

MUTANT INTERLEUKIN-2 POLYPEPTIDES

Field of the invention

The present invention generally relates to mutant interleukin-2 polypeptides. More particularly, the invention concerns mutant IL-2 polypeptides that exhibit improved properties for use as immunotherapeutic agents. In addition, the invention relates to immunoconjugates comprising
5 said mutant IL-2 polypeptides, polynucleotide molecules encoding the mutant IL-2 polypeptides or immunoconjugates, and vectors and host cells comprising such polynucleotide molecules. The invention further relates to methods for producing the mutant IL-2 polypeptides or immunoconjugates, pharmaceutical compositions comprising the same, and uses thereof.

Background

Interleukin-2 (IL-2), also known as T cell growth factor (TCGF), is a 15.5 kDa globular glycoprotein playing a central role in lymphocyte generation, survival and homeostasis. It has a length of 133 amino acids and consists of four antiparallel, amphiphatic α -helices that form a quaternary structure indispensable of its function (Smith, Science 240, 1169-76 (1988); Bazan,
15 Science 257, 410-413 (1992)). Sequences of IL-2 from different species are found under NCBI RefSeq Nos. NP000577 (human), NP032392 (mouse), NP446288 (rat) or NP517425 (chimpanzee).

IL-2 mediates its action by binding to IL-2 receptors (IL-2R), which consist of up to three individual subunits, the different association of which can produce receptor forms that differ in
20 their affinity to IL-2. Association of the α (CD25), β (CD122), and γ (γ_c , CD132) subunits results in a trimeric, high-affinity receptor for IL-2. Dimeric IL-2 receptor consisting of the β and γ subunits is termed intermediate-affinity IL-2R. The α subunit forms the monomeric low affinity IL-2 receptor. Although the dimeric intermediate-affinity IL-2 receptor binds IL-2 with approximately 100-fold lower affinity than the trimeric high-affinity receptor, both the dimeric
25 and the trimeric IL-2 receptor variants are able to transmit signal upon IL-2 binding (Minami et al., Annu Rev Immunol 11, 245-268 (1993)). Hence, the α -subunit, CD25, is not essential for IL-

2 signalling. It confers high-affinity binding to its receptor, whereas the β subunit, CD122, and the γ -subunit are crucial for signal transduction (Krieg et al., Proc Natl Acad Sci 107, 11906-11 (2010)). Trimeric IL-2 receptors including CD25 are expressed by (resting) CD4⁺ forkhead box P3 (FoxP3)⁺ regulatory T (T_{reg}) cells. They are also transiently induced on conventional activated
5 T cells, whereas in the resting state these cells express only dimeric IL-2 receptors. T_{reg} cells consistently express the highest level of CD25 in vivo (Fontenot et al., Nature Immunol 6, 1142-51 (2005)).

IL-2 is synthesized mainly by activated T-cells, in particular CD4⁺ helper T cells. It stimulates the proliferation and differentiation of T cells, induces the generation of cytotoxic T lymphocytes
10 (CTLs) and the differentiation of peripheral blood lymphocytes to cytotoxic cells and lymphokine-activated killer (LAK) cells, promotes cytokine and cytolytic molecule expression by T cells, facilitates the proliferation and differentiation of B-cells and the synthesis of immunoglobulin by B-cells, and stimulates the generation, proliferation and activation of natural
15 killer (NK) cells (reviewed e.g. in Waldmann, Nat Rev Immunol 6, 595-601 (2009); Olejniczak and Kasprzak, Med Sci Monit 14, RA179-89 (2008); Malek, Annu Rev Immunol 26, 453-79 (2008)).

Its ability to expand lymphocyte populations in vivo and to increase the effector functions of these cells confers antitumor effects to IL-2, making IL-2 immunotherapy an attractive treatment
20 option for certain metastatic cancers. Consequently, high-dose IL-2 treatment has been approved for use in patients with metastatic renal-cell carcinoma and malignant melanoma.

However, IL-2 has a dual function in the immune response in that it not only mediates expansion and activity of effector cells, but also is crucially involved in maintaining peripheral immune tolerance.

A major mechanism underlying peripheral self-tolerance is IL-2 induced activation-induced cell
25 death (AICD) in T cells. AICD is a process by which fully activated T cells undergo programmed cell death through engagement of cell surface-expressed death receptors such as CD95 (also known as Fas) or the TNF receptor. When antigen-activated T cells expressing a high-affinity IL-2 receptor (after previous exposure to IL-2) during proliferation are re-stimulated with antigen via the T cell receptor (TCR)/CD3 complex, the expression of Fas ligand
30 (FasL) and/or tumor necrosis factor (TNF) is induced, making the cells susceptible for Fas-mediated apoptosis. This process is IL-2 dependent (Lenardo, Nature 353, 858-61 (1991)) and

mediated via STAT5. By the process of AICD in T lymphocytes tolerance can not only be established to self-antigens, but also to persistent antigens that are clearly not part of the host's makeup, such as tumor antigens.

Moreover, IL-2 is also involved in the maintenance of peripheral CD4⁺ CD25⁺ regulatory T (T_{reg}) cells (Fontenot et al., Nature Immunol 6, 1142-51 (2005); D'Cruz and Klein, Nature Immunol 6, 1152-59 (2005); Maloy and Powrie, Nature Immunol 6, 1171-72 (2005), which are also known as suppressor T cells. They suppress effector T cells from destroying their (self-)target, either through cell-cell contact by inhibiting T cell help and activation, or through release of immunosuppressive cytokines such as IL-10 or TGF- β . Depletion of T_{reg} cells was shown to enhance IL-2 induced anti-tumor immunity (Imai et al., Cancer Sci 98, 416-23 (2007)).

Therefore, IL-2 is not optimal for inhibiting tumor growth, because in the presence of IL-2 either the CTLs generated might recognize the tumor as self and undergo AICD or the immune response might be inhibited by IL-2 dependent T_{reg} cells.

A further concern in relation to IL-2 immunotherapy are the side effects produced by recombinant human IL-2 treatment. Patients receiving high-dose IL-2 treatment frequently experience severe cardiovascular, pulmonary, renal, hepatic, gastrointestinal, neurological, cutaneous, haematological and systemic adverse events, which require intensive monitoring and in-patient management. The majority of these side effects can be explained by the development of so-called vascular (or capillary) leak syndrome (VLS), a pathological increase in vascular permeability leading to fluid extravasation in multiple organs (causing e.g. pulmonary and cutaneous edema and liver cell damage) and intravascular fluid depletion (causing a drop in blood pressure and compensatory increase in heart rate). There is no treatment of VLS other than withdrawal of IL-2. Low-dose IL-2 regimens have been tested in patients to avoid VLS, however, at the expense of suboptimal therapeutic results. VLS was believed to be caused by the release of proinflammatory cytokines, such as tumor necrosis factor (TNF)- α from IL-2-activated NK cells, however it has recently been shown that IL-2-induced pulmonary edema resulted from direct binding of IL-2 to lung endothelial cells, which expressed low to intermediate levels of functional $\alpha\beta\gamma$ IL-2 receptors (Krieg et al., Proc Nat Acad Sci USA 107, 11906-11 (2010)).

