IL-1 ANTAGONIST FORMULATIONS

BACKGROUND OF INVENTION

Field of the Invention

[0001] The present invention is directed to pharmaceutical formulations comprising agents capable of inhibiting interleukin-1 (IL-1), and to methods for making and using such formulations.

Statement of Related Art

[0002] Interleukin-1 (IL-1) antagonists capable of blocking or inhibiting the biological action of IL-1, have been described. An example IL-1 antagonist, an IL-1 trap, is described in U.S. Patent Publication No. 2003/0143697, published 31 July 2003. An IL-1 trap is an IL-1-specific fusion protein comprising two IL-1 receptor components and a multimerizing component.

[0003] Lyophilization (freeze drying under controlled conditions) is commonly used for long term storage of proteins. The lyophilized protein is substantially resistant to degradation, aggregation, oxidation, and other degenerative processes while in the freeze dried state (see, for example, U.S. 6,436,897).

BRIEF SUMMARY OF THE INVENTION

[0004] Stable formulations of an interleukin-1 (IL-1) antagonist are herein provided. The pharmaceutically acceptable formulations of the invention comprise an IL-1 trap with a pharmaceutically acceptable carrier. In specific embodiments, liquid and freeze-dried, or lyophilized formulations are provided.

[0005] In a first example aspect, the invention features a pre-lyophilization formulation of an interleukin-1 (IL-1) antagonist, comprising an IL-1 protein antagonist capable of binding to and inhibiting the biological action of IL-1, a buffer, an organic co-solvent or bulking agent, and one or more lyoprotectants. In a specific embodiment, the IL-1 antagonist is a fusion protein capable of binding to IL-1, the buffer is histidine, the organic co-solvent or bulking agent is PEG, and the lyoprotectant(s) is at least one of glycine, arginine, and sucrose. In one embodiment, the pre-lyophilized formulation of the invention does not contain a preservative.

[0006] In one embodiment of the pre-lyophilization formulation of the invention, the formulation comprises 5-100 mM histidine, 0.5-3.0% PEG, 0.25-3.0% glycine, 5-50 mM arginine, 0.5-30.0% sucrose, and 5-50 mg/ml of an IL-1 antagonist, at a pH of about 6.5. In one embodiment, the pre-lyophilization formulation may further comprise up to 5 mM citrate and/or 0.003-0.005% polysorbate. The polysorbate present may be, for example, polysorbate 20 or 80.

[0007] In a more specific embodiment, the pre-lyophilization formulation of an IL-1 antagonist comprises about 20 mM histidine, about 1.5% PEG 3350, about 0.5% glycine, about 25 mM

arginine, about 1.0% sucrose, and about 40 mg/ml IL-1 trap, at a pH of about 6.5. In a specific embodiment, the IL-1 antagonist is an IL-1 trap fusion protein as shown in SEQ ID NO:2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26. More preferably, the IL-1 trap is the trap shown in SEQ ID NO:10.

[0008] In a preferred embodiment, the pre-lyophilization IL-1 antagonist formulation consists essentially of about 20 mM histidine, about 1.5% PEG 3350, about 0.5% glycine, about 25 mM arginine, about 1.0% sucrose, and about 40 mg/ml of the IL-1 fusion protein having the sequence of SEQ ID NO:10, at a pH of about 6.5. Citrate (less than or equal to about 0.15 mM) and polysorbate (less than or equal to about 0.005%) may be present.

[0009] In a second aspect, the invention features a pre-lyophilization IL-1 antagonist formulation that consists essentially of about 20 mM histidine, about 1.5% PEG 3350, about 0.5% glycine, about 25 mM arginine, about 1.0% sucrose, and about 40 mg/ml of the IL-1 fusion protein having the sequence of SEQ ID NO:10, at a pH of about 6.5, wherein the pre-lyophilization formulation does not contain a preservative, a phosphate buffer, more than trace amounts of NaCl, and/or more than 1.5% sucrose. Citrate may be present in amounts of less than about 0.15 mM and up to about 0.005-0.01% polysorbate 20 may also be present.

[0010] In a third aspect, the invention features a method of producing a lyophilized formulation of an IL-1 antagonist, comprising subjecting the pre-lyophilization IL-1 antagonist formulation of the invention to lyophilization to generate a lyophilized IL-1 antagonist formulation. The lyophilized formulation may be lyophilized by any method known in the art for lyophilizing a liquid.

