Arg, Gln, Lys, Glu, His
Leu	Ile, Phe, Tyr, Met, Val, Leu
Pro	Gly, Ala, Thr, Pro
Thr	Pro, Ser, Ala, Gly, His, Gln, Thr
Ala	Gly, Thr, Pro, Ala
Val	Met, Tyr, Phe, Ile, Leu, Val
Gly	Ala, Thr, Pro, Ser, Gly
Ile	Met, Tyr, Phe, Val, Leu, Ile
Phe	Trp, Met, Tyr, Ile, Val, Leu, Phe
Tyr	Trp, Met, Phe, Ile, Val, Leu, Tyr
Cys	Ser, Thr, Cys
His	Glu, Lys, Gln, Thr, Arg, His
Gln	Glu, Lys, Asn, His, Thr, Arg, Gln
Asn	Gln, Asp, Ser, Asn
Lys	Glu, Gln, His, Arg, Lys
Asp	Glu, Asn, Asp
Glu	Asp, Lys, Asn, Gln, His, Arg, Glu
Met	Phe, Ile, Val, Leu, Met
Trp	Trp

TABLE II

More Preferred Groups of Synonymous Amino Acids

Amino Acid	Synonymous Group
Ser	Ser
Arg	His, Lys, Arg
Leu	Leu, Ile, Phe, Met
Pro	Ala, Pro
Thr	Thr
Ala	Pro, Ala
Val	Val, Met, Ile
Gly	Gly
Ile	Ile, Met, Phe, Val, Leu
Phe	Met, Tyr, Ile, Leu, Phe
Tyr	Phe, Tyr
Cys	Cys, Ser
His	His, Gln, Arg
Gln	Glu, Gln, His
Asn	Asp, Asn
Lys	Lys, Arg
Asp	Asp, Asn
Glu	Glu, Gln
Met	Met, Phe, Ile, Val, Leu
Trp	Trp

TABLE III

Most Preferred Groups of Synonymous Amino Acids

Amino Acid	Synonymous Group
Ser	Ser
Arg	Arg
Leu	Leu, Ile, Met
Pro	Pro
Thr	Thr
Ala	Ala
Val	Val
Gly	Gly
Ile	Ile, Met, Leu
Phe	Phe
Tyr	Tyr
Cys	Cys, Ser
His	His
Gln	Gln
Asn	Asn
Lys	Lys
Asp	Asp
Glu	Glu
Met	Met, Ile, Leu
Trp	Met

Examples of production of amino acid substitutions in proteins which can be used for obtaining muteins of IL-18BP polypeptides or proteins, or muteins of viral IL-18BPs, for use in the present invention include any known method steps, such as presented in US patents RE 33,653, 4,959,314, 4,588,585 and 4,737,462, to Mark et al; 5,116,943 to Koths et al., 4,965,195 to Namen et al; 4,879,111 to Chong et al; and 5,017,691 to Lee et al; and lysine substituted proteins presented in US patent No. 4,904,584 (Shaw et al).

In another preferred embodiment of the present invention, any mutein of an IL-18BP or a viral IL-18BP, has an amino acid sequence essentially corresponding to that of an IL-18BP, or to a viral IL-18BP. The term "essentially corresponding to" is intended to comprehend proteins with minor changes to the sequence of the natural protein which do not affect the basic characteristics of the natural proteins, particularly insofar as their ability to bind IL-18. The type of changes which are generally considered to fall within the "essentially corresponding to" language are those which would result from conventional mutagenesis techniques of the DNA encoding these proteins, resulting in a few minor modifications, and screening for the desired activity in the manner discussed above. In addition to binding IL-18, the muteins may also modulate and/or block IL-18 activity.

Muteins in accordance with the present invention include proteins encoded by a nucleic acid, such as DNA or RNA, which hybridizes to DNA or RNA, which encodes an IL-18BP or encodes a viral IL-18BP, in accordance with the present invention, under stringent conditions. The invention also includes such nucleic acid, which is also useful as a probe in identification and purification of the desired nucleic acid. Furthermore, such nucleic acid would be a prime candidate to determine whether it encodes a polypeptide, which retains the functional activity of an IL-18BP of the present invention. The term "stringent conditions" refers to hybridization and subsequent washing conditions, which those of ordinary skill in the art conventionally refer to as "stringent". See Ausubel et al., Current Protocols in Molecular Biology, supra, Interscience, N.Y., §§6.3 and 6.4 (1987, 1992), and Sambrook et al., supra. Without limitation, examples of stringent conditions include washing conditions 12-20°C below the calculated Tm of the hybrid under study in, *e.g.*, 2 x SSC and 0.5% SDS for 5 minutes, 2 x SSC and 0.1% SDS for 15 minutes; 0.1 x SSC and 0.5% SDS at 37°C for 30-60 minutes and then, a 0.1 x SSC and 0.5% SDS at 68°C for 30-60 minutes. Those of ordinary skill in this art understand that stringency conditions also depend on the length of the DNA sequences, oligonucleotide probes (such as 10-40 bases) or mixed oligonucleotide probes. If mixed probes are used, it is preferable to use tetramethyl ammonium chloride (TMAC) instead of SSC. See Ausubel, supra.

The invention further includes nucleic acids which code for IL-18BP according to the present invention, but which differ in codon sequence due to the degeneracy of the genetic

code. Such a DNA which possibly does not hybridize under stringent conditions to the DNA sequences shown in Figures 4 to 7, but is nevertheless capable of encoding an IL-18BP according to the present invention is also included by the invention.

The term "fused protein" refers to a polypeptide comprising an IL-18BP, or a viral IL-18BP, or a mutein thereof, fused with another protein, which, *e.g.*, has an extended residence time in body fluids. An IL-18BP or a viral IL-18BP, may thus be fused to another protein, polypeptide or the like, *e.g.*, an immunoglobulin or a fragment thereof. It may also be fused to polyethylene glycol (PEG) in order to prolong residence time.

The term "salts" herein refers to both salts of carboxyl groups and to acid addition salts of amino groups of an IL-18BP, a viral IL-18BP, muteins, or fused proteins thereof. Salts of a carboxyl group may be formed by means known in the art and include inorganic salts, for example, sodium, calcium, ammonium, ferric or zinc salts, and the like, and salts with organic bases as those formed, for example, with amines, such as triethanolamine, arginine or lysine, piperidine, procaine and the like. Acid addition salts include, for example, salts with mineral acids such as, for example, hydrochloric acid or sulfuric acid, and salts with organic acids such as, for example, acetic acid or oxalic acid. Of course, any such salts must have substantially similar activity to IL-18BP.

"Functional derivatives" as used herein cover derivatives of IL-18BPs or a viral IL-18BP, and their muteins and fused proteins, which may be prepared e.g. from the functional groups which occur as side chains on the residues or the N- or C-terminal groups, by means known in the art, and are included in the invention as long as they remain pharmaceutically acceptable, *i.e.* they do not destroy the activity of the protein which is substantially similar to the activity of IL-18BP, or viral IL-18BPs, and do not confer toxic properties on compositions containing it. These derivatives may, for example, include polyethylene glycol side-chains, which may mask antigenic sites and extend the residence of an IL-18BP or a viral IL-18BP in body fluids. Other derivatives include aliphatic esters of the carboxyl groups, amides of the carboxyl groups by reaction with ammonia or with primary or secondary amines, N-acyl derivatives of free amino groups of the amino acid residues formed with acyl moieties (*e.g.* alkanoyl or carbocyclic aroyl groups) or O-acyl derivatives of

free hydroxyl groups (for example that of seryl or threonyl residues) formed with acyl moieties.

As "active fractions" of an IL-18BP, or a viral IL-18BP, muteins and fused proteins, the present invention covers any fragment or precursors of the polypeptide chain of the protein molecule alone or together with associated molecules or residues linked thereto, *e.g.*, sugar or phosphate residues, or aggregates of the protein molecule or the sugar residues by themselves, provided said fraction substantially retains the capability of binding IL-18.

The term "circularly permuted derivatives" as used herein refers to a linear molecule in which the termini have been joined together, either directly or through a linker, to produce a circular molecule, and then the circular molecule is opened at another location to produce a new linear molecule with termini different from the termini in the original molecule. Circular permutations include those molecules whose structure is equivalent to a molecule that has been circularized and then opened. Thus, a circularly permuted molecule may be synthesized *de novo* as a linear molecule and never go through a circularization and opening step. The preparation of circularly permutated derivatives is described in WO95/27732.

Various recombinant cells such as prokaryotic cells, e.g., E. coli, or other eukaryotic cells, such as yeast or insect cells can produce IL-18BPs or viral IL-18BPs. Methods for constructing appropriate vectors, carrying DNA that codes for an IL-18BP and suitable for transforming (*e.g.*, E. coli, mammalian cells and yeast cells), or infecting insect cells in order to produce a recombinant IL-18BP or a viral IL-18BP are well known in the art. See, for example, Ausubel et al., eds. "Current Protocols in Molecular Biology" Current Protocols, 1993; and Sambrook et al., eds. "Molecular Cloning: A Laboratory Manual", 2nd ed., Cold Spring Harbor Press, 1989.

For the purposes of expression of IL-18BP proteins, or viral IL-18BPs, DNA encoding an IL-18BP or a viral IL-18BP, their fragments, muteins or fused proteins, and the operably linked transcriptional and translational regulatory signals, are inserted into vectors which are capable of integrating the desired gene sequences into the host cell chromosome. In order to be able to select the cells which have stably integrated the introduced DNA into their chromosomes, one or more markers which allow for selection of host cells which contain the expression vector is used. The marker may provide for prototrophy to an auxotropic host, biocide resistance, *e.g.*, antibiotics, or resistance to heavy metals, such as

copper, or the like. The selectable marker gene can either be directly linked to the DNA gene sequences to be expressed, or introduced into the same cell by cotransfection. Additional elements may also be needed for optimal synthesis of single chain binding protein mRNA. These elements may include splice signals, as well as transcription promoters, enhancers, and termination signals.