Several approaches have been taken to overcome these problems associated with IL-2 immunotherapy. For example, it has been found that the combination of IL-2 with certain anti-IL-2 monoclonal antibodies enhances treatment effects of IL-2 in vivo (Kamimura et al., J

Immunol 177, 306-14 (2006); Boyman et al., Science 311, 1924-27 (2006)). In an alternative approach, IL-2 has been mutated in various ways to reduce its toxicity and/or increase its efficacy. Hu et al. (Blood 101, 4853-4861 (2003), US Pat. Publ. No. 2003/0124678) have substituted the arginine residue in position 38 of IL-2 by tryptophan to eliminate IL-2's vasopermeability activity. Shanafelt et al. (Nature Biotechnol 18, 1197-1202 (2000)) have mutated asparagine 88 to arginine to enhance selectivity for T cells over NK cells. Heaton et al. (Cancer Res 53, 2597-602 (1993); US Pat. No. 5,229,109) have introduced two mutations, Arg38Ala and Phe42Lys, to reduce the secretion of proinflammatory cytokines from NK cells. Gillies et al. (US Pat. Publ. No. 2007/0036752) have substituted three residues of IL-2 (Asp20Thr, Asn88Arg, and Gln126Asp) that contribute to affinity for the intermediate-affinity IL-2 receptor to reduce VLS. Gillies et al. (WO 2008/0034473) have also mutated the interface of IL-2 with CD25 by amino acid substitution Arg38Trp and Phe42Lys to reduce interaction with CD25 and activation of T_{reg} cells for enhancing efficacy. To the same aim, Wittrup et al. (WO 2009/061853) have produced IL-2 mutants that have enhanced affinity to CD25, but do not activate the receptor, thus act as antagonists. The mutations introduced were aimed at disrupting the interaction with the β - and/or γ -subunit of the receptor.

However, none of the known IL-2 mutants was shown to overcome all of the above-mentioned problems associated with IL-2 immunotherapy, namely toxicity caused by the induction of VLS, tumor tolerance caused by the induction of AICD, and immunosuppression caused by activation of T_{reg} cells. Thus there remains a need in the art to further enhance the therapeutic usefulness of IL-2 proteins.

Summary of the invention

The present invention is based, in part, on the recognition that the interaction of IL-2 with the α -subunit of the trimeric, high-affinity IL-2 receptor is responsible for the problems associated with IL-2 immunotherapy.

Accordingly, in a first aspect the invention provides a mutant interleukin-2 (IL-2) polypeptide comprising a first amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2

polypeptide. In one embodiment said first amino acid mutation is at a position corresponding to residue 72 of human IL-2. In one embodiment said first amino acid mutation is an amino acid substitution, selected from the group of L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In a more specific embodiment said first amino acid mutation is the amino acid substitution L72G. In certain embodiments the mutant IL-2 polypeptide comprises a second amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide. In one embodiment said second amino acid mutation is at a position selected from the positions corresponding to residue 35, 38, 42, 43, and 45 of human IL-2. In a specific embodiment said second amino acid mutation is at a position corresponding to residue 42 of human IL-2. In a more specific embodiment said second amino acid mutation is an amino acid substitution, selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, and F42K. In an even more specific embodiment said second amino acid mutation is the amino acid substitution F42A. In certain embodiments the mutant interleukin-2 polypeptide comprises a third amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide. In a particular embodiment, the mutant interleukin-2 polypeptide comprises three amino acid mutations that abolish or reduce affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserve affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide, wherein said three amino acid mutations are at positions corresponding to residue 42, 45, and 72 of human IL-2. In one embodiment said three amino acid mutations are amino acid substitutions selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, Y45K, L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In a specific embodiment said three amino acid mutations are the amino acid substitutions F42A, Y45A and L72G. In certain embodiments the mutant interleukin-2 polypeptide further comprises an amino acid mutation which eliminates the O-glycosylation site of IL-2 at a position corresponding to residue 3 of human IL-2. In one embodiment said amino acid mutation which eliminates the O-glycosylation site of IL-2 at a position corresponding to residue 3 of human IL-2 is an amino acid substitution selected from the group of T3A, T3G, T3Q, T3E, T3N, T3D, T3R, T3K, and T3P. In a specific embodiment the amino acid mutation which eliminates the O-glycosylation

site of IL-2 at a position corresponding to residue 3 of human IL-2 is T3A. In certain embodiments the mutant IL-2 polypeptide is essentially a full-length IL-2 molecule, particularly a human full-length IL-2 molecule.

The invention further provides for a mutant interleukin-2 polypeptide linked to a non-IL-2 moiety. In certain embodiments said non-IL-2 moiety is a targeting moiety. In certain embodiments said non-IL-2 moiety is an antigen binding moiety. In one embodiment said antigen binding moiety is an antibody. In another embodiment said antigen binding moiety is an antibody fragment. In a more specific embodiment said antigen binding moiety is selected from a Fab molecule and a scFv molecule. In a particular embodiment said antigen binding moiety is a Fab molecule. In another embodiment said antigen binding moiety is a scFv molecule. In particular embodiments the mutant IL-2 polypeptide is linked to a first and a second non-IL-2 moiety. In one such embodiment the mutant interleukin-2 polypeptide shares a carboxy-terminal peptide bond with said first non-IL-2 moiety and an amino-terminal peptide bond with said second non-IL-2 moiety. In one embodiment said antigen binding moiety is an immunoglobulin molecule. In a more specific embodiment said antigen binding moiety is an IgG class, particularly an IgG₁ subclass, immunoglobulin molecule. In certain embodiments said antigen binding moiety is directed to an antigen presented on a tumor cell or in a tumor cell environment, particularly an antigen selected from the group of Fibroblast Activation Protein (FAP), the A1 domain of Tenascin-C (TNC A1), the A2 domain of Tenascin-C (TNC A2), the Extra Domain B of Fibronectin (EDB), Carcinoembryonic Antigen (CEA) and the Melanoma-associated Chondroitin Sulfate Proteoglycan (MCSP).

Also provided by the invention is an immunoconjugate comprising a mutant IL-2 polypeptide as described herein, and an antigen binding moiety. In one embodiment of the immunoconjugate according to the invention the mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with said antigen binding moiety. In particular embodiments the immunoconjugate comprises as first and a second antigen binding moiety. In one such embodiment the mutant IL-2 polypeptide comprised in the immunoconjugate according to the invention shares an amino- or carboxy-terminal peptide bond with a first antigen binding moiety and a second antigen binding moiety shares an amino- or carboxy-terminal peptide bond with either i) the mutant IL-2 polypeptide or ii) said first antigen binding moiety. In one embodiment the antigen binding moiety comprised in the immunoconjugate according to the invention is an antibody, in another embodiment said antigen binding moiety is an antibody fragment. In a specific embodiment said

antigen binding moiety is selected from a Fab molecule and a scFv molecule. In a particular embodiment said antigen binding moiety is a Fab molecule. In another particular embodiment said antigen binding moiety is an immunoglobulin molecule. In a more specific embodiment said antigen binding moiety is an IgG class, particularly an IgG₁ subclass, immunoglobulin molecule.