[0011] In a fourth related aspect, the invention features a method of producing a reconstituted lyophilized formulation of an IL-1 antagonist, comprising reconstituting the lyophilized formulation of the invention to a reconstituted formulation. In one embodiment, the reconstituted formulation is twice the concentration of the pre-lyophilized formulation, e.g., the method of the invention comprises: (a) producing a pre-lyophilization formulation of an IL-1 antagonist consisting of about 20 mM histidine, about 1.5% PEG 3350, about 0.5% glycine, about 25 mM arginine, about 1.0% sucrose, and about 40 mg/ml of an IL-1 protein antagonist, at a pH of about 6.5; (b) subjecting the pre-lyophilized formulation of step (a) to lyophilization; and (c) reconstituting the lyophilized formulation of step (b) to a composition consisting of about 40 mM histidine, about 3% PEG 3350, about 1% glycine, about 50 mM arginine, about 2.0% sucrose, and about 80 mg/ml of the IL-1 protein antagonist, wherein the reconstituted formulation may further contain about 0.2 mM citrate and/or about 0.008% polysorbate 20. In a specific embodiment, the IL-1 antagonist is an IL-1 trap fusion protein as shown in SEQ ID NO:2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26. More preferably, the IL-1 trap is the trap shown in SEQ ID NO:10. In separate embodiments, the reconstituted formulation is 3 times the concentration of the pre-lyophilized formulation, e.g., a 20 mg IL-1 antagonist protein/ml pre-lyophilization

formulation is reconstituted to a final formulation of 60 mg IL-1 antagonist protein/ml. Generally, the lyophilized formulation is reconstituted with sterile water suitable for injection. In one embodiment, the reconstitution liquid may be bacteriostatic water.

[0012] In specific embodiments of the method of producing a reconstituted lyophilized formulation, a pre-lyophilization solution is present in a vial as a 40 mg IL-1 antagonist protein per ml solution of pre-lyophilization formulation, which is lyophilized and reconstituted to an 80 mg/ml solution. In another embodiment, a 20 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 40 mg/ml solution. In another embodiment, a 25 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 50 mg/ml solution. In another embodiment, a 12.5 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 25 mg/ml solution. In another embodiment, a 12.5 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 50 mg/ml solution. In another embodiment, a 25 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 75 mg/ml solution. In another embodiment, a 40 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 120 mg/ml solution. In another embodiment, a 40 mg/ml pre-lyophilization solution is lyophilized and reconstituted to a 20 mg/ml solution. Preferably, the reconstituted lyophilized formulation does not contain a preservative. In another embodiment, the reconstituted formulation includes up to 30% sucrose and one or more preservatives.

[0013] In a fifth aspect, the invention features a stable liquid formulation of an IL-1 antagonist, comprising an IL-1 antagonist protein capable of binding to and inhibiting the biological action of IL-1, a buffer, an organic co-solvent, and one or more thermal stabilizers. In a specific embodiment, the IL-1 antagonist is an IL-1 trap fusion protein as shown in SEQ ID NO:2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26. More preferably, the IL-1 trap is the trap shown in SEQ ID NO:10. In one embodiment, the buffer is a phosphate buffer. In one embodiment, the organic co-solvent agent is PEG, preferably PEG 3350. In one embodiment, the thermal stabilizers are NaCl and/or sucrose. More preferably, the thermal stabilizers are both NaCl and sucrose.

[0014] In a specific embodiment, the stable liquid formulation of an IL-1 antagonist comprises 5-100 mM phosphate buffer, 0.5-3% PEG, 25-150 mM NaCl, 5-30% sucrose, 10-500 mg/ml of an IL-1 trap protein, at a pH of about 6-6.5. In a more specific embodiment, the stable liquid formulation of an IL-1 antagonist comprises 10 mM phosphate buffer, 3% PEG 3350, 50 mM NaCl, 5-20% sucrose, 12.5-50 mg/ml of an IL-1 trap protein, at a pH of about 6-6.5. Additionally, low or trace amounts of a citrate buffer or polysorbate may be present. The stable liquid formulation of the IL-1 antagonist of the invention exhibits little or no precipitation as determined by visual inspection after storage of a 50 mg/ml IL-1 trap formulation for up to about 29 months at 5°C. Further, little or no aggregation is observed as determine by size-exclusion chromatography, e.g., HPLC, after storage of a 50 mg/ml IL-1 trap formulation for up to about 24 months at 5°C.