Said DNA molecule to be introduced into the cells of choice will preferably be incorporated into a plasmid or viral vector capable of autonomous replication in the recipient host. Preferred prokaryotic plasmids are derivatives of pBr322. Preferred eukaryotic vectors include BPV, vaccinia, SV40, 2-micron circle, etc., or their derivatives. Such plasmids and vectors are well known in the art (2-5, 22). Once the vector or DNA sequence containing the construct(s) has been prepared for expression, the expression vector may be introduced into an appropriate host cell by any of a variety of suitable means, such as transformation, transfection, lipofection, conjugation, protoplast fusion, electroporation, calcium phosphate precipitation, direct microinjection, etc.

Host cells to be used in this invention may be either prokaryotic or eukaryotic. Preferred prokaryotic hosts include bacteria such as E. coli, Bacillus, Streptomyces, Pseudomonas, Salmonella, Serratia, etc. The most preferred prokaryotic host is E. coli. Bacterial hosts of particular interest include E. coli K12 strain 294 (ATCC 31446), E. coli X1776 (ATCC 31537), E. coli W3110 (F^-, $lambda^-$, phototropic (ATCC 27325). Under such conditions, the protein will not be glycosylated. The prokaryotic host must be compatible with the replicon and control sequences in the expression plasmid.

However, since natural IL-18BPs are glycosylated proteins, eukaryotic hosts are preferred over prokaryotic hosts. Preferred eukaryotic hosts are mammalian cells, *e.g.*, human, monkey, mouse and Chinese hamster ovary (CHO) cells, because they provide post-translational modifications to protein molecules including correct folding, correct disulfide bond formation, as well as glycosylation at correct sites. Also yeast cells and insect cells can carry out post-translational peptide modifications including high mannose glycosylation.

A number of recombinant DNA strategies exist which utilize strong promoter sequences and high copy number of plasmids, which can be utilized for production of the desired proteins in yeast and in insect cells. Yeast and insect cells recognize leader sequences

on cloned mammalian gene products and secrete mature IL-18BP. After the introduction of the vector, the host cells are grown in a selective medium, which selects for the growth of vector-containing cells. Expression of the cloned gene sequence(s) results in the production of an IL-18BP, a viral IL-18BP, fusion proteins, or muteins or fragments thereof. The above-mentioned cloning, clone isolation, identification, characterization and sequencing procedures are described in more detail hereinafter in the Examples.

The expressed proteins are then isolated and purified by any conventional procedure involving extraction, precipitation, chromatography, electrophoresis, or the like, or by affinity chromatography, using, e.g., an anti-IL-18BP monoclonal antibodies immobilized on a gel matrix contained within a column. Crude preparations containing said recombinant IL-18BP are passed through the column whereby IL-18BP will be bound to the column by the specific antibody, while the impurities will pass through. After washing, the protein is eluted from the gel under conditions usually employed for this purpose, *i.e.* at a high or a low pH, *e.g.* pH 11 or pH 2.

The invention further relates to vectors useful for expression of an IL-18BP or a viral IL-18BP or their derivatives in mammals and more specifically in humans. Vectors for short and long-term expression of genes in mammals are well known in the literature. Studies have shown that gene delivery to e.g., skeletal muscle, vascular smooth muscle and liver result in systemic levels of therapeutic proteins. Skeletal muscle is a useful target because of its large mass, vascularity and accessibility. However, other targets and particularly bone marrow precursors of immune cells have been used successfully. Currently available vectors for expression of proteins in e.g., muscle include plasmid DNA, liposomes, protein-DNA conjugates and vectors based on adenovirus, adeno-associated virus and herpes virus. Of these, vectors based on adeno-associated virus (AAV) have been most successful with respect to duration and levels of gene expression and with respect to safety considerations (Kessler, P.D. 1996, Proc. Natl. Acad. Sci. USA 93, 14082-14087).

Procedures for construction of an AAV-based vector have been described in detail (Snyder et al, 1996, Current Protocols in Human Genetics, Chapters 12.1.1-12.1.17, John Wiley & Sons) and are incorporated into this patent. Briefly plasmid psub201, containing the wild-type AAV genome is cut with the restriction enzyme Xba I and ligated with a construct

consisting of an efficient eukaryotic promoter, e.g., the cytomegalovirus promoter, a Kozak consensus sequence, a DNA sequence coding for an IL-18BP or a viral IL-18BP, or their muteins or fusion proteins or fragments thereof, a suitable 3' untranslated region and a polyadenylation signal, e.g., the polyadenylation signal of simian virus 40. The resulting recombinant plasmid is cotransfected with an helper AAV plasmid e.g., pAAV/Ad into mammalian cells e.g., human T293 cells. The cultures are then infected with adenovirus as a helper virus and culture supernatants are collected after 48-60 hours. The supernatants are fractionated by ammonium sulfate precipitation, purified on a CsCl density gradient, dialyzed and then heated at 56°C to destroy any adenovirus, whereas the resulting recombinant AAV, capable of expressing IL-18BP or a viral IL-18BP, or their muteins or fusion proteins remains stable at this step.

So far, the physiological role of the soluble cytokine receptors has not been established. The soluble receptors bind their specific ligands and in most cases inhibit their biological activity, as was shown, e.g., in the TNF system (11, 12). In very few cases, e.g., IL-6, the soluble receptor enhances the biological activity. The recombinant soluble TNF receptor, also known as TBP (TNF binding protein) was found to prevent septic shock in animal models, while soluble forms of IL-1 receptor were found to have profound inhibitory effects on the development of in vivo alloreactivity in mouse allograft recipients.

Similarly, the IL-18BPs and viral IL-18BPs of the present invention may find use as modulators of IL-18 activity, *e.g.* in type I diabetes, in sepsis, in autoimmune diseases, in graft rejections, rheumatoid arthritis, inflammatory bowel disease, sepsis, multiple sclerosis, ischemic heart disease including acute heart attacks, ischemic brain injury, chronic hepatitis, psoriasis, chronic hepatitis and acute hepatitis. They may thus be used, *e.g.* in any disease in which endogenous production or exogenous administration of IL-18 induces the disease or aggravates the situation of the patient.

The present invention further relates to pharmaceutical compositions comprising a pharmaceutically acceptable carrier and an IL-18BP or a viral IL-18BP of the invention or their active muteins, fused proteins and their salts, functional derivatives or active fractions thereof.

The present invention further relates to pharmaceutical compositions comprising a pharmaceutically acceptable carrier and e.g., a viral vector such as any one of said

AAV-based viral vectors or another vector expressing an IL-18BP or viral IL-18BP or their muteins, fragments or fusion proteins thereof and suitable for administration to humans and other mammals for the purpose of attaining expression in vivo of IL-18BP or a viral IL-18BP or their muteins or fragments or fusion protein of the invention, i.e. for use in gene therapy.

The pharmaceutical compositions of the invention are prepared for administration by mixing an IL-18BP or a viral IL-18BP, or their derivatives, or vectors for expressing same with physiologically acceptable carriers, and/or stabilizers and/or excipients, and prepared in dosage form, *e.g.*, by lyophilization in dosage vials. The method of administration can be via any of the accepted modes of administration for similar agents and will depend on the condition to be treated, *e.g.*, intravenously, intramuscularly, subcutaneously, by local injection or topical application, or continuously by infusion, etc. The amount of active compound to be administered will depend on the route of administration, the disease to be treated and the condition of the patient. Local injection, for instance, will require a lower amount of the protein on a body weight basis than will intravenous infusion.

Accordingly, IL-18BPs, or viral IL-18BPs, or vectors expressing same in vivo are indicated for the treatment of autoimmune diseases, Type I diabetes, rheumatoid arthritis, graft rejections, inflammatory bowel disease, sepsis, multiple sclerosis, ischemic heart disease including acute heart attacks, ischemic brain injury, chronic hepatitis, psoriasis, chronic pancreatitis and acute pancreatitis and similar diseases, in which there is an aberrant expression of IL-18, leading to an excess of IL-18 or in cases of complications due to exogenously administered IL-18.

The invention also includes antibodies against an IL-18BP or a viral IL-18BP, as well as against their muteins, fused proteins, salts, functional derivatives and active fractions. The term "antibody" is meant to include polyclonal antibodies, monoclonal antibodies (MAbs), chimeric antibodies, anti-idiotypic (anti-Id) antibodies to antibodies that can be labeled in soluble or bound form, and humanized antibodies as well as fragments thereof provided by any known technique, such as, but not limited to enzymatic cleavage, peptide synthesis or recombinant techniques.

Polyclonal antibodies are heterogeneous populations of antibody molecules derived from the sera of animals immunized with an antigen. A monoclonal antibody contains a substantially homogeneous population of antibodies specific to antigens, which population contains substantially similar epitope binding sites. MAbs may be obtained by methods known to those skilled in the art. See, for example Kohler and Milstein, Nature 256:495-497 (1975); US Patent No. 4,376,110; Ausubel et al, eds., supra, Harlow and Lane, ANTIBODIES: A LABORATORY MANUAL, Cold Spring Harbor Laboratory (1988); and Colligan et al., eds., Current Protocols in Immunology, Greene Publishing Assoc. and Wiley Interscience, N.Y., (1992, 1993), the contents of which references are incorporated entirely herein by reference. Such antibodies may be of any immunoglobulin class including IgG, IgM, IgE, IgA, GILD and any subclass thereof. A hybridoma producing a MAb of the present invention may be cultivated *in vitro*, *in situ* or *in vivo*. Production of high titers of MAbs *in vivo* or *in situ* makes this the presently preferred method of production.