- 5 In certain embodiments said antigen binding moiety is directed to an antigen presented on a tumor cell or in a tumor cell environment, particularly an antigen selected from the group of Fibroblast Activation Protein (FAP), the A1 domain of Tenascin-C (TNC A1), the A2 domain of Tenascin-C (TNC A2), the Extra Domain B of Fibronectin (EDB), Carcinoembryonic Antigen (CEA) and the Melanoma-associated Chondroitin Sulfate Proteoglycan (MCSP).
- 10 The invention further provides isolated polynucleotides encoding a mutant IL-2 polypeptide or an immunoconjugate as described herein, expression vectors comprising said polynucleotides, and host cells comprising the polynucleotides or the expression vectors.

- Also provided is a method of producing a mutant IL-2 polypeptide or an immunoconjugate as described herein, a pharmaceutical composition comprising a mutant IL-2 polypeptide or an
- 15 immunoconjugate as described herein and a pharmaceutically acceptable carrier, and methods of using a mutant IL-2 polypeptide or an immunoconjugate as described herein.

- In particular, the invention encompasses a mutant IL-2 polypeptide or an immunoconjugate as described herein for use in the treatment of a disease in an individual in need thereof. In a particular embodiment said disease is cancer. In a particular embodiment the individual is a
- 20 human.

Also encompassed by the invention is the use of the mutant IL-2 polypeptide or immunoconjugate as described herein for the manufacture of a medicament for treating a disease in an individual in need thereof.

- Further provided is a method of treating disease in an individual, comprising administering to
- 25 said individual a therapeutically effective amount of a composition comprising a mutant IL-2 polypeptide or an immunoconjugate as described herein. Said disease preferably is cancer.

Also provided is a method of stimulating the immune system of an individual, comprising administering to said individual an effective amount of a composition comprising the mutant IL-2 polypeptide or immunoconjugate described herein in a pharmaceutically acceptable form.

Detailed description of the invention

Definitions

5 Terms are used herein as generally used in the art, unless otherwise defined in the following.

The term “interleukin-2” or “IL-2” as used herein, refers to any native IL-2 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses unprocessed IL-2 as well as any form of IL-2 that results from processing in the cell. The term also encompasses naturally occurring variants
10 of IL-2, e.g. splice variants or allelic variants. The amino acid sequence of an exemplary human IL-2 is shown in SEQ ID NO: 1. Unprocessed human IL-2 additionally comprises an N-terminal 20 amino acid signal peptide having the sequence of SEQ ID NO: 272, which is absent in the mature IL-2 molecule.

The term "IL-2 mutant" or "mutant IL-2 polypeptide" as used herein is intended to encompass
15 any mutant forms of various forms of the IL-2 molecule including full-length IL-2, truncated forms of IL-2 and forms where IL-2 is linked to another molecule such as by fusion or chemical conjugation. "Full-length" when used in reference to IL-2 is intended to mean the mature, natural length IL-2 molecule. For example, full-length human IL-2 refers to a molecule that has 133 amino acids (see e.g. SEQ ID NO: 1). The various forms of IL-2 mutants are characterized in
20 having a at least one amino acid mutation affecting the interaction of IL-2 with CD25. This mutation may involve substitution, deletion, truncation or modification of the wild-type amino acid residue normally located at that position. Mutants obtained by amino acid substitution are preferred. Unless otherwise indicated, an IL-2 mutant may be referred to herein as an IL-2 mutant peptide sequence, an IL-2 mutant polypeptide, IL-2 mutant protein or IL-2 mutant analog.

25 Designation of various forms of IL-2 is herein made with respect to the sequence shown in SEQ ID NO: 1. Various designations may be used herein to indicate the same mutation. For example a mutation from phenylalanine at position 42 to alanine can be indicated as 42A, A42, A₄₂, F42A, or Phe42Ala.

The term “amino acid mutation” as used herein is meant to encompass amino acid substitutions,
30 deletions, insertions, and modifications. Any combination of substitution, deletion, insertion, and

modification can be made to arrive at the final construct, provided that the final construct possesses the desired characteristics, e.g., reduced binding to CD25. Amino acid sequence deletions and insertions include amino- and/or carboxy-terminal deletions and insertions of amino acids. An example of a terminal deletion is the deletion of the alanine residue in position 1 of full-length human IL-2. Preferred amino acid mutations are amino acid substitutions. For the purpose of altering e.g. the binding characteristics of an IL-2 polypeptide, non-conservative amino acid substitutions, i.e. replacing one amino acid with another amino acid having different structural and/or chemical properties, are particularly preferred. Preferred amino acid substitutions include replacing a hydrophobic by a hydrophilic amino acid. Amino acid substitutions include replacement by non-naturally occurring amino acids or by naturally occurring amino acid derivatives of the twenty standard amino acids (e.g. 4-hydroxyproline, 3-methylhistidine, ornithine, homoserine, 5-hydroxylysine). Amino acid mutations can be generated using genetic or chemical methods well known in the art. Genetic methods may include site-directed mutagenesis, PCR, gene synthesis and the like. It is contemplated that methods of altering the side chain group of an amino acid by methods other than genetic engineering, such as chemical modification, may also be useful.

As used herein, a “wild-type” form of IL-2 is a form of IL-2 that is otherwise the same as the mutant IL-2 polypeptide except that the wild-type form has a wild-type amino acid at each amino acid position of the mutant IL-2 polypeptide. For example, if the IL-2 mutant is the full-length IL-2 (i.e. IL-2 not fused or conjugated to any other molecule), the wild-type form of this mutant is full-length native IL-2. If the IL-2 mutant is a fusion between IL-2 and another polypeptide encoded downstream of IL-2 (e.g. an antibody chain) the wild-type form of this IL-2 mutant is IL-2 with a wild-type amino acid sequence fused to the same downstream polypeptide. Furthermore, if the IL-2 mutant is a truncated form of IL-2 (the mutated or modified sequence within the non-truncated portion of IL-2) then the wild-type form of this IL-2 mutant is a similarly truncated IL-2 that has a wild-type sequence. For the purpose of comparing IL-2 receptor binding affinity or biological activity of various forms of IL-2 mutants to the corresponding wild-type form of IL-2, the term wild-type encompasses forms of IL-2 comprising one or more amino acid mutation that does not affect IL-2 receptor binding compared to the naturally occurring, native IL-2, such as e.g. a substitution of cysteine at a position corresponding to residue 125 of human IL-2 to alanine. In some embodiments wild-type IL-2 for the purpose of the present invention comprises the amino acid substitution C125A (see SEQ ID NO: 3). In certain embodiments according to the invention the wild-type IL-2 polypeptide to

which the mutant IL-2 polypeptide is compared comprises the amino acid sequence of SEQ ID NO: 1. In other embodiments the wild-type IL-2 polypeptide to which the mutant IL-2 polypeptide is compared comprises the amino acid sequence of SEQ ID NO: 3.

The term “CD25” or “ α -subunit of the IL-2 receptor” as used herein, refers to any native CD25 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses “full-length”, unprocessed CD25 as well as any form of CD25 that results from processing in the cell. The term also encompasses naturally occurring variants of CD25, e.g. splice variants or allelic variants. In certain embodiments CD25 is human CD25. The amino acid sequence of an exemplary human CD25 (with signal sequence, Avi-tag and His-tag) is shown in SEQ ID NO: 278.