[0015] Other objects and advantages will become apparent from a review of the ensuing detailed description.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention is not limited to particular methods, and experimental conditions described, as such methods and conditions may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting unless indicated, since the scope of the present invention will be limited only by the appended claims.

[0017] As used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise. Thus for example, references to "a method" include one or more methods, and/or steps of the type described herein and/or which will become apparent to those persons skilled in the art upon reading this disclosure.

[0018] Unless stated otherwise, all technical and scientific terms and phrases used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described.

General Description

[0019] Safe handling and administration of formulations comprising proteins represent significant challenges to pharmaceutical formulators. Proteins possess unique chemical and physical properties that present stability problems: a variety of degradation pathways exist for proteins, implicating both chemical and physical instability. Chemical instability includes deamination, aggregation, clipping of the peptide backbone, and oxidation of methionine residues. Physical instability encompasses many phenomena, including, for example, aggregation.

[0020] Chemical and physical stability can be promoted by removing water from the protein. Lyophilization (freeze-drying under controlled conditions) is commonly used for long-term storage of proteins. The lyophilized protein is substantially resistant to degradation, aggregation, oxidation, and other degenerative processes while in the freeze-dried state. The lyophilized protein is normally reconstituted with water optionally containing a bacteriostatic preservative (e.g., benzyl alcohol) prior to administration.

Definitions

[0021] By the term "therapeutically or pharmaceutically effective dose" is meant a dose that produces the desired effect for which it is administered. The exact dose will depend on the

purpose of the treatment, and will be ascertainable by one skilled in the art using known techniques (see, for example, Lloyd (1999) The Art, Science and Technology of Pharmaceutical Compounding).

[0022] By the term "blocker", "inhibitor", or "antagonist" is meant a substance that retards or prevents a chemical or physiological reaction or response. Common blockers or inhibitors include, but are not limited to, antisense molecules, antibodies, antagonists and their derivatives.

[0023] The term "pharmaceutically acceptable" includes approval by a regulatory agency of the federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly in humans.

[0024] The term "carrier" includes a diluent, adjuvant, excipient, or vehicle with which a composition is administered. Carriers can include sterile liquids, such as, for example, water and oils, including oils of petroleum, animal, vegetable or synthetic origin, such as, for example, peanut oil, soybean oil, mineral oil, sesame oil and the like.

[0025] The term "excipient" includes a non-therapeutic agent added to a pharmaceutical composition to provide a desired consistency or stabilizing effect. Suitable pharmaceutical excipients include, for example, starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene glycol, water, ethanol and the like.

[0026] The term "lyophilized" or "freeze-dried" includes a state of a substance that has been subjected to a drying procedure such as lyophilization, where at least 50% of moisture has been removed.

[0027] The phrase "bulking agent" includes a compound that is pharmaceutically acceptable and that adds bulk to a lyo cake. Generally, acceptable bulking agents known to the art include, for example, carbohydrates, including simple sugars such as dextrose, ribose, fructose and the like, alcohol sugars such as mannitol, inositol and sorbitol, disaccharides including trehalose, sucrose and lactose, naturally occurring polymers such as starch, dextrans, chitosan, hyaluronate, proteins (e.g., gelatin and serum albumin), glycogen, and synthetic monomers and polymers. In the formulations of the invention, PEG 3350 is an organic co-solvent which is used to stabilize the IL-1 protein antagonist when agitated, mixed, or handled, and as a bulking agent to help produce an acceptable bulk.

[0028] The term "lyoprotectant" includes a substance that may be added to a freeze-dried or lyophilized formulation to help maintain protein structure when freeze-dried or lyophilized.

[0029] A "preservative" includes a bacteriostatic, bacteriocidal, fungistatic or fungicidal compound that is generally added to formulations to retard or eliminate growth of bacteria or other contaminating microorganisms in the formulations. Preservatives include, for example, benzyl alcohol, phenol, benzalkonium chloride, m-cresol, thimerosol, chlorobutanol,

methylparaben, propylparaben and the like. Other examples of pharmaceutically acceptable preservatives can be found in the USP.