Chimeric antibodies are molecules, different portions of which are derived from different animal species, such as those having the variable region derived from a murine MAb and a human immunoglobulin constant region. Chimeric antibodies are primarily used to reduce immunogenicity in application and to increase yields in production, for example, where murine MAbs have higher yields from hybridomas but higher immunogenicity in humans, such that human/murine chimeric MAbs are used. Chimeric antibodies and methods for their production are known in the art (Cabilly et al, Proc. Natl. Acad. Sci. USA 81:3273-3277 (1984); Morrison et al., Proc. Natl. Acad. Sci. USA 81:6851-6855 (1984); Boulianne et al., Nature 312:643-646 (1984); Cabilly et al., European Patent Application 125023 (published November 14, 1984); Neuberger et al., Nature 314:268-270 (1985); Taniguchi et al., European Patent Application 171496 (published February 19, 1985); Morrison et al., European Patent Application 173494 (published March 5, 1986); Neuberger et al., PCT Application WO 8601533, (published March 13, 1986); Kudo et al., European Patent Application 184187 (published June 11, 1986); Morrison et al., European Patent Application 173494 (published March 5, 1986); Sahagan et al., J. Immunol. 137:1066-1074 (1986); Robinson et al., International Patent Publication, WO 9702671 (published 7 May 1987); Liu et al., Proc. Natl. Acad. Sci. USA 84:3439-3443 (1987); Sun et al., Proc. Natl.

Acad. Sci. USA 84:214-218 (1987); Better et al., Science 240:1041- 1043 (1988); and Harlow and Lane, ANTIBODIES: A LABORATORY MANUAL, supra. These references are entirely incorporated herein by reference.

An anti-idiotypic (anti-Id) antibody is an antibody, which recognizes unique determinants generally, associated with the antigen-binding site of an antibody. An Id antibody can be prepared by immunizing an animal of the same species and genetic type (*e.g.*, mouse strain) as the source of the MAb with the MAb to which an anti-Id is being prepared. The immunized animal will recognize and respond to the idiotypic determinants of the immunizing antibody by producing an antibody to these idiotypic determinants (the anti-Id antibody). See, for example, US patent No. 4,699,880, which is herein entirely incorporated by reference.

The anti-Id antibody may also be used as an "immunogen" to induce an immune response in yet another animal, producing a so-called anti-anti-Id antibody. The anti-anti-Id may be epitopically identical to the original MAb, which induced the anti-Id. Thus, by using antibodies to the idiotypic determinants of a MAb, it is possible to identify other clones expressing antibodies of identical specificity.

Accordingly, MAbs generated against IL-18BP and related proteins of the present invention may be used to induce anti-Id antibodies in suitable animals, such as BALB/c mice. Spleen cells from such immunized mice are used to produce anti-Id hybridomas secreting anti-Id Mabs. Further, the anti-Id Mabs can be coupled to a carrier such as keyhole limpet hemocyanin (KLH) and used to immunize additional BALB/c mice. Sera from these mice will contain anti-anti-Id antibodies that have the binding properties of the original MAb specific for an IL-18BP epitope or epitopes of a viral IL-18BP.

The anti-Id MAbs thus have their own idiotypic epitopes, or "idiotopes" structurally similar to the epitope being evaluated, such as an IL-18BP or a viral IL-18BP.

The term "humanized antibody" is meant to include e.g. antibodies which were obtained by manipulating mouse antibodies through genetic engineering methods so as to be more compatible with the human body. Such humanized antibodies have reduced

immunogenicity and improved pharmacokinetics in humans. They may be prepared by techniques known in the art, such as described, e.g. for humanzied anti-TNF antibodies in Molecular Immunology, Vol. 30, No. 16, pp. 1443-1453, 1993.

The term "antibody" is also meant to include both intact molecules as well as fragments thereof, such as, for example, Fab and F(ab')2, which are capable of binding antigen. Fab and F(ab')2 fragments lack the Fc fragment of intact antibody, clear more rapidly from the circulation, and may have less non-specific tissue binding than an intact antibody (Wahl et al., J. Nucl. Med. 24:316-325 (1983)). It will be appreciated that Fab and F(ab')2 and other fragments of the antibodies useful in the present invention may be used for the detection and quantitation of an IL-18BP or a viral IL-18BP, according to the methods disclosed herein for intact antibody molecules. Such fragments are typically produced by proteolytic cleavage, using enzymes such as papain (to produce Fab fragments) or pepsin (to produce F(ab')2 fragments).

An antibody is said to be "capable of binding" a molecule if it is capable of specifically reacting with the molecule to thereby bind the molecule to the antibody. The term "epitope" is meant to refer to that portion of any molecule capable of being bound by an antibody which can also be recognized by that antibody. Epitopes or "antigenic determinants" usually consist of chemically active surface groupings of molecules such as amino acids or sugar side chains and have specific three dimensional structural characteristics as well as specific charge characteristics.

An "antigen" is a molecule or a portion of a molecule capable of being bound by an antibody which is additionally capable of inducing an animal to produce antibody capable of binding to an epitope of that antigen. An antigen may have one or more than one epitope. The specific reaction referred to above is meant to indicate that the antigen will react, in a highly selective manner, with its corresponding antibody and not with the multitude of other antibodies which may be evoked by other antigens.

The antibodies, including fragments of antibodies, useful in the present invention may be used to detect quantitatively or qualitatively an IL-18BP or a viral IL-18BP, or

related proteins in a sample or to detect presence of cells, which express such proteins of the present invention. This can be accomplished by immunofluorescence techniques employing a fluorescently labeled antibody (see below) coupled with light microscopic, flow cytometric, or fluorometric detection.

The antibodies (or fragments thereof) useful in the present invention may be employed histologically, as in immunofluorescence or immunoelectron microscopy, for *in situ* detection of an IL-18BP or a viral IL-18BP, and related proteins of the present invention. *In situ* detection may be accomplished by removing a histological specimen from a patient, and providing the a labeled antibody of the present invention to such a specimen. The antibody (or fragment) is preferably provided by applying or by overlaying the labeled antibody (or fragment) to a biological sample. Through the use of such a procedure, it is possible to determine not only the presence of an IL-18BP or a viral IL-18BP, or related proteins but also its distribution on the examined tissue. Using the present invention, those of ordinary skill will readily perceive that any of wide variety of histological methods (such as staining procedures) can be modified in order to achieve such *in situ* detection.

Such assays for an IL-18BP or a viral IL-18BP, or related proteins of the present invention typically comprises incubating a biological sample, such as a biological fluid, a tissue extract, freshly harvested cells such as lymphocytes or leukocytes, or cells which have been incubated in tissue culture, in the presence of a detectably labeled antibody capable of identifying IL-18BP or related proteins, and detecting the antibody by any of a number of techniques well-known in the art.

The biological sample may be treated with a solid phase support or carrier such as nitrocellulose, or other solid support or carrier which is capable of immobilizing cells, cell particles or soluble proteins. The support or carrier may then be washed with suitable buffers followed by treatment with a detectably labeled antibody in accordance with the present invention. The solid phase support or carrier may then be washed with the buffer a second time to remove unbound antibody. The amount of bound label on said solid support or carrier may then be detected by conventional means.

By "solid phase support", "solid phase carrier", "solid support", "solid carrier", "support" or "carrier" is intended any support or carrier capable of binding antigen or antibodies. Well-known supports or carriers, include glass, polystyrene, polypropylene, polyethylene, dextran, nylon amylases, natural and modified celluloses, polyacrylamides, gabbros, and magnetite. The nature of the carrier can be either soluble to some extent or insoluble for the purposes of the present invention. The support material may have virtually any possible structural configuration so long as the coupled molecule is capable of binding to an antigen or antibody. Thus, the support or carrier configuration may be spherical, as in a bead, or cylindrical, as in the inside surface of a test tube, or the external surface of a rod. Alternatively, the surface may be flat such as a sheet, test strip, etc. Preferred supports or carriers include polystyrene beads. Those skilled in the art will know many other suitable carriers for binding antibody or antigen, or will be able to ascertain the same by use of routine experimentation.

The binding activity of a given lot of antibody in accordance with the present invention may be determined according to well known methods. Those skilled in the art will be able to determine operative and optimal assay conditions for each determination by employing routine experimentation.

Other such steps as washing, stirring, shaking, filtering and the like may be added to the assays as is customary or necessary for the particular situation.

One of the ways in which an antibody in accordance with the present invention can be detectably labeled is by linking the same to an enzyme and use in an enzyme immunoassay (EIA). This enzyme, in turn, when later exposed to an appropriate substrate, will react with the substrate in such a manner as to produce a chemical moiety which can be detected, for example, by spectrophotometric, fluorometric or by visual means. Enzymes which can be used detectably label the antibody include, but are not limited to, malate dehydrogenase, staphylococcal nuclease, delta-5-steroid isomerase, yeast alcohol dehydrogenase, alpha- glycerophosphate dehydrogenase, triose phosphate isomerase, horseradish peroxidase, alkaline phosphatase, asparaginase, glucose oxidase, beta-galactosidase, ribonuclease, urease, catalase, glucose-6- phosphate dehydrogenase,

glucoamylase and acetylcholinesterase. The detection can be accomplished by colorimetric methods, which employ a chromogenic substrate for the enzyme. Detection may also be accomplished by visual comparison of the extent of enzymatic reaction of a substrate in comparison with similarly prepared standards.

Detection may be accomplished using any of a variety of other immunoassays. For example, by radioactivity labeling the antibodies or antibody fragments, it is possible to detect an IL-18BP or a viral IL-18BP, through the use of a radioimmunoassay (RIA). A good description of RIA maybe found in Laboratory Techniques and Biochemistry in Molecular Biology, by Work, T.S. et al., North Holland Publishing Company, NY (1978) with particular reference to the chapter entitled "An Introduction to Radioimmuno Assay and Related Techniques" by Chard, T., incorporated by reference herein. The radioactive isotope can be detected by such means as the use of a gamma counter or a scintillation counter or by autoradiography.