The term “high-affinity IL-2 receptor” as used herein refers to the heterotrimeric form of the IL-2 receptor, consisting of the receptor γ -subunit (also known as common cytokine receptor γ -subunit, γ_c , or CD132), the receptor β -subunit (also known as CD122 or p70) and the receptor α -subunit (also known as CD25 or p55). The term “intermediate-affinity IL-2 receptor” by contrast refers to the IL-2 receptor including only the γ -subunit and the β -subunit, without the α -subunit (for a review see e.g. Olejniczak and Kasprzak, Med Sci Monit 14, RA179-189 (2008)).

“Affinity” refers to the strength of the sum total of non-covalent interactions between a single binding site of a molecule (e.g., a receptor) and its binding partner (e.g., a ligand). Unless indicated otherwise, as used herein, “binding affinity” refers to intrinsic binding affinity which reflects a 1:1 interaction between members of a binding pair (e.g., receptor and a ligand). The affinity of a molecule X for its partner Y can generally be represented by the dissociation constant (K_D), which is the ratio of dissociation and association rate constants (k_{off} and k_{on} , respectively). Thus, equivalent affinities may comprise different rate constants, as long as the ratio of the rate constants remains the same. Affinity can be measured by well established methods known in the art, including those described herein.

The affinity of the mutant or wild-type IL-2 polypeptide for various forms of the IL-2 receptor can be determined in accordance with the method set forth in the Examples by surface plasmon resonance (SPR), using standard instrumentation such as a BIAcore instrument (GE Healthcare) and receptor subunits such as may be obtained by recombinant expression (see e.g. Shanafelt et al., Nature Biotechnol 18, 1197-1202 (2000)). Alternatively, binding affinity of IL-2 mutants for different forms of the IL-2 receptor may be evaluated using cell lines known to express one or

the other such form of the receptor. Specific illustrative and exemplary embodiments for measuring binding affinity are described hereinafter.

By "regulatory T cell" or " T_{reg} cell" is meant a specialized type of $CD4^{+}$ T cell that can suppress the responses of other T cells. T_{reg} cells are characterized by expression of the α -subunit of the IL-2 receptor (CD25) and the transcription factor forkhead box P3 (FOXP3) (Sakaguchi, Annu Rev Immunol 22, 531-62 (2004)) and play a critical role in the induction and maintenance of peripheral self-tolerance to antigens, including those expressed by tumors. T_{reg} cells require IL-2 for their function and development and induction of their suppressive characteristics.

As used herein, the term "effector cells" refers to a population of lymphocytes that mediate the cytotoxic effects of IL-2. Effector cells include effector T cells such as $CD8^{+}$ cytotoxic T cells, NK cells, lymphokine-activated killer (LAK) cells and macrophages/monocytes.

As used herein, the term "antigen binding moiety" refers to a polypeptide molecule that specifically binds to an antigenic determinant. In one embodiment, an antigen binding moiety is able to direct the entity to which it is attached (e.g. a cytokine or a second antigen binding moiety) to a target site, for example to a specific type of tumor cell or tumor stroma bearing the antigenic determinant. Antigen binding moieties include antibodies and fragments thereof as further defined herein. Preferred antigen binding moieties include an antigen binding domain of an antibody, comprising an antibody heavy chain variable region and an antibody light chain variable region. In certain embodiments, the antigen binding moieties may include antibody constant regions as further defined herein and known in the art. Useful heavy chain constant regions include any of the five isotypes: α , δ , ϵ , γ , or μ . Useful light chain constant regions include any of the two isotypes: κ and λ .

By "specifically binds" is meant that the binding is selective for the antigen and can be discriminated from unwanted or non-specific interactions. The ability of an antigen binding moiety to bind to a specific antigenic determinant can be measured either through an enzyme-linked immunosorbent assay (ELISA) or other techniques familiar to one of skill in the art, e.g. surface plasmon resonance technique (analyzed on a BIAcore instrument) (Liljeblad et al., Glyco J 17, 323-329 (2000)), and traditional binding assays (Heeley, Endocr Res 28, 217-229 (2002)).

As used herein, the term "antigenic determinant" is synonymous with "antigen" and "epitope," and refers to a site (e.g. a contiguous stretch of amino acids or a conformational configuration

made up of different regions of non-contiguous amino acids) on a polypeptide macromolecule to which an antigen binding moiety binds, forming an antigen binding moiety-antigen complex. Useful antigenic determinants can be found, for example, on the surfaces of tumor cells, on the surfaces of virus-infected cells, on the surfaces of other diseased cells, free in blood serum, and/or in the extracellular matrix (ECM).

As used herein, term "polypeptide" refers to a molecule composed of monomers (amino acids) linearly linked by amide bonds (also known as peptide bonds). The term "polypeptide" refers to any chain of two or more amino acids, and does not refer to a specific length of the product. Thus, peptides, dipeptides, tripeptides, oligopeptides, "protein," "amino acid chain," or any other term used to refer to a chain of two or more amino acids, are included within the definition of "polypeptide," and the term "polypeptide" may be used instead of, or interchangeably with any of these terms. The term "polypeptide" is also intended to refer to the products of post-expression modifications of the polypeptide, including without limitation glycosylation, acetylation, phosphorylation, amidation, derivatization by known protecting/blocking groups, proteolytic cleavage, or modification by non-naturally occurring amino acids. A polypeptide may be derived from a natural biological source or produced by recombinant technology, but is not necessarily translated from a designated nucleic acid sequence. It may be generated in any manner, including by chemical synthesis. A polypeptide of the invention may be of a size of about 3 or more, 5 or more, 10 or more, 20 or more, 25 or more, 50 or more, 75 or more, 100 or more, 200 or more, 500 or more, 1,000 or more, or 2,000 or more amino acids. Polypeptides may have a defined three-dimensional structure, although they do not necessarily have such structure. Polypeptides with a defined three-dimensional structure are referred to as folded, and polypeptides which do not possess a defined three-dimensional structure, but rather can adopt a large number of different conformations, and are referred to as unfolded.

By an "isolated" polypeptide or a variant, or derivative thereof is intended a polypeptide that is not in its natural milieu. No particular level of purification is required. For example, an isolated polypeptide can be removed from its native or natural environment. Recombinantly produced polypeptides and proteins expressed in host cells are considered isolated for the purpose of the invention, as are native or recombinant polypeptides which have been separated, fractionated, or partially or substantially purified by any suitable technique.