IL-1 Antagonists

[0030] An IL-1 antagonist is a compound capable of blocking or inhibiting the biological action of IL-1, including fusion proteins capable of trapping IL-1, such as an IL-1 trap. In a preferred embodiment, the IL-1 trap is an IL-1-specific fusion protein comprising two IL-1 receptor components and a multimerizing component, for example, an IL-1 trap described in U.S. Patent Publication No. 2003/0143697, published 31 July 2003. In a specific embodiment, the IL-1 trap is the fusion protein shown in SEQ ID NO:2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26. A preferred IL-1 trap is shown in SEQ ID NO:10. The invention encompasses the use of an IL-1 trap substantially identical to the protein of SEQ ID NO: 2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26, that is, a protein having at least 95% identity, preferably at least 97% identity, and more preferably at least 98% identity to the protein of SEQ ID NO: 2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26 and capable of binding and inhibiting IL-1. Further, in specific embodiments, the IL-1 antagonist is a modified IL-1 trap comprising one or more receptor components and one or more immunoglobulin-derived components specific for IL-1 and/or an IL-1 receptor. In another embodiment, the IL-1 antagonist is a modified IL-1 trap comprising one or more immunoglobulin-derived components specific for IL-1 and/or an IL-1 receptor.

[0031] The IL-1 trap of the methods and formulations of the invention can be prepared by any suitable method known in the art, or that comes to be known, that is useful in preparing an IL-1 trap. The IL-1 trap is preferably substantially free of protein contaminants at the time it is used to prepare the pharmaceutically acceptable formulation. By "substantially free of protein contaminants" is meant, preferably, that at least 90 % of the weight of protein of an IL-1 trap preparation used for making a formulation comprising an IL-1 trap is IL-1 trap protein, more preferably at least 95%, most preferably at least 99%. The IL-1 trap is preferably substantially free of aggregates. "Substantially free of aggregates" means that at least 90% of the weight of IL-1 trap protein is not present in an aggregate at the time the IL-1 trap is used to prepare the pharmaceutically effective formulation. The IL-1 trap of the methods and formulations of the invention may contain low or trace amounts of compounds as a results of the purification process, for example, low or trace amounts of citrate and/or polysorbate. In one embodiment of the pre-lyophilization formulation of the invention containing about 40 mg of IL-1 trap/ml, citrate may be present at a concentration of about 0.1 mM and/or polysorbate may be present at a concentration of about 0.004%. If the pre-lyophilization formulation is reconstituted after lyophilization to half of the original volume (e.g., 80 mg/ml of IL-1 trap), the resulting concentrations may be 0.2 mM citrate and/or 0.008% polysorbate. If the pre-lyophilization

formulation is reconstituted after lyophilization to a third of the original volume (e.g., 120 mg/ml of IL-1 trap), the resulting concentrations may be 0.6 mM citrate and/or 0.012% polysorbate.

Lyophilization and Lyophilized Formulations

[0032] In one aspect of the invention, a pharmaceutically acceptable formulation comprising an IL-1 trap is provided, wherein the formulation is a freeze-dried or lyophilized formulation. Preferably, the freeze-dried or lyophilized formulation comprises a pharmaceutically effective amount of an IL-1 trap. Lyophilized formulations can be reconstituted into solutions, suspensions, emulsions, or any other suitable form for administration or use. Lyophilized formulations are typically first prepared as liquids, then frozen and lyophilized. The total liquid volume before lyophilization can be less, equal to, or more than, the final reconstituted volume of the lyophilized formulation. The lyophilization process is well known to those of ordinary skill in the art, and typically includes sublimation of water from a frozen formulation under controlled conditions.

[0033] Lyophilized formulations can be stored at a wide range of temperatures. Lyophilized formulations may be stored at or below 30°C, for example, refrigerated at 4°C, or at room temperature (e.g., approximately 25°C). Preferably, lyophilized formulations are stored below about 25°C, more preferably, at about 4-20°C; below about 4°C; below about -20°C; about -40°C; or about -70°C.

[0034] Lyophilized formulations are typically reconstituted for use by addition of an aqueous solution to dissolve the lyophilized formulation. A wide variety of aqueous solutions can be used to reconstitute a lyophilized formulation. Preferably, lyophilized formulations are reconstituted using water. Lyophilized formulations are preferably reconstituted with a solution consisting essentially of water (e.g., USP WFI, or water for injection) or bacteriostatic water (e.g., USP WFI with 0.9% benzyl alcohol). However, solutions comprising buffers and/or excipients and/or one or more pharmacetically acceptable carries can also be used.