It is also possible to label an antibody in accordance with the present invention with a fluorescent compound. When the fluorescently labeled antibody is exposed to light of the proper wavelength, its presence can be then be detected due to fluorescence. Among the most commonly used fluorescent labeling compounds are fluorescein isothiocyanate, rhodamine, phycoerythrin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine.

The antibody can also be detectably labeled using fluorescence emitting metals such as ^{152}Eu, or others of the lanthanide series. These metals can be attached to the antibody using such metal chelating groups as diethylenetriamine pentaacetic acid (ETPA).

The antibody can also be detectably labeled by coupling it to biotin. Biotinylated antibody can then be detected by avidin or streptavidin coupled to a fluorescent compound or to an enzyme such as peroxidase or to a radioactive isotope and the like.

The antibody also can be detectably labeled by coupling it to a chemiluminescent compound. The presence of the chemiluminescent-tagged antibody is then determined by detecting the presence of luminescence that arises during the course of a chemical reaction.

Examples of particularly useful chemiluminescent labeling compounds are luminol, isoluminol, theromatic acridinium ester, imidazole, acridinium salt and oxalate ester.

Likewise, a bioluminescent compound may be used to label the antibody of the present invention. Bioluminescence is a type of chemiluminescence found in biological systems in which a catalytic protein increases the efficiency of the chemiluminescent reaction. The presence of a bioluminescent protein is determined by detecting the presence of luminescence. Important bioluminescent compounds for purposes of labeling are luciferin, luciferase and aequorin.

An antibody molecule of the present invention may be adapted for utilization in a immunometric assay, also known as a "two-site" or "sandwich" assay. In a typical immunometric assay, a quantity of unlabeled antibody (or fragment of antibody) is bound to a solid support or carrier and a quantity of detectably labeled soluble antibody is added to permit detection and/or quantitation of the ternary complex formed between solid-phase antibody, antigen, and labeled antibody.

Typical, and preferred, immunometric assays include "forward" assays in which the antibody bound to the solid phase is first contacted with the sample being tested to extract the antigen form the sample by formation of a binary solid phase antibody-antigen complex. After a suitable incubation period, the solid support or carrier is washed to remove the residue of the fluid sample, including unreacted antigen, if any, and then contacted with the solution containing an unknown quantity of labeled antibody (which functions as a "reporter molecule"). After a second incubation period to permit the labeled antibody to complex with the antigen bound to the solid support or carrier through the unlabeled antibody, the solid support or carrier is washed a second time to remove the unreacted labeled antibody.

In another type of "sandwich" assay, which may also be useful with the antigens of the present invention, the so-called "simultaneous" and "reverse" assays are used. A "simultaneous" assay involves a single incubation step as the antibody bound to the solid support or carrier and labeled antibody are both added to the sample being tested at the same time. After the incubation is completed, the solid support or carrier is washed to remove the residue of fluid sample and uncomplexed labeled antibody. The presence of labeled antibody

associated with the solid support or carrier is then determined as it would be in a conventional "forward" sandwich assay.

In the "reverse" assay, stepwise addition first of a solution of labeled antibody to the fluid sample followed by the addition of unlabeled antibody bound to a solid support or carrier after a suitable incubation period is utilized. After a second incubation, the solid phase is washed in conventional fashion to free it of the residue of the sample being tested and the solution of unreacted labeled antibody. The determination of labeled antibody associated with a solid support or carrier is then determined as in the "simultaneous" and "forward" assays.

The present invention also provides DNA molecules encoding any of the proteins of the present invention as defined above, replicable expression vehicles comprising any such DNA molecules, host cells transformed with any such expression vehicles including prokaryotic and eukaryotic and host cells, preferably CHO cells. The invention also includes a process for the production of expression vectors coding for any of the proteins of the present invention for the purpose of their expression in humans and other mammals.

The invention also includes a process for the production of any of the proteins of the present invention by culturing a transformed cell in accordance with the present invention and recovering the protein encoded by the DNA molecule and the expression vehicle within such transformed host cell.

In addition to the use of an IL-18BP or a viral IL-18BP, in modulating the activity of IL-18, they can, of course, also be employed for the purification of IL-18 itself. For this purpose, IL-18BP or a viral IL-18BP is coupled to an affinity column and crude IL-18 is passed through. The IL-18 can then be recovered from the column by, *e.g.*, elution at low pH.

The invention will now be illustrated by the following non-limiting examples:

EXAMPLE 1: Isolation of an IL-18 binding protein

E. coli IL-18 (2.5 mg, Peprotech, NJ) was coupled to Affigel-10 (0.5 ml, BioRad), according to the manufacturer's instructions and packed into a column. Crude urinary proteins (1000-fold concentrated, 500 ml) were loaded onto the column at a flow rate of 0.25 ml/min. The column was washed with 250 ml 0.5M NaCl in phosphate buffered saline (PBS). Bound proteins were then eluted with 25 mM citric acid, pH 2.2 and benzamidine (1 mM), immediately neutralized by 1M Na_2CO_3. Fractions of 1 ml were collected. The fractions were analyzed by SDS-PAGE and silver staining. The IL-18 binding protein eluted in fractions 2-8 as a ~40,000 Dalton protein (Fig. 1). The ~40 kD band, corresponding to the IL-18BP exhibited a distinct yellow color upon silver staining. The various fractions were analyzed by cross-linking with ^{125}I-IL-18, SDS-PAGE and autoradiography as described in Example 2. An IL-18 binding protein was found in fractions 2-8, eluted from the IL-18-agarose column (Fig. 2).

EXAMPLE 2: Cross-linking of affinity-purified IL-18BP to labeled IL-18.

Samples (40 µl) of IL-18BP from the affinity purification step were incubated (70 min. at 4°C) with ^{125}I-IL-18 (5,000,000 cpm). Disuccinimidyl suberate (DSS), dissolved in dimethyl sulfoxide (Me_2SO, 20 mM), was then added to a final concentration of 2 mM and the mixture was left for 20 min. at 4°C. The reaction was stopped by the addition of 1M Tris-HCl pH 7.5, and 1M NaCl to a final concentration of 100 mM. A sample buffer containing Dithiothreitol (DTT, 25 mM final) was added and the mixtures were analyzed by SDS-PAGE (7.5 % acrylamide) followed by autoradiography (Fig. 2).

A specific band of molecular weight 58 kD, probably consisting of a ~40 kD protein cross-linked to the ~20 kD ^{125}I-IL-18, was observed in fractions eluted from the IL-18 affinity column (lanes 2 and 3) but not in the column wash (lane 1), containing all other crude urinary proteins.

EXAMPLE 3: Protein sequence analysis.

Eluted fractions from the affinity column of Example 1 were resolved by SDS-PAGE (10% acrylamide) under non-reducing conditions, electroblotted on a PVDF membrane (Pro-Blot, Applied Biosystems, USA). The membrane was stained with coomassie blue, the ~40 kD band was excised and subjected to protein sequence analysis by a Procise microsequencer (Applied Biosystems, USA). The following major sequence was obtained:

```
T-P-V-S-Q-Q-x-x-x-A-A-A
1 . . . 5 . . . .10 . .
```

wherein x represents a yet undetermined amino acid.

In addition, a minor sequence was obtained:

```
A-x-Y-x-R-I-P-A-x-A-I-A
1 . . . 5 . . . .10 . .
```

Because of this double sequence it was not possible to obtain a longer sequence data. The minor sequence was identified as a fragment of human defensin, (accession No. p11398) starting at amino acid 65 of defensin. The major sequence could not be associated with any other known protein, as determined by searching all available databases in NCBI and TIGR by the blastp and tblastn search programs.

In order to obtain a longer and more accurate sequence and in order to identify potential cysteine residues, another aliquot of the fraction eluted from the IL-18-agarose column was reduced with DTT in 6 M guanidine HCl, reacted with 4-vinyl pyridine, desalted by a micro-ultrafiltration device (Ultrafree, cutoff 10,000 Daltons, Millipore) and subjected to protein microsequence analysis. After cycle No. 1 of sequencing, the filter was reacted with o-phtalaldehyde to block all N-terminal polypeptides other than Pro. In this way only the major sequence was obtained as follows:

```
TPVSQXXXAA XASVRSTKDP CPSQPPVFPA AKQCPALEVT
1         10          20          30          40
```

(T=Thr; P=Pro; V=Val; S=Ser; Q=Gln; X=Unknown; A=Ala; R=Arg; K=Lys; D=Asp; C=Cys; F=Phe; L=Leu; E=Glu)

In cycles 6,7,8 and 11 a low level of a Thr signal was obtained. Because of this low level we considered it more prudent not to assign a specific amino acid residue at said cycles.

The resulting sequence is significantly different from that of any other known protein, as determined by searching protein databases. However, searching the TIGR database by the tblastn search program provided a cDNA file, denoted THC123801, whose open reading frame (218 codons), when translated contains a sequence highly homologous to that of the N-terminal sequence of IL-18BP. The homology is hereby shown:

```
1 .......TPVSQXXXAAXASVRSTKDPCPSQPPVFPAAKQCPALEVT... 40
              | | |   || ||||||||||||||||||||||||||||
  51 VTLLVRATXVXQTTTAATASVRSTKDPCPSQPPVFPAAKQCPALEVTWPE 100
```

(The upper sequence (1-40) is that of the IL-18BP isolated according to the invention; the lower sequence (51-100) is deduced by translation of the cDNA of TIGR file THC123801).