"Percent (%) amino acid sequence identity" with respect to a reference polypeptide sequence is defined as the percentage of amino acid residues in a candidate sequence that are identical with

the amino acid residues in the reference polypeptide sequence, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent sequence identity, and not considering any conservative substitutions as part of the sequence identity. Alignment for purposes of determining percent amino acid sequence identity can be achieved in various ways that are within the skill in the art, for instance, using publicly available computer software such as BLAST, BLAST-2, ALIGN or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for aligning sequences, including any algorithms needed to achieve maximal alignment over the full length of the sequences being compared. For purposes herein, however, % amino acid sequence identity values are generated using the sequence comparison computer program ALIGN-2. The ALIGN-2 sequence comparison computer program was authored by Genentech, Inc., and the source code has been filed with user documentation in the U.S. Copyright Office, Washington D.C., 20559, where it is registered under U.S. Copyright Registration No. TXU510087. The ALIGN-2 program is publicly available from Genentech, Inc., South San Francisco, California, or may be compiled from the source code. The ALIGN-2 program should be compiled for use on a UNIX operating system, including digital UNIX V4.0D. All sequence comparison parameters are set by the ALIGN-2 program and do not vary. In situations where ALIGN-2 is employed for amino acid sequence comparisons, the % amino acid sequence identity of a given amino acid sequence A to, with, or against a given amino acid sequence B (which can alternatively be phrased as a given amino acid sequence A that has or comprises a certain % amino acid sequence identity to, with, or against a given amino acid sequence B) is calculated as follows:

100 times the fraction X/Y

where X is the number of amino acid residues scored as identical matches by the sequence alignment program ALIGN-2 in that program's alignment of A and B, and where Y is the total number of amino acid residues in B. It will be appreciated that where the length of amino acid sequence A is not equal to the length of amino acid sequence B, the % amino acid sequence identity of A to B will not equal the % amino acid sequence identity of B to A. Unless specifically stated otherwise, all % amino acid sequence identity values used herein are obtained as described in the immediately preceding paragraph using the ALIGN-2 computer program.

The term "polynucleotide" refers to an isolated nucleic acid molecule or construct, e.g. messenger RNA (mRNA), virally-derived RNA, or plasmid DNA (pDNA). A polynucleotide may comprise a conventional phosphodiester bond or a non-conventional bond (e.g. an amide

bond, such as found in peptide nucleic acids (PNA). The term "nucleic acid molecule" refers to any one or more nucleic acid segments, e.g. DNA or RNA fragments, present in a polynucleotide.

By "isolated" nucleic acid molecule or polynucleotide is intended a nucleic acid molecule, DNA
5 or RNA, which has been removed from its native environment. For example, a recombinant polynucleotide encoding a therapeutic polypeptide contained in a vector is considered isolated for the purposes of the present invention. Further examples of an isolated polynucleotide include recombinant polynucleotides maintained in heterologous host cells or purified (partially or substantially) polynucleotides in solution. An isolated polynucleotide includes a polynucleotide
10 molecule contained in cells that ordinarily contain the polynucleotide molecule, but the polynucleotide molecule is present extrachromosomally or at a chromosomal location that is different from its natural chromosomal location. Isolated RNA molecules include *in vivo* or *in vitro* RNA transcripts of the present invention, as well as positive and negative strand forms, and double-stranded forms. Isolated polynucleotides or nucleic acids according to the present
15 invention further include such molecules produced synthetically. In addition, a polynucleotide or a nucleic acid may be or may include a regulatory element such as a promoter, ribosome binding site, or a transcription terminator.

By a nucleic acid or polynucleotide having a nucleotide sequence at least, for example, 95% "identical" to a reference nucleotide sequence of the present invention, it is intended that the
20 nucleotide sequence of the polynucleotide is identical to the reference sequence except that the polynucleotide sequence may include up to five point mutations per each 100 nucleotides of the reference nucleotide sequence. In other words, to obtain a polynucleotide having a nucleotide sequence at least 95% identical to a reference nucleotide sequence, up to 5% of the nucleotides in the reference sequence may be deleted or substituted with another nucleotide, or a number of
25 nucleotides up to 5% of the total nucleotides in the reference sequence may be inserted into the reference sequence. These alterations of the reference sequence may occur at the 5' or 3' terminal positions of the reference nucleotide sequence or anywhere between those terminal positions, interspersed either individually among residues in the reference sequence or in one or more contiguous groups within the reference sequence. As a practical matter, whether any
30 particular polynucleotide sequence is at least 80%, 85%, 90%, 95%, 96%, 97%, 98% or 99% identical to a nucleotide sequence of the present invention can be determined conventionally

using known computer programs, such as the ones discussed above for polypeptides (e.g. ALIGN-2).

The term "expression cassette" refers to a polynucleotide generated recombinantly or synthetically, with a series of specified nucleic acid elements that permit transcription of a particular nucleic acid in a target cell. The recombinant expression cassette can be incorporated into a plasmid, chromosome, mitochondrial DNA, plastid DNA, virus, or nucleic acid fragment. Typically, the recombinant expression cassette portion of an expression vector includes, among other sequences, a nucleic acid sequence to be transcribed and a promoter. In certain embodiments, the expression cassette of the invention comprises polynucleotide sequences that encode mutant IL-2 polypeptides or immunoconjugates of the invention or fragments thereof.

The term "vector" or "expression vector" is synonymous with "expression construct" and refers to a DNA molecule that is used to introduce and direct the expression of a specific gene to which it is operably associated in a target cell. The term includes the vector as a self-replicating nucleic acid structure as well as the vector incorporated into the genome of a host cell into which it has been introduced. The expression vector of the present invention comprises an expression cassette. Expression vectors allow transcription of large amounts of stable mRNA. Once the expression vector is inside the target cell, the ribonucleic acid molecule or protein that is encoded by the gene is produced by the cellular transcription and/or translation machinery. In one embodiment, the expression vector of the invention comprises an expression cassette that comprises polynucleotide sequences that encode mutant IL-2 polypeptides or immunoconjugates of the invention or fragments thereof.

The term "artificial" refers to a synthetic, or non-host cell derived composition, e.g. a chemically-synthesized oligonucleotide.

The terms "host cell," "host cell line," and "host cell culture" are used interchangeably and refer to cells into which exogenous nucleic acid has been introduced, including the progeny of such cells. Host cells include "transformants" and "transformed cells," which include the primary transformed cell and progeny derived therefrom without regard to the number of passages. Progeny may not be completely identical in nucleic acid content to a parent cell, but may contain mutations. Mutant progeny that have the same function or biological activity as screened or selected for in the originally transformed cell are included herein.

The term "antibody" herein is used in the broadest sense and encompasses various antibody structures, including but not limited to monoclonal antibodies, polyclonal antibodies, multispecific antibodies (e.g. bispecific antibodies), and antibody fragments so long as they exhibit the desired antigen binding activity.

- 5 The terms "full length antibody," "intact antibody," and "whole antibody" are used herein interchangeably to refer to an antibody having a structure substantially similar to a native antibody structure or having heavy chains that contain an Fc region as defined herein.

An "antibody fragment" refers to a molecule other than an intact antibody that comprises a portion of an intact antibody that binds the antigen to which the intact antibody binds. Examples
10 of antibody fragments include but are not limited to Fv, Fab, Fab', Fab'-SH, F(ab')₂, diabodies, linear antibodies, single-chain antibody molecules (e.g. scFv), and multispecific antibodies formed from antibody fragments. For a review of certain antibody fragments, see Hudson et al., Nat Med 9, 129-134 (2003). For a review of scFv fragments, see e.g. Plückthun, in The Pharmacology of Monoclonal Antibodies, vol. 113, Rosenberg and Moore eds., Springer-Verlag,
15 New York, pp. 269-315 (1994); see also WO 93/16185; and U.S. Patent Nos. 5,571,894 and 5,587,458. For discussion of Fab and F(ab')₂ fragments comprising salvage receptor binding epitope residues and having increased in vivo half-life, see U.S. Patent No. 5,869,046. Diabodies are antibody fragments with two antigen binding sites that may be bivalent or bispecific. See, for example, EP 404,097; WO 1993/01161; Hudson et al., Nat Med 9, 129-134 (2003); and
20 Hollinger et al., Proc Natl Acad Sci USA 90, 6444-6448 (1993). Triabodies and tetrabodies are also described in Hudson et al., Nat Med 9, 129-134 (2003). Antibody fragments can be made by various techniques, including but not limited to proteolytic digestion of an intact antibody as well as production by recombinant host cells (e.g. E. coli or phage), as described herein.