[0035] Freeze-dried or lyophilized formulations are typically prepared from liquids, that is, from solutions, suspensions, emulsions, and the like. Thus, the liquid that is to undergo freeze-drying or lyophilization preferably comprises all components desired in a final reconstituted liquid formulation. As a result, when reconstituted, the freeze-dried or lyophilized formulation will render a desired liquid formulation upon reconstitution. A preferred liquid formulation used to generate a freeze-dried or lyophilized formulation comprises an IL-1 trap in a pharmaceutically effective amount, a buffer, a stabilizer, and a bulking agent. Freeze-dried or lyophilized formulations preferably comprise histidine, since histidine, in comparison to phosphate, is more effective at stabilizing the IL-1 trap when the IL-1 trap is lyophilized. Organic cosolvents, such as PEG 3350, are used to stabilize the IL-1 trap when agitated, mixed, or handled. A lyoprotectant is preferably used in freeze-dried or lyophilized formulations. Lyoprotectants help

to maintain the secondary structure of proteins when freeze-dried or lyophilized. Three preferred example lyoprotectants are glycine, arginine, and sucrose, which are preferably used together.

Stable Liquid Formulations

[0036] In one aspect, the invention provides a stable pharmaceutically acceptable formulation comprising an IL-1 trap, wherein the formulation is a liquid formulation. Preferably, the liquid formulation comprises a pharmaceutically effective amount of an IL-1 trap. The formulation can also comprise one or more pharmaceutically acceptable carriers, buffers, bulking agents, stabilizers, preservatives, and/or excipients. An example of a pharmaceutically acceptable liquid formulation comprising an IL-1 trap comprises an IL-1 trap in a pharmaceutically effective amount, a buffer, a co-solvent, and one or more stabilizers.

[0037] A preferred liquid formulation comprises phosphate buffer, an organic co-solvent, and one or more thermal stabilizers to minimize formation of aggregates and low molecular weight products when stored, and about 12.5 mg/ml to about 50 mg/ml IL-1 trap, wherein the formulation is from about pH 6.0 to about pH 6.75. A more preferred liquid formulation comprises 10 mM phosphate buffer, 3% PEG, 50 mM NaCl, 5-20% sucrose, and 10-100 mg/ml IL-1 trap, wherein the formulation is at a pH of about 6.0 to about 6.5. Although either NaCl or sucrose can be used as a stabilizer, a combination of NaCl and sucrose has been established to stabilize the IL-1 trap more effectively than either individual stabilizer alone. Preferably, PEG is PEG 3350, which has been established to enhance IL-1 trap stability.

[0038] Table 1 shows the percent of native IL-1 trap or percent aggregated IL-1 trap in samples containing either 5 or 20% sucrose as determined over a period of up to 24 months when incubated at 5°C. In the presence of 20% sucrose, the native (non-aggregated) form of IL-1 trap dropped from 92.6% at day 0 to 88.9% at 24 months and the percentage aggregate increased from 2.3% to 3.4% over the same time period. The 5% sucrose formulation had a native (non-aggregated) form of IL-1 trap dropped from 92.4% at day 0 to 86.9% at 24 months and the percentage aggregate increased from 2.6% to 3.6% over the same time period.

TABLE 1

Incubation time at 5 °C (months)	% Native (20% sucrose)	% Aggregate (20% sucrose)	% Native (5% sucrose)	% Aggregate (5% sucrose)
0	92.6	2.3	92.4	2.6
1.0	92.6	2.4	92.5	2.5
2.0	91.9	2.6	91.5	2.9
6.0	91.6	2.8	91.0	2.9
18	91.8	3.2	90.7	3.6
21.0	91.3	2.9	89.5	3.6
24.0	88.9	3.4	86.9	3.6

[0039] Table 2 shows the percent of native IL-1 trap in samples containing either 0, 5 or 20% sucrose as determined over a period of up to 2.9 months when incubated at 5°C (50 mg/ml IL-1 trap, 10 mM Phosphate, 0.2% polysorbate-20, 50 or 135 (with 0% sucrose) mM NaCl, pH 6.5. In the presence of 0% sucrose, the native (non-aggregated) form of IL-1 trap dropped from 96.4% at day 0 to 0.5% at 2.9 months. The 5% sucrose formulation had a native (non-aggregated) form of IL-1 trap which dropped from 96.5% at day 0 to 39.2% at 2.9 months. The 20% sucrose formulation had a native (non-aggregated) form of IL-1 trap which dropped from 96.4% at day 0 to 95.3% at 2.9 months.

TABLE 2

Incubation Time (months)	% Native (0% Sucrose)	% Native (5% sucrose)	% Native (20% sucrose)
0	96.4	96.5	96.4
1	96.7	89.3	96.2
2.9	0.5	39.2	95.3

[0040] Formulations, whether liquid or freeze-dried and lyophilized, can be stored in an oxygen-deprived environment. Oxygen-deprived environments can be generated by storing the formulations under an inert gas such as, for example, argon, nitrogen, or helium.