The putative protein sequence, obtained by translating file THC123801, was ambiguous at residues 2 and 4 of the IL-18BP. It confirms the identity of amino acid residues 6,7 and 8 of IL-18BP as Thr and seems to do so also for residue 11.

EXAMPLE 4: The IL-18BP is a glycoprotein.

Aliquot (0.3 ml) of eluted fractions of Example 1 were further purified by size exclusion chromatography on a Superose 12 column (1X30 cm, Pharmacia, Sweden). The column was pre-equilibrated and eluted with phosphate buffered saline and sodium azide (0.02%) at a flow rate of 0.5 ml/min. and fractions of 1 min. were collected. The IL-18 binding protein eluted in fractions 20-25 as a ~40,000 Dalton protein, as determined by SDS-PAGE and silver staining. A sample containing the ~40,000 Dalton protein (fraction 23, 50 µl, ~50 ng protein) was reacted with N-glycosidase F (PNGase F, Biolab) according to the manufacturers instructions. Briefly, the aliquot was denatured by boiling in the presence of 5% SDS for 10 min., 10xG7 buffer (2.5 µl), 10% NP-40 (2.5 µl) and PNGase F (1 µl), 1 h at 37°C. The sample was analyzed by SDS-PAGE (10% acrylamide) under non-reducing conditions and compared with undigested IL-18BP from the same Superose 12 fraction. It was found that the ~40 kD band of IL-18BP disappeared in the PNGase-treated fraction.

New bands, corresponding to 30 kD (just above the PNGase band) and 20 kD were obtained. The elimination of the ~40 kD band indicates that this band is an N-glycosylated protein.

EXAMPLE 5: Blocking of the biological activity of IL-18 by IL-18BP.

The ability of the IL-18BP isolated from urine to block IL-18 activity was determined by measuring the IL-18-induced production of IFN-γ in mononuclear cells. IL-18 induces IFN-γ when added together with either low concentration of LPS, IL-12, IL-2, or other stimulants. The activity of IL-18 was tested in murine splenocytes, in human peripheral blood mononuclear cells (PBMC) and in the human KG-1 cell line. Spleen cells were prepared from a healthy mouse, washed and suspended in RPMI 1640 medium supplemented with 10% fetal bovine serum at $5x10^6$ cells/ml. 1.0 ml cultures were stimulated with LPS (either 0.5 or 1 μg/ml) together with recombinant human or murine IL-18 (either 0.5 or 5 ng/ml). Human IL-18 binding protein (0, 5 or 50 ng/ml) was added to the recombinant IL-18 before adding to spleen cells. After culturing for 24h, the spleen cells were subjected to three freeze (-70°C) and thaw (room temperature) cycles, the cellular debris was removed by centrifugation and the supernatants were assayed for IFN-γ using the ELISA kits for mouse IFN-γ (Endogen). As shown in Fig. 3A, IL-18BP blocked the activity of huIL-18 in murine splenocytes in a dose-dependent manner. In contrast, as a control, soluble interferon-α/β receptor had no effect. The activity of recombinant murine IL-18 was similarly inhibited by the human IL-18BP, suggesting that human IL-18BP recognizes murine IL-18 (Fig. 3B). Endogenous IL-18 is induced in murine splenocytes by high concentrations of LPS, leading to production of IFN-γ. Indeed, IFN-γ induction by LPS (10 μg/ml) was also inhibited by the urinary IL-18BP (Fig. 3C). Concanavalin A (con A) activates T-cells to produce IFN-γ in the absence of IL-18 (13)]. Indeed, induction of IFN-γ by Con A was not inhibited by IL-18BP even at high concentrations (Fig. 3D). This observation demonstrated that IL-18BP was a specific inhibitor of IL-18 bioactivity rather than a non-specific inhibitor of IFN-γ production. IL-18BP also inhibited the activity of human IL-18 in human KG-1 cells induced by a combination of IL-18 and TNF-α (Fig. 3E).

The above data demonstrate that urinary IL-18BP inhibits human as well as murine IL-18 activity as measured by co-induction of IFN-γ in human and murine mononuclear cells.

The concentration of IL-18BP which reduced IL-18 activity by >90% was comparable to that of IL-18 itself, suggesting a high affinity interaction between these two proteins.

EXAMPLE 6: Isolation of cDNA clones coding for IL-18BP.

Total RNA from Jurkat T-cells (CRL 8163, American Type Culture Collection) was reverse-transcribed with SuperScript RNase H^- reverse transcriptase (Gibco-BRL) and random primers (Promega, Madison WI). The resulting cDNA fragments were then amplified by PCR, using Taq DNA polymerase (Sigma) and primers corresponding to TIGR clone THC123801 nucleotides 24-44 (sense) and 500-481 (reverse). The amplification was done in 30 cycles of annealing (55°C, 2 min) and extension (70°C, 1 min). The resulting PCR products were resolved by agarose (1%) gel electrophoresis, eluted and cloned into pGEM-Teasy TA cloning vector (Promega). DNA from individual clones was sequenced with T7 and SP6 primers.

The resulting 477 bp fragment was ^{32}P-labeled by random priming. This probe was used for screening various human cDNA and genomic libraries. Duplicate nitrocellulose filters were lifted and hybridized with the probe at 60°C in a buffer consisting of 6xSSC, 10x Denhardt's solution, 0.1% SDS and 100 μg/ml Salmon sperm DNA. The filters were washed and exposed overnight at -80°C to Kodak XAR film. Double positive clones were plaque-purified. Plasmids were excised from the λpCEV9 clones and self-ligated. cDNA clones from other libraries were isolated according to the manufacturer's instructions. Automated DNA sequence analysis of the isolated clones was performed with Models 373A and 377 sequencers (Applied Biosystems) using sense and antisense primers. Standard protocols were used for these cloning procedures (33).

The following libraries were screened: a human monocyte cDNA library, constructed in λpCEV9 cloning vector (15), kindly provided by T. Miki; a human Jurkat leukemic T-cell cDNA library, a human peripheral blood leukocyte cDNA library and a human spleen cDNA library, all from Clontech (Palo Alto, CA). A human placenta genomic library in lambda FIX II vector was from Stratagene (La Jolla, CA).

All cDNA clones corresponded to four different IL-18BP splice variants were obtained and characterized. All splice variants coded for putative soluble secreted proteins.

The most abundant one (IL-18BPa) had an open reading frame of 192 codons, coding for a signal peptide of 28 amino acid residues followed by a mature putative IL-18BPa, whose first 40 residues (SEQ ID NO:10) matched perfectly with the N-terminal protein sequence of the urinary IL-18BP (SEQ ID NO:2). The position of the cysteine residues suggested that this polypeptide belongs to the immunoglobulin (Ig) super-family. Each of the four Gln residues within mature IL-18BPa was a potential N-glycosylation site. The other three splice variants of IL-18BP were significantly less abundant.

Another 1 kb IL-18BPb cDNA coded for a mature protein of 85 amino acid residues (SEQ ID NO:4). A third variant, IL-18BPc, was represented by a 2.3 kb cDNA, coding for a mature IL-18BP of 169 amino acid residues (SEQ ID NO:6). The fourth variant, IL-18BPd coded for a mature IL-18BP of 133 amino acid residues (SEQ ID NO:8). In-exon splicing occurred at two sites along the pro-mRNA. These events and an additional 5' exon in IL-18BPd gave rise to 3 different 5' UTRs in the various cDNA clones. It is therefore quite possible that different IL-18BP variants may be generated in response to distinct transcription regulation signals.

No cDNA coding for a receptor with a transmembrane domain was found so far.

Example 7. Construction of a mammalian expression vector, production of recombinant IL-18BP, and evaluation of the biological activities of recombinant IL-18BP

The coding region of the IL-18BPa cDNA was amplified by PCR with the sense primer 5' TATATCTAGAGCCACCATGAGACACAACTGGACACCA

and the reverse primer:

5' ATATCTAGATTAATGATGATGATGATGATGACCCTGCTGCTGTGGACTGC.

The PCR products were cut with Xba I and cloned into the Xba I site of the pEF-BOS expression vector (25), to yield pEF-BOS-IL-18BPa. The constructs were confirmed by DNA sequencing.

Batches of $6x10^7$ COS7 cells in 1.4 ml TD buffer, containing pEF-BOS-IL-18BPa plasmid DNA (10 μg) and DEAE-dextran (120 μg) were incubated for 30 min at room

temperature, as described (35). The cells were then washed with DMEM -10% FBS, plated for 4 hr in DMEM-10, washed and incubated for 3-5 days in serum-free DMEM. Culture medium was collected, concentrated 6-fold by ultrafiltration (10 kD cutoff) and the IL-18BP-His_6 was isolated on a Talon column (Clontech) with imidazole as eluant according to the manufacturer's instructions.

Immunological cross-reactivity of the urinary and the COS7-expressed IL-18BP was assessed as follows: Urinary IL-18BP (5 μg) was labeled with ^{125}I by the chloramine T procedure. Supernatants of COS7 cells (250 μl) were mixed (1 h, room temperature final volume 500 μl) with the antibody to urinary IL-18BP, diluted 1:1000 in phosphate-buffered saline (PBS), 0.05% Tween 20 and 0.5 % bovine serum albumin (Wash Buffer). ^{125}I-labeled urinary IL-18BP (10^6 cpm) was then added and after 1 h protein G-sepharose (20 μl) was added. The mixture was suspended (1.5 h, 4°C), the beads were then isolated and washed wash 3x Wash Buffer and once in PBS. The beads were then eluted with a Sample buffer, resolved by SDS-PAGE (10% acrylamide under reducing conditions followed by Autoradiography.

IL-18BPa ran as a single band upon SDS-PAGE with silver staining under reducing and non-reducing conditions and had the same apparent molecular mass as that of the urinary IL-18BP (data not shown). Protein sequence analysis of this preparation revealed the same N-terminal sequence as that of the urinary IL-18BP, indicating that the latter was not degraded at its N-terminus.