The term "immunoglobulin molecule" refers to a protein having the structure of a naturally
25 occurring antibody. For example, immunoglobulins of the IgG class are heterotetrameric glycoproteins of about 150,000 daltons, composed of two light chains and two heavy chains that are disulfide-bonded. From N- to C-terminus, each heavy chain has a variable region (VH), also called a variable heavy domain or a heavy chain variable domain, followed by three constant domains (CH1, CH2, and CH3), also called a heavy chain constant region. Similarly, from N- to
30 C-terminus, each light chain has a variable region (VL), also called a variable light domain or a light chain variable domain, followed by a constant light (CL) domain, also called a light chain constant region. The heavy chain of an immunoglobulin may be assigned to one of five classes,

called α (IgA), δ (IgD), ϵ (IgE), γ (IgG), or μ (IgM), some of which may be further divided into subclasses, e.g. γ_1 (IgG₁), γ_2 (IgG₂), γ_3 (IgG₃), γ_4 (IgG₄), α_1 (IgA₁) and α_2 (IgA₂). The light chain of an immunoglobulin may be assigned to one of two types, called kappa (κ) and lambda (λ), based on the amino acid sequence of its constant domain. An immunoglobulin essentially
5 consists of two Fab molecules and an Fc domain, linked via the immunoglobulin hinge region.

The term "antigen binding domain" refers to the part of an antibody that comprises the area which specifically binds to and is complementary to part or all of an antigen. An antigen binding domain may be provided by, for example, one or more antibody variable domains (also called antibody variable regions). Preferably, an antigen binding domain comprises an antibody light
10 chain variable region (VL) and an antibody heavy chain variable region (VH).

The term "variable region" or "variable domain" refers to the domain of an antibody heavy or light chain that is involved in binding the antibody to antigen. The variable domains of the heavy chain and light chain (VH and VL, respectively) of a native antibody generally have similar structures, with each domain comprising four conserved framework regions (FRs) and three
15 hypervariable regions (HVRs). See, e.g., Kindt et al., Kuby Immunology, 6th ed., W.H. Freeman and Co., page 91 (2007). A single VH or VL domain may be sufficient to confer antigen binding specificity.

The term "hypervariable region" or "HVR", as used herein, refers to each of the regions of an antibody variable domain which are hypervariable in sequence and/or form structurally defined
20 loops ("hypervariable loops"). Generally, native four-chain antibodies comprise six HVRs; three in the VH (H1, H2, H3), and three in the VL (L1, L2, L3). HVRs generally comprise amino acid residues from the hypervariable loops and/or from the complementarity determining regions (CDRs), the latter being of highest sequence variability and/or involved in antigen recognition. With the exception of CDR1 in VH, CDRs generally comprise the amino acid residues that form
25 the hypervariable loops. Hypervariable regions (HVRs) are also referred to as "complementarity determining regions" (CDRs), and these terms are used herein interchangeably in reference to portions of the variable region that form the antigen binding regions. This particular region has been described by Kabat et al., U.S. Dept. of Health and Human Services, Sequences of Proteins of Immunological Interest (1983) and by Chothia et al., J Mol Biol 196:901-917 (1987), where
30 the definitions include overlapping or subsets of amino acid residues when compared against each other. Nevertheless, application of either definition to refer to a CDR of an antibody or variants thereof is intended to be within the scope of the term as defined and used herein. The

appropriate amino acid residues which encompass the CDRs as defined by each of the above cited references are set forth below in Table 1 as a comparison. The exact residue numbers which encompass a particular CDR will vary depending on the sequence and size of the CDR. Those skilled in the art can routinely determine which residues comprise a particular CDR given the variable region amino acid sequence of the antibody.

TABLE 1. CDR Definitions¹

CDR	Kabat	Chothia	AbM²
V _H CDR1	31-35	26-32	26-35
V _H CDR2	50-65	52-58	50-58
V _H CDR3	95-102	95-102	95-102
V _L CDR1	24-34	26-32	24-34
V _L CDR2	50-56	50-52	50-56
V _L CDR3	89-97	91-96	89-97

¹ Numbering of all CDR definitions in Table 1 is according to the numbering conventions set forth by Kabat et al. (see below).

² "AbM" with a lowercase "b" as used in Table 1 refers to the CDRs as defined by Oxford Molecular's "AbM" antibody modeling software.

Kabat et al. also defined a numbering system for variable region sequences that is applicable to any antibody. One of ordinary skill in the art can unambiguously assign this system of "Kabat numbering" to any variable region sequence, without reliance on any experimental data beyond the sequence itself. As used herein, "Kabat numbering" refers to the numbering system set forth by Kabat et al., U.S. Dept. of Health and Human Services, "Sequence of Proteins of Immunological Interest" (1983). Unless otherwise specified, references to the numbering of specific amino acid residue positions in an antibody variable region are according to the Kabat numbering system.

The polypeptide sequences of the sequence listing (i.e., SEQ ID NOs: 23, 25, 27, 29, 31, 33, etc.) are not numbered according to the Kabat numbering system. However, it is well within the ordinary skill of one in the art to convert the numbering of the sequences of the Sequence Listing to Kabat numbering.

"Framework" or "FR" refers to variable domain residues other than hypervariable region (HVR) residues. The FR of a variable domain generally consists of four FR domains: FR1, FR2, FR3,

and FR4. Accordingly, the HVR and FR sequences generally appear in the following sequence in VH (or VL): FR1-H1(L1)-FR2-H2(L2)-FR3-H3(L3)-FR4.

The “class” of an antibody refers to the type of constant domain or constant region possessed by its heavy chain. There are five major classes of antibodies: IgA, IgD, IgE, IgG, and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG₁, IgG₂, IgG₃, IgG₄, IgA₁, and IgA₂. The heavy chain constant domains that correspond to the different classes of immunoglobulins are called α , δ , ϵ , γ , and μ , respectively.

The term “Fc region” herein is used to define a C-terminal region of an immunoglobulin heavy chain that contains at least a portion of the constant region. The term includes native sequence Fc regions and variant Fc regions. Although the boundaries of the Fc region of an IgG heavy chain might vary slightly, the human IgG heavy chain Fc region is usually defined to extend from Cys226, or from Pro230, to the carboxyl-terminus of the heavy chain. However, the C-terminal lysine (Lys447) of the Fc region may or may not be present.