[0041] The stability of pre-lyophilized and lyophilized formulations was determined. A pre-lyophilized formulation containing 40 mg/ml IL-1 trap (SEQ ID NO:10), 20 mM histidine, 1.5% PEG-3350, 1% sucrose, 0.5% glycine, 25 mM arginine-HCl, pH 6.5 was incubated at 5°C for 0-52 weeks. As shown in Table 3, the native (non-aggregated) form of IL-1 decreased from 94.9 (0 weeks) to 92.3 (52 weeks), and the percent aggregate increased from 1% to 1.8% in the same time period.

TABLE 3

Incubation time (weeks at 5°C)	% Native	% Aggregate
0	94.9	1.0
4	94.3	1.3
12	93.5	1.7
24	93.3	1.5
36	92.6	1.5
52	92.3	1.8

[0042] The stability of a lyophilized formulation containing 40 mg/ml IL-1 trap (SEQ ID NO:10), 20 mM histidine, 1.5% PEG-3350, 1% sucrose, 0.5% glycine, 25 mM arginine-hcl, pH 6.5 (pre-lyophilized concentrations) was incubated at 25°C for 0-56 weeks. As shown in Table 4, the native (non-aggregated) form of IL-1 decreased from 97.0 (0 weeks) to 94.0 (56 weeks), and the

percent aggregate increased from 0.8% to 3.6% in the same time period.

TABLE 4

Incubation time (weeks at 25°C)	% Native	% Aggregate
0	97.0	0.8
3.9	96.3	1.4
6.1	95.5	1.5
12.3	95.4	1.9
25.7	94.7	2.2
39.3	94.4	2.9
56	94.0	3.6

[0043] Although the foregoing invention has been described in some detail by way of illustration and examples, it will be readily apparent to those of ordinary skill in the art that certain changes and modifications may be made to the teachings of the invention without departing from the spirit or scope of the appended claims.

We claim:

1. A formulation suitable for lyophilization, comprising 5-100 mM histidine, 0.5-3.0% PEG, 0.25-3% glycine, 5-50 mM arginine, 0.5-30% sucrose, and 5-50 mg/ml of an IL-1 protein antagonist.

2. The formulation of claim 1, wherein the IL-1 antagonist is a dimer of a fusion protein selected from SEQ ID NO:2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, and 26; preferably SEQ ID NO:10.

3. The formulation of claims 1 or 2, comprising about 20 mM histidine, about 1.5% PEG 3350, about 0.5% glycine, about 25 mM arginine, about 1.0% sucrose, and about 40 mg/ml IL-1 antagonist.

4. The formulation of any one of the preceding claims which does not contain a phosphate buffer, more than about 1.5% sucrose, more than about 0.15 mM citrate and more than about 0.005% polysorbate 20.

5. The formulation of any one of the preceding claims, wherein pH may be from 6 to 6.75, preferably 6 to 6.5; more preferably 6.5.

6. A method of producing a lyophilized formulation of an IL-1 antagonist, comprising reconstituting the formulation of claim of any one of the preceding claims to to generate a lyophilized IL-1 antagonist formulation.

7. The method of claim 6, wherein the reconstituted formulation comprises about 20-120 mg/ml of the IL-1 antagonist.

8. A stable liquid formulation, comprising an IL-1 protein antagonist capable of binding and inhibiting the biological action of IL-1, a buffer, an organic co-solvent or bulking agent, and one or more thermal stabilizers, wherein the IL-1 antagonist is a dimer comprising two fusion proteins shown in SEQ ID NO:2, 4, 6, 8, 10, 12,14, 16, 18, 20, 22, 24, 26.

9. The liquid formulation of claim 8, wherein the fusion protein comprise SEQ ID NO:10.

10. The liquid formulation of claim 8 or 9, comprising 5-100 mM phosphate buffer, preferably 10 mM phosphate buffer; 0.5-3% PEG 3350, preferably 3% PEG 3350, 25-150 mM NaCl, preferably 50 mM NaCl, 5-30% sucrose, preferably 5-20% sucrose, and 10-100 mg/ml of the IL-1 antagonist.

11. The liquid formulation of any one of claims 8 to 10, wherein the IL-1 antagonist exhibits less than 4% aggregation upon visual inspection after storage of a 50 mg/ml IL-1 trap formulation for 29 months at 5°C.