Immunoblot analysis of IL-18BPa with antibodies raised against the urinary IL-18BP revealed the same molecular mass band as that of the urinary protein. Furthermore, using immunoprecipitation followed by SDS-PAGE and autoradiography, IL-18BPa was able to displace urinary ^{125}I-IL-18BP from binding to the antibody. Therefore, IL-18BPa corresponds structurally to the urinary IL-18BP.

Crude and purified IL-18BPa was tested for its ability to inhibit the biological activity of IL-18. IL-18BPa inhibited in a dose dependent manner the IFN-γ inducing activity of human and mouse IL-18 in murine splenocytes, PBMC and the human KG-1 cell line (Fig. 9).

The results of the various bioassays as well as the mobility shift assay (Example 8) demonstrated that inhibition of IL-18 activity is an intrinsic property of the cloned IL-18BP and not that of any accompanying impurities in urinary IL-18BP, such as the co-eluting fragment of defensin.

Example 8. Electrophoretic mobility shift assays

The effect of the urinary and the recombinant IL-18BP on IL-18-induced activation of NF-κB in human KG-1 cells was also studied. Human KG-1 cells ($4x10^6$ in 1 ml RMPI) were stimulated with either huIL-18 (10 ng/ml) or huIL-18 pre-mixed with an IL-18BP (20 min, room temperature). After 20 min at 37°C, cells were washed three times with ice-cold PBS and immediately frozen in liquid nitrogen. Cell pellets were resuspended in three times the packed cell volume in buffer A (20 mM Tris pH 7.6, 0.4M NaCl, 0.2 mM EDTA, glycerol (20% by volume), 1.5 mM $MgCl_2$, 2 mM dithiothreitol (DDT), 0.4 mM PMSF, 1 mM Na_3VO_4, 2μg/ml each of leupeptin, pepstatin and aprotinin). Cell debris was removed by centrifugation (15,000xg, 15 min.), aliquots of the supernatant were frozen in liquid nitrogen and stored at -80°C. Protein concentration was determined by a Bradford assay (Bio-Rad) using bovine serum albumin as standard. A double-stranded oligonucleotide corresponding to NF-κB binding element (10 pmol, Promega) was labeled with [^{32}P]dCTP (300 Ci/mmol) and T4 polynucleotide kinase (New England Biolabs). Free nucleotides were removed by a spin column. Extracts (10 μg protein) of cells treated with IL-18 or IL-18 plus IL-18BP were incubated (15 min., room temperature) with the labeled probe ($3x10^4$ cpm) together with poly dI.dC (500 ng, Pharmacia) and denatured salmon sperm DNA (100 ng, Sigma) in 20 μl buffer consisting of HEPES (pH 7.5, 10 mM), 60 mM KCl, 1 mM $MgCl_2$, 2 mM EDTA, 1 mM DTT and glycerol (5% by volume). The mixtures were then loaded onto 5% non-denaturing polyacrylamide gels. Electrophoresis was performed at 185 V in 0.5xTBE (40 mM Tris HCl, 45 mM boric acid and 2.5 mM EDTA). Gels were vacuum dried and autoradiographed overnight at -80°C. IL-18 was found to induce the formation of the p50 NF-κB homodimer and the p65/p50 NF-κB heterodimer. Urinary as well as recombinant IL-18BP inhibited the activation of NF-κB by IL-18, as determined by an electrophoretic mobility shift assay with KG-1 cell extracts binding a radiolabeled oligonucleotide corresponding to the NF-κB consensus sequence.

Example 9. Expression of IL-18BP in E. coli, yeast and insect cells.

IL-18BP may also be produced by other recombinant cells such as prokaryotic cells, *e.g.*, E. coli, or other eukaryotic cells, such as yeast and insect cells. Well known methods are available for constructing appropriate vectors, carrying DNA that codes for either IL-18BP and suitable for transforming E. coli and yeast cells, or infecting insect cells in order to produce recombinant IL-18BP. For expression in yeast cells, the DNA coding for IL-18BP (Example 6) is cut out and inserted into expression vectors suitable for transfection of yeast cells. For expression in insect cells, a DNA coding for IL-18BP is inserted into baculovirus and the insect cells are infected with said recombinant baculovirus. For expression in E. coli, the DNA coding for IL-18BP is subjected to site directed mutagenesis with appropriate oligonucleotides, so that an initiation ATG codon is inserted just prior to the first codon of mature IL-18BP. Alternatively, such DNA can be prepared by PCR with suitable sense and antisense primers. The resulting cDNA constructs are then inserted into appropriately constructed prokaryotic expression vectors by techniques well known in the art (23).

Example 10: Construction of adeno-associated expression vector for in vivo expression of IL-18BPa

A functional gene coding for IL-18BPa is constructed based on plasmid pcDNA3 (Invitrogen, San Diego CA). The IL-18BP cDNA with a Kozak consensus sequence at the 5' end is ligated into the Xba I site of pcDNA3 in a way that destroys the restriction site. New Xba I sites are inserted by site-directed mutagenesis before the neomycin cassette (base 2151 of the original pcDNA3 sequence) and after the SV40 polyadenylation signal (base 3372 of the original pcDNA3 sequence). This construct is then cut with Xba I and the resulting 4.7 kb minigen is inserted at the Xba I site of plasmid psub201 as described (Snyder et al, 1996, Current Protocols in Human Genetics, Chapters 12.1.1-12.1.17, John Wiley & Sons). The resulting recombinant plasmid is cotransfected with the helper AAV plasmid pAAV/Ad into human T293 cells. The cultures are then infected with adenovirus as a helper virus and the cells are collected after 48-60 hours of incubation. The cells are subjected to 3 freeze-thaw cycles, cell debris is removed by centrifugation, and the supernatant is brought to 33% saturation with ammonium sulfate. The mixture is then centrifuged and rAAV is precipitated from the supernatant by bringing the ammonium sulfate to 50% saturation. The virus is

further purified by CsCl, dialyzed and finally heated for 15 min at 56°C to destroy any adenovirus.

Example 11: Construction of recombinant fusion proteins of IL-18BP

The production of proteins comprising IL-18BP fused to the constant region of IgG2 heavy chain may be carried out as follows: the DNA of IL-18BP is subjected to site-directed mutagenesis with appropriate oligonucleotides so that a unique restriction site is introduced immediately before and after the coding sequences. A plasmid bearing the constant region of IgG2 heavy chain, *e.g.* pRKCO42Fc1(6) is subjected to similar site-directed mutagenesis to introduce the same unique restriction site as close as possible to Asp 216 of IgG1 heavy chain in a way that allows translation in phase of the fused protein. A dsDNA fragment, consisting of 5' non-translated sequences and encoding for IL-18BP is prepared by digestion at the unique restriction sites or alternatively by PCR with appropriately designed primers. The mutated pRKCD42Fc1 is similarly digested to generate a large fragment containing the plasmid and the IgG1 sequences. The two fragments are then ligated to generate a new plasmid, encoding a polypeptide precursor consisting of IL-18BP and about 227 C-terminal amino acids of IgG1 heavy chain (hinge region and CH2 and CH3 domains). The DNA encoding the fused proteins may be isolated from the plasmid by digestion with appropriate restriction enzymes and then inserted into efficient prokaryotic or eukaryotic expression vectors.

Example 12 : Production of chemically modified IL-18BPs

In order to increase the half-life of the IL-18BPs in plasma, IL-18BPs which are chemically modified with polyethylene glycol (PEG) may be made. The modification may be done by cross linking PEG to a cysteine residue of the IL-18BP molecules. Mutant IL-18BPs may be constructed which contain an extra cysteine residue at the amino terminus, glycosylation sites, and the carboxyl terminus of each IL-18BP. The mutagenesis may be carried out by PCR using oligonucleotides containing the desired mutation. These mutant

proteins are expressed in the usual manner as well known in the art. Pegylation of these proteins will be carried out and the activity will be assessed.

Example 13: Preparation of polyclonal antibodies to IL-18BP

Rabbits were initially injected subcutaneously with 5 μg of a pure preparation of the urinary IL-18BP, emulsified in complete Freund's adjuvant. Three weeks later, they were injected again subcutaneously with 5 μg of the IL-18BP preparation in incomplete Freund's adjuvant. Two additional injections of IL-18BP as solution in PBS were given at 10 day intervals. The rabbits were bled 10 days after the last immunization. The development of antibody level was followed by a radioimmunoassay. ^{125}I-labeled IL-18BP (166,000 cpm) was mixed with various dilutions (1:50, 1:500, 1:5,000 and 1:50,000) of the rabbit serum. A suspension of protein-G agarose beads (20 μl, Pharmacia) was added in a total volume of 200 μl. The mixture was left for 1 hour at room temperature, the beads were then washed 3 times and bound radioactivity was counted. Rabbit antiserum to human leptin was used as a negative control. The titer of the IL-18R antiserum was between 1:500 and 1:5000, while that of the negative control was less than 1:50.

EXAMPLE 14: Preparation of monoclonal antibodies to IL-18BP

Female Balb/C mice (3 months old) are first injected with 2 μg purified IL-18BP in an emulsion of complete Freund's adjuvant, and three weeks later, subcutaneously in incomplete Freund's adjuvant. Three additional injections are given at 10 day intervals, subcutaneously in PBS. Final boosts are given intraperitoneally 4 and 3 days before the fusion to the mouse showing the highest binding titer as determined by IRIA (see below). Fusion is performed using NSO/1 myeloma cell line and lymphocytes prepared from both the spleen and lymph nodes of the animal as fusion partners. The fused cells are distributed into microculture plates and the hybridomas are selected in DMEM supplemented with HAT and 15% horse serum. Hybridomas that are found to produce antibodies to IL-18BP are subcloned by the limiting dilution method and injected into Balb/C mice that had been primed with pristane for the production of ascites. The isotypes of the antibodies are defined with the use of a commercially available ELISA kit (Amersham, UK).