A “modification promoting heterodimerization” is a manipulation of the peptide backbone or the post-translational modifications of a polypeptide, e.g. an immunoglobulin heavy chain, that reduces or prevents the association of the polypeptide with an identical polypeptide to form a homodimer. A modification promoting heterodimerization as used herein particularly includes separate modifications made to each of two polypeptides desired to form a dimer, wherein the modifications are complementary to each other so as to promote association of the two polypeptides. For example, a modification promoting heterodimerization may alter the structure or charge of one or both of the polypeptides desired to form a dimer so as to make their association sterically or electrostatically favorable, respectively. Heterodimerization occurs between two non-identical polypeptides, such as two immunoglobulin heavy chains wherein further immunoconjugate components fused to each of the heavy chains (e.g. IL-2 polypeptide) are not the same. In the immunoconjugates of the present invention, the modification promoting heterodimerization is in the heavy chain(s), specifically in the Fc domain, of an immunoglobulin molecule. In some embodiments the modification promoting heterodimerization comprises an amino acid mutation, specifically an amino acid substitution. In a particular embodiment, the modification promoting heterodimerization comprises a separate amino acid mutation, specifically an amino acid substitution, in each of the two immunoglobulin heavy chains.

The term "effector functions" when used in reference to antibodies refer to those biological activities attributable to the Fc region of an antibody, which vary with the antibody isotype. Examples of antibody effector functions include: C1q binding and complement dependent cytotoxicity (CDC), Fc receptor binding, antibody-dependent cell-mediated cytotoxicity (ADCC), antibody-dependent cellular phagocytosis (ADCP), cytokine secretion, down
5 regulation of cell surface receptors (e.g. B cell receptor), and B cell activation.

An "activating Fc receptor" is an Fc receptor that following engagement by an Fc region of an antibody elicits signaling events that stimulate the receptor-bearing cell to perform effector functions. Activating Fc receptors include Fc γ RIIIa (CD16a), Fc γ RI (CD64), Fc γ RIIa (CD32),
10 and Fc α RI (CD89).

As used herein, the terms "engineer, engineered, engineering", are considered to include any manipulation of the peptide backbone or the post-translational modifications of a naturally occurring or recombinant polypeptide or fragment thereof. Engineering includes modifications of the amino acid sequence, of the glycosylation pattern, or of the side chain group of individual
15 amino acids, as well as combinations of these approaches.

As used herein, the term "immunoconjugate" refers to a polypeptide molecule that includes at least one IL-2 moiety and at least one antigen binding moiety. In certain embodiments, the immunoconjugate comprises at least one IL-2 moiety, and at least two antigen binding moieties. Particular immunoconjugates according to the invention essentially consist of one IL-2 moiety
20 and two antigen binding moieties joined by one or more linker sequences. The antigen binding moiety can be joined to the IL-2 moiety by a variety of interactions and in a variety of configurations as described herein.

As used herein, the term "control antigen binding moiety" refers to an antigen binding moiety as it would exist free of other antigen binding moieties and effector moieties. For example, when
25 comparing an Fab-IL2-Fab immunoconjugate of the invention with a control antigen binding moiety, the control antigen binding moiety is free Fab, wherein the Fab-IL2-Fab immunoconjugate and the free Fab molecule can both specifically bind to the same antigen determinant.

As used herein, the terms "first" and "second" with respect to antigen binding moieties etc., are
30 used for convenience of distinguishing when there is more than one of each type of moiety. Use

of these terms is not intended to confer a specific order or orientation of the immunoconjugate unless explicitly so stated.

An "effective amount" of an agent refers to the amount that is necessary to result in a physiological change in the cell or tissue to which it is administered.

- 5 A "therapeutically effective amount" of an agent, e.g. a pharmaceutical composition, refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic or prophylactic result. A therapeutically effective amount of an agent for example eliminates, decreases, delays, minimizes or prevents adverse effects of a disease.

10 An "individual" or "subject" is a mammal. Mammals include, but are not limited to, domesticated animals (e.g. cows, sheep, cats, dogs, and horses), primates (e.g. humans and non-human primates such as monkeys), rabbits, and rodents (e.g. mice and rats). Preferably, the individual or subject is a human.

15 The term "pharmaceutical composition" refers to a preparation which is in such form as to permit the biological activity of an active ingredient contained therein to be effective, and which contains no additional components which are unacceptably toxic to a subject to which the composition would be administered.

A "pharmaceutically acceptable carrier" refers to an ingredient in a pharmaceutical composition, other than an active ingredient, which is nontoxic to a subject. A pharmaceutically acceptable carrier includes, but is not limited to, a buffer, excipient, stabilizer, or preservative.

- 20 As used herein, "treatment" (and grammatical variations thereof such as "treat" or "treating") refers to clinical intervention in an attempt to alter the natural course of a disease in the individual being treated, and can be performed either for prophylaxis or during the course of clinical pathology. Desirable effects of treatment include, but are not limited to, preventing occurrence or recurrence of disease, alleviation of symptoms, diminishment of any direct or
25 indirect pathological consequences of the disease, preventing metastasis, decreasing the rate of disease progression, amelioration or palliation of the disease state, and remission or improved prognosis. In some embodiments, antibodies of the invention are used to delay development of a disease or to slow the progression of a disease.

Detailed description of the embodiments

The present invention aims at providing a mutant IL-2 polypeptide having improved properties for immunotherapy. In particular the invention aims at eliminating pharmacological properties of IL-2 that contribute to toxicity but are not essential for efficacy of IL-2. As discussed above, 5 different forms of the IL-2 receptor consist of different subunits and exhibit different affinities for IL-2. The intermediate-affinity IL-2 receptor, consisting of the β and γ receptor subunits, is expressed on resting effector cells and is sufficient for IL-2 signaling. The high-affinity IL-2 receptor, additionally comprising the α -subunit of the receptor, is mainly expressed on regulatory T (T_{reg}) cells as well as on activated effector cells where its engagement by IL-2 can promote T_{reg} 10 cell-mediated immunosuppression or activation-induced cell death (AICD), respectively. Thus, without wishing to be bound by theory, reducing or abolishing the affinity of IL-2 to the α -subunit of the IL-2 receptor should reduce IL-2 induced downregulation of effector cell function by regulatory T cells and development of tumor tolerance by the process of AICD. On the other hand, maintaining the affinity to the intermediate-affinity IL-2 receptor should preserve the 15 induction of proliferation and activation of effector cells like NK and T cells by IL-2.

Several IL-2 mutants already exist in the art, however, the inventors have found novel amino acid mutations of the IL-2 polypeptide and combinations thereof that are particularly suitable to confer to IL-2 the desired characteristics for immunotherapy.

In a first aspect the invention provides a mutant interleukin-2 (IL-2) polypeptide comprising an 20 amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor each compared to a wild-type IL-2 polypeptide.

Mutants of human IL-2 (hIL-2) with decreased affinity to CD25 may for example be generated by amino acid substitution at amino acid position 35, 38, 42, 43, 45 or 72 or combinations 25 thereof. Exemplary amino acid substitutions include K35E, K35A, R38A, R38E, R38N, R38F, R38S, R38L, R38G, R38Y, R38W, F42L, F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, K43E, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, Y45K, L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. Particular IL-2 mutants according to the invention comprise a mutation at an amino acid position corresponding to 30 residue 42, 45, or 72 of human IL-2, or a combination thereof. These mutants exhibit substantially similar binding affinity to the intermediate-affinity IL-2 receptor, and have

substantially reduced affinity to the α -subunit of the IL-2 receptor and the high-affinity IL-2 receptor compared to a wild-type form of the IL-2 mutant.