The screening of hybridomas producing anti-IL-18BP monoclonal antibodies is performed as follows: Hybridoma supernatants are tested for the presence of anti-IL-18BP antibodies by an inverted solid phase radioimmunoassay (IRIA). ELISA plates (Dynatech Laboratories, Alexandria, VA) are coated with Talon-purified IL-18BPa-His_6 (10 µg/ml, 100 µl/well). Following overnight incubation at 4°C, the plates are washed twice with PBS containing BSA (0.5%) and Tween 20 (0.05%) and blocked in washing solution for at least 2 hrs at 37°C. Hybridoma culture supernatants (100 µl/well) are added and the plates are incubated for 4 hrs at 37°C. The plates are washed 3 times and a conjugate of goat-anti-mouse horseradish peroxidase (HRP, Jackson Labs, 1:10,000, 100 µl/well) is added for 2 hrs at room temperature. The plates are washed 4 times and the color is developed by ABTS (2,2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid, Sigma) with H_2O_2 as a substrate. The plates are read by an automatic ELISA reader. Samples giving OD that are at least 5 times higher than the negative control value are considered positive.

EXAMPLE 15: Affinity chromatography of IL-18BP with monoclonal antibodies

Antibodies against IL-18BP are utilized for the purification of IL-18BP by affinity chromatography. Ascitic fluid containing the monoclonal antibody secreted by the hybridoma is purified by ammonium sulfate precipitation at 50% saturation followed by extensive dialysis against PBS. About 10 mg of immunoglobulins are bound to 1 ml Affigel 10 (BioRad USA), as specified by the manufacturer.

250 ml of human urinary proteins (equivalent to 250 l of crude urine) are loaded on 0.5 ml of the anti IL-18BP antibody column at 4°C at a flow rate of 0.25 ml/min. The column is washed with PBS until no protein is detected in the washings. IL-18BP is eluted by 25 mM citric acid buffer, pH 2.2 (8 x 1 column volume fractions) and immediately neutralized by 1 M Na_2CO_3. Further purification of this preparation is obtained by size exclusion chromatography.

EXAMPLE 16: ELISA test

Microtiter plates (Dynatech or Maxisorb, by Nunc) are coated with anti-IL-18BP monoclonal antibody (serum free hybridoma supernatant or ascitic fluid immunoglobulins) overnight at 4°C. The plates are washed with PBS containing BSA (0.5%) and Tween 20 (0.05%) and blocked in the same solution for at least 2 hrs at 37°C. The tested samples are diluted in the blocking solution and added to the wells (100 µl/well) for 4 hrs at 37°C. The plates are then washed 3 times with PBS containing Tween 20 (0.05%) followed by the addition of rabbit anti-IL-18BP serum (1:1000, 100 µl/well) for further incubation overnight at 4°C. The plates are washed 3 times and a conjugate of goat-anti-rabbit horseradish peroxidase (HRP, Jackson Labs, 1:10,000, 100 µl/well) was added for 2 hrs at room temperature. The plates were washed 4 times and the color is developed by ABTS (2,2'-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid, Sigma) with H_2O_2 as a substrate. The plates are read by an automatic ELISA reader.

EXAMPLE 17 : Non-glycosylated human IL-18BP is biologically active.

Purified recombinant IL-18BPa was tested for its ability to inhibit the biological activity of IL-18. IL-18BPa inhibited in a dose dependent manner the IFN-γ inducing activity of human and mouse IL-18 in murine splenocytes, PBMC and the human KG-1 cell line (Fig. 9).

Purified IL-18BPa having an His_6 tag at the C-terminus (1.5 µg, 50 µl) was adjusted to pH 7.5 and mixed with N-glycosidase F (3 µl, 500,000 U/ml, PNGase F, New England Biolabs). The mixture was incubated for 24 h at 37°C under non-denaturing conditions. Aliquots from the sample and from undigested IL-18BP-His_6 were analyzed by SDS-PAGE under non-reducing conditions followed by immunoblotting with antibodies to IL-18PB. It was found that the ~40 kD band of IL-18BP-His_6 disappeared in the PNGase-treated fraction and a new ~20 kD band was obtained. The molecular mass of the product and the specificity of PNGase F indicated that IL-18BP-His_6 was fully deglycosylated.

The PNGase-treated fraction, undigested IL-18BP-His_6 and control sample containing PNGase in buffer were absorbed separately on Talon beads, washed with phosphate buffer and eluted with imidazole (100 mM). The eluted fractions were subjected to bioassay using human IL-18 (20 ng/ml), LPS (2 μg/ml) and murine splenocytes. The results are shown in the following table:

Sample	IFN-γ (ng/ml)
Control	7.5
Non-digested IL-18BP-His_6	0
PNGase-treated IL-18BP-His_6	0

Therefore, it is concluded that deglycosylated IL-18BP is biologically active as a modulator of IL-18 activity.

The foregoing description of the specific embodiments reveal the general nature of the invention so that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

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CLAIMS

1. An isolated polypeptide comprising an amino acid sequence selected from the group consisting of:

(a) an amino acid sequence selected from the group consisting of AA1-AA192 of SEQ ID NO: 2, AA29-AA192 of SEQ ID NO: 2, AA1-AA197 of SEQ ID NO: 6, and AA29-AA197 of SEQ ID NO: 6,

(b) a mutein of any one of the sequences in (a), wherein the amino acid sequence of said mutein has at least 70% identity to at least one of the sequences in (a);

wherein the polypeptide of (a) or (b) binds to IL-18.

2. The polypeptide of claim 1 wherein any changes in the amino acid residues in the mutein of (b) are conservative amino acid substitutions to the amino acid sequences in (a).

3. The polypeptide of claim 1 wherein the amino acid sequence comprises AA1-AA192 of SEQ ID NO: 2 or AA29-AA192 of SEQ ID NO: 2.

4. The polypeptide of claim 1, wherein the polypeptide is glycosylated at one or more sites.

5. The polypeptide of claim 1, wherein the polypeptide is not glycosylated.

6. The polypeptide of claim 1, wherein the polypeptide further comprises at least one moiety attached to one or more functional groups which occur as one or more side chains on the amino acid residues or the N- or C-terminal groups.

7. The polypeptide of claim 1, wherein the polypeptide is circularly permutated.

8. The polypeptide of claim 1, wherein the polypeptide is a non-viral protein.

9. The polypeptide of claim 1, wherein the polypeptide is a human protein.

10. The polypeptide of claim 1, wherein the polypeptide is a fused protein.

11. The polypeptide of claim 9 wherein the polypeptide

comprises an Ig fusion.

12. The polypeptide of claims 1 or 10, wherein the polypeptide is soluble.

13. The polypeptide of claim 1, wherein the polypeptide is pegylated.

14. The polypeptide of claim 5, wherein said at least one moiety is a polyethylene glycol moiety.

15. An isolated polypeptide that includes the amino acid sequence of AA1-192 of SEQ ID NO: 2 or AA29-AA192 of SEQ ID NO: 2, or conservatively substituted variants thereof.

16. An isolated polypeptide that includes the amino acid sequence of AA1-112 of SEQ ID NO: 4 or AA29-AA112 of SEQ ID NO: 4, or conservatively substituted variants thereof.

17. An isolated polypeptide that includes the amino acid sequence of AA1-197 of SEQ ID NO: 6 or AA29-AA197 of SEQ ID NO: 6, or conservatively substituted variants thereof.

18. An isolated polypeptide that includes the amino acid sequence of AA1-161 of SEQ ID NO: 8 or AA29-AA161 of SEQ ID NO: 8, or conservatively substituted variants thereof.

19. An isolated polypeptide that includes the amino acid sequence of AA29-40 of SEQ ID NO: 10 or AA1-AA40 of SEQ ID NO: 10, wherein the polypeptide binds to IL-18 and modulates or blocks the biological activity of IL-18.

20. The polypeptide of claim 19, wherein the polypeptide contains an Ig domain.

21. A purified IL-18 binding protein (IL-18BP), wherein the protein is characterized as follows:

(a) the protein has a molecular weight of about 40 kD as measured by SDS-PAGE in its originally glycosylated form;

(b) the protein binds to IL-18, and modulates or blocks the activity of IL-18; and

(c) the protein has an N-terminal sequence that includes the amino acid sequence of AA29-40 of SEQ ID NO: 10 or AA1-AA40 of SEQ ID NO: 10, or conservative amino acid substituents

thereof.

22. An active fragment of the IL-18BP protein of claims 1 or 21, wherein the active fragment binds to IL-18, and modulates or blocks the activity of IL-18.

23. An isolated IL-18BP polypeptide having an N-terminal sequence that includes the amino acid sequence of AA29-40 of SEQ ID NO: 10 or AA1-AA40 of SEQ ID NO: 10, or conservative amino acid substituents thereof, and an Ig domain, wherein the polypeptide binds to IL-18, and modulates or blocks the activity of IL-18.

24. A mixture of any of the polypeptides according to claims 1, 15-19, 21 and 22.

25. An isolated nucleic acid molecule comprising a nucleic acid sequence encoding a polypeptide comprising an amino acid sequence selected from the group consisting of:

(a) an amino acid sequence selected from the group consisting of AA1-AA192 of SEQ ID NO: 2, AA29-AA192 of SEQ ID NO: 2, AA1-AA112 of SEQ ID NO: 4, AA29-AA112 of SEQ ID NO: 4, AA1-AA197 of SEQ ID NO: 6, AA29-AA197 of SEQ ID NO: 6, AA1-AA161 of SEQ ID NO: 8, and AA29-AA161 of SEQ ID NO: 8,

(b) a mutein of any one of the sequences in (a), wherein the amino acid sequence of said mutein has at least 70% identity to at least one of the sequences in (a).

26. An isolated nucleic acid molecule, comprising a nucleic acid sequence selected from the group selected of:

(a) a nucleic acid sequence of SEQ ID NO: 1 encoding AA1-AA192 of SEQ ID NO: 2 or AA29-AA192 of SEQ ID NO: 2;

(b) a nucleic acid sequence of SEQ ID NO: 3 encoding AA1-AA112 of SEQ ID NO: 4 or AA29-AA112 of SEQ ID NO: 4;

(c) a nucleic acid sequence of SEQ ID NO: 5 encoding AA1-AA197 of SEQ ID NO: 6 or AA29-AA197 of SEQ ID NO: 6;

(d) a nucleic acid sequence of SEQ ID NO: 7 encoding AA1-AA161 of SEQ ID NO: 8 or AA29-AA161 of SEQ ID NO: 8;

(e) a nucleic acid sequence whose complement binds, under

high stringency conditions, to any one of the nucleic acid sequences in (a) through (d) and which encodes an amino acid sequence selected from the group consisting of AA1-AA192 of SEQ ID NO: 2, AA29-AA192 of SEQ ID NO: 2, AA1-AA112 of SEQ ID NO: 4, AA29-AA112 of SEQ ID NO: 4, AA1-AA197 of SEQ ID NO: 6, AA29-AA197 of SEQ ID NO: 6, AA1-AA161 of SEQ ID NO: 8, and AA29-AA161 of SEQ ID NO: 8.

27. An isolated nucleic acid molecule containing the nucleic acid sequence of SEQ ID NO: 9, or a nucleic acid sequence whose complement binds, under high stringency conditions, thereto.

28. An isolated nucleic acid molecule comprising a nucleotide sequence selected from the group consisting of SEQ ID NO: 1, 3, 5 and 7 or a mature protein encoding portion of any one of SEQ ID NO: 1, 3, 5 and 7.

29. A method for identifying, isolating or amplifying an IL-18BP encoding nucleic acid sequence, comprising using the nucleic acids of any one of claims 25-28 as a primer or probe.

30. A vector comprising the nucleic acid molecule of any one of claims 25-28.

31. The vector of claim 30, further comprising a promoter operably linked to said nucleic acid molecule.

32. A strain of eukaryotic cells that has been genetically modified to produce a polypeptide according to any one of claims 1-23.

33. A strain of prokaryotic cells that has been genetically modified to produce a polypeptide according to any one of claims 1-23.

34. The strain of claim 32 or 33 wherein the cells have been genetically modified with the vector of claim 30.

35. The strain of claim 32, wherein the cells are mammalian cells.

36. A method for production of the polypeptide of any one of claims 1-23, comprising culturing the cell strain of claims

32-35 under conditions suitable for expression of said polypeptide.

37. A monoclonal antibody that immunospecifically binds to the polypeptide of any one of claims 1-23.

38. The antibody of claim 37, wherein the antibody is a humanized antibody.

39. A method for detecting an IL-18BP in a sample, comprising contacting said sample with an antibody of claim 37 and further detecting the presence of bound antibody.

40. A method for purifying an IL-18BP polypeptide, comprising contacting an IL-18BP sample with an IL-18BP antibody of claim 37, removing unbound protein in the sample and then eluting the bound IL-18BP.

41. A process for the isolation or purification of an IL-18BP according to any one of claims 1-23, comprising:

(a) passing a sample through a chromatographic column to which IL-18 is coupled;

(b) washing the column to remove unbound protein in the sample, and

(c) eluting the bound IL-18 BP.

42. A process for the isolation or purification of an IL-18BP according to any one of claims 1-23, comprising contacting a sample with a substrate to which IL-18 is coupled, removing unbound protein in the sample and then eluting the bound IL-18BP.

43. A method for the preparation of an IL-18BP derivative comprising preparing a DNA construct that encodes a polypeptide according to claims 1, 15-19 and 21-23, ligated to a nucleic acid encoding a second polypeptide, wherein on expression, said DNA construct encodes a fusion protein comprising the polypeptide of any one of claims 1, 15-19 and 21-23, fused to the second polypeptide.

44. The method of claim 43 wherein the second polypeptide is Ig.

45. A method for the preparation of an IL-18BP derivative comprising chemically modifying a polypeptide according to claims 1 or 15-19, to include at least one derivative moiety.

46. The method of claim 45 wherein the derivative moiety is a polyethylene glycol moiety.

47. A composition comprising the polypeptides of any one of claims 1-24 and a pharmaceutically acceptable carrier.

48. A composition comprising the nucleic acid molecule of any one of claims 25-28 and a pharmaceutically acceptable carrier.

49. A composition comprising the antibody of claim 37 or 38 and a pharmaceutically acceptable carrier.

50. A kit, comprising in one or more vials, the pharmaceutical composition of claim 47.

51. A kit, comprising in one or more vials, the pharmaceutical composition of claim 48.

52. A kit, comprising in one or more vials, the pharmaceutical composition of claim 49.

53. An isolated nucleic acid molecule comprising a nucleic acid sequence encoding a polypeptide comprising an amino acid sequence selected from the group consisting of:

(a) an amino acid sequence selected from the group consisting of AA1-AA192 of SEQ ID NO: 2, AA29-AA192 of SEQ ID NO: 2, AA1-AA197 of SEQ ID NO: 6, AA29-AA197 of SEQ ID NO: 6;

(b) a mutein of any one of the sequences in (a), wherein the amino acid sequence of said mutein has at least 70% identity to at least one of the sequences in (a);

wherein said nucleic acid molecule encodes for a polypeptide that binds IL-18.

54. An isolated nucleic acid molecule, comprising a nucleic acid sequence selected from the group consisting of:

(a) a nucleic acid sequence of SEQ ID NO: 1 encoding AA1-AA192 of SEQ ID NO: 2 or AA29-AA192 of SEQ ID NO: 2;

(b) a nucleic acid sequence of SEQ ID NO: 5, encoding

AA1-AA197 of SEQ ID NO: 6 or AA29-AA197 of SEQ ID NO: 6;

(c) a nucleic acid sequence whose complement binds, under high stringency conditions, to any one of the nucleic acid sequences in (a) through (b);

wherein said nucleic acid encodes a polypeptide that binds IL-18.

55. A recombinant DNA molecule comprising the nucleic acid molecule according to claim 53 or 54, ligated to a second nucleic acid encoding a second polypeptide wherein on expression, said recombinant DNA molecule encodes a fusion protein comprising the polypeptide of any one of claims 1, 15-19 and 21-23, fused to the second polypeptide.

56. Use of IL-18BP according to any one of claims 1 to 24 for the manufacture of a medicament for the treatment and/or prevention of liver injury.

57. The use according to claim 56, wherein the liver injury is acute.

58. The use according to claim 56, wherein the liver injury is chronic.

59. The use according to any one of claims 56 to 58, wherein the liver injury is alcoholic hepatitis, viral hepatitis, immune hepatitis, fulminant hepatitis, liver cirrhosis, and primary billary cirrhosis.

60. The use according to claim 59, wherein the liver injury is fulminant hepatitis.

61. Use of IL-18BP according to any one of claims 1 to 24 for the manufacture of a medicament for the treatment and/or prevention of arthritis.

62. The use according to claim 61, wherein arthritis is inflammatory arthritis.

63. The use according to claim 62, wherein inflammatory arthritis is rheumatoid arthritis.

64. Use of IL-18BP according to any one of claims 1 to 24 for the manufacture of a medicament for the treatment and/or

prevention of cartilage destruction.

65. Use of IL-18BP according to any one of claims 1 to 24 for the manufacture of a medicament for the treatment and/or prevention of an inflammatory bowel disease.

66. The use according to claim 65, wherein the inflammatory bowel disease is Crohn's disease.

67. The use according to claim 65, wherein the inflammatory bowel disease is ulcerative colitis.

68. The use according to any one of claims 56 to 67, wherein said medicament is administered subcutaneously.

69. The use according to any one of claims 56 to 67, wherein said medicament is administered intramuscularly.

70. The use according to any one of claims 56 to 69, wherein said medicament is administered daily.

71. The use according to any one of claims 56 to 69, wherein said medicament is administered every other day.

72. Use of the vector of claim 30 or 31 in the manufacture of a medicament for the treatment and/or prevention of liver injury.

73. Use of the vector of claim 30 or 31 in the manufacture of a medicament for the treatment and/or prevention of arthritis.

74. Use of the vector of claim 30 or 31 in the manufacture of a medicament for the treatment and/or prevention of inflammatory bowel disease.

75. Use according to any of claims 72 to 74 for gene therapy.

76. Use of the vector of claim 30 or 31 for inducing and/or enhancing the endogenous production of IL-18BP in a cell in the manufacture of a medicament for the treatment and/or prevention of liver injury.

77. Use of the vector of claim 30 or 31 for inducing and/or enhancing the endogenous production of IL-18BP in a cell in the manufacture of a medicament for treatment and/or

prevention of arthritis.

78. Use of the vector of claim 30 or 31 for inducing and/or enhancing the endogenous production of IL-18BP in a cell in the manufacture of a medicament for the treatment and/or prevention of inflammatory bowel disease.

79. Use of the strain of cells according to any one of claims 32 to 35 in the manufacture of a medicament for the treatment and/or prevention of liver injury.

80. Use of the strain of cells according to any one of claims 32 to 35 in the manufacture of a medicament for the treatment and/or prevention of arthritis.

81. Use of the strain of cells according to any one of claims 32 to 35 in the manufacture of a medicament for the treatment and/or prevention of inflammatory bowel disease.