Other characteristics of useful mutants may include the ability to induce proliferation of IL-2 receptor-bearing T and/or NK cells, the ability to induce IL-2 signaling in IL-2 receptor-bearing T and/or NK cells, the ability to generate interferon (IFN)- γ as a secondary cytokine by NK cells, a reduced ability to induce elaboration of secondary cytokines – particularly IL-10 and TNF- α – by peripheral blood mononuclear cells (PBMCs), a reduced ability to activate regulatory T cells, a reduced ability to induce apoptosis in T cells, and a reduced toxicity profile in vivo.

In one embodiment according to the invention, the amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor is at a position corresponding to residue 72 of human IL-2. In one embodiment said amino acid mutation is an amino acid substitution. In one embodiment said amino acid substitution is selected from the group of L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In a more specific embodiment said amino acid mutation is the amino acid substitution L72G.

In a particular aspect the invention provides a mutant IL-2 polypeptide comprising a first and a second amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate affinity IL-2 receptor. In one embodiment said first amino acid mutation is at a position corresponding to residue 72 of human IL-2. In one embodiment said first amino acid mutation is an amino acid substitution. In a specific embodiment said first amino acid mutation is an amino acid substitution selected from the group of L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In an even more specific embodiment said amino acid substitution is L72G. Said second amino acid mutation is at a different position than said first amino acid mutation. In one embodiment said second amino acid mutation is at a position selected from a position corresponding to residue 35, 38, 42, 43 and 45 of human IL-2. In one embodiment said second amino acid mutation is an amino acid substitution. In a specific embodiment said amino acid substitution is selected from the group of K35E, K35A, R38A, R38E, R38N, R38F, R38S, R38L, R38G, R38Y, R38W, F42L, F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, K43E, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, and Y45K. In a particular embodiment said second amino acid mutation is at a position corresponding to residue 42 or 45 of human IL-2. In a specific embodiment said second

amino acid mutation is an amino acid substitution, selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, and Y45K. In a more specific embodiment said second amino acid mutation is the amino acid substitution F42A or Y45A. In a more particular embodiment said second amino acid

5 mutation is at the position corresponding to residue 42 of human IL-2. In a specific embodiment said second amino acid mutation is an amino acid substitution, selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, and F42K. In a more specific embodiment said amino acid substitution is F42A. In another embodiment said second amino acid mutation is at the position corresponding to residue 45 of human IL-2. In a specific embodiment said second

10 amino acid mutation is an amino acid substitution, selected from the group of Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, and Y45K. In a more specific embodiment said amino acid substitution is Y45A. In certain embodiments the mutant IL-2 polypeptide comprises a third amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor and preserves affinity of the mutant IL-2

15 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide. Said third amino acid mutation is at a different position than said first and second amino acid mutations. In one embodiment said third amino acid mutation is at a position selected from a position corresponding to residue 35, 38, 42, 43 and 45 of human IL-2. In a preferred embodiment said third amino acid mutation is at a position corresponding to residue 42 or 45 of

20 human IL-2. In one embodiment said third amino acid mutation is at a position corresponding to residue 42 of human IL-2. In another embodiment said third amino acid mutation is at a position corresponding to residue 45 of human IL-2. In one embodiment said third amino acid mutation is an amino acid substitution. In a specific embodiment said amino acid substitution is selected from the group of K35E, K35A, R38A, R38E, R38N, R38F, R38S, R38L, R38G, R38Y, R38W,

25 F42L, F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, K43E, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, and Y45K. In a more specific embodiment said amino acid substitution is selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, and Y45K. In an even more specific embodiment said amino acid substitution is F42A or Y45A. In

30 one embodiment said amino acid substitution is F42A. In another embodiment said amino acid substitution is Y45A. In certain embodiments the mutant IL-2 polypeptide does not comprise an amino acid mutation at the position corresponding to residue 38 of human IL-2.

In an even more particular aspect of the invention is provided a mutant IL-2 polypeptide comprising three amino acid mutations that abolish or reduce affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor but preserve affinity of the mutant IL-2 polypeptide to the intermediate affinity IL-2 receptor. In one embodiment said three amino acid mutations are at positions corresponding to residue 42, 45 and 72 of human IL-2. In one embodiment said three amino acid mutations are amino acid substitutions. In one embodiment said three amino acid mutations are amino acid substitutions selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, Y45K, L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In a specific embodiment said three amino acid mutations are amino acid substitutions F42A, Y45A and L72G.

In certain embodiments said amino acid mutation reduces the affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor by at least 5-fold, specifically at least 10-fold, more specifically at least 25-fold. In embodiments where there is more than one amino acid mutation that reduces the affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor, the combination of these amino acid mutations may reduce the affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor by at least 30-fold, at least 50-fold, or even at least 100-fold. In one embodiment said amino acid mutation or combination of amino acid mutations abolishes the affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor so that no binding is detectable by surface plasmon resonance as described hereinbelow.

Substantially similar binding to the intermediate-affinity receptor, i.e. preservation of the affinity of the mutant IL-2 polypeptide to said receptor, is achieved when the IL-2 mutant exhibits greater than about 70% of the affinity of a wild-type form of the IL-2 mutant to the intermediate-affinity IL-2 receptor. IL-2 mutants of the invention may exhibit greater than about 80% and even greater than about 90% of such affinity.

The inventors have found that a reduction of the affinity of IL-2 for the α -subunit of the IL-2 receptor in combination with elimination of the O-glycosylation of IL-2 results in an IL-2 protein with improved properties. For example, elimination of the O-glycosylation site results in a more homogenous product when the mutant IL-2 polypeptide is expressed in mammalian cells such as CHO or HEK cells.

Thus, in certain embodiments the mutant IL-2 polypeptide according to the invention comprises an additional amino acid mutation which eliminates the O-glycosylation site of IL-2 at a position corresponding to residue 3 of human IL-2. In one embodiment said additional amino acid mutation which eliminates the O-glycosylation site of IL-2 at a position corresponding to residue 3 of human IL-2 is an amino acid substitution. Exemplary amino acid substitutions include T3A, T3G, T3Q, T3E, T3N, T3D, T3R, T3K, and T3P. In a specific embodiment, said additional amino acid mutation is the amino acid substitution T3A.

In certain embodiments the mutant IL-2 polypeptide is essentially a full-length IL-2 molecule. In certain embodiments the mutant IL-2 polypeptide is a human IL-2 molecule. In one embodiment the mutant IL-2 polypeptide comprises the sequence of SEQ ID NO: 1 with at least one amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor but preserve affinity of the mutant IL-2 polypeptide to the intermediate affinity IL-2 receptor, compared to an IL-2 polypeptide comprising SEQ ID NO: 1 without said mutation. In another embodiment, the mutant IL-2 polypeptide comprises the sequence of SEQ ID NO: 3 with at least one amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor but preserve affinity of the mutant IL-2 polypeptide to the intermediate affinity IL-2 receptor, compared to an IL-2 polypeptide comprising SEQ ID NO: 3 without said mutation.

In a specific embodiment, the mutant IL-2 polypeptide can elicit one or more of the cellular responses selected from the group consisting of: proliferation in an activated T lymphocyte cell, differentiation in an activated T lymphocyte cell, cytotoxic T cell (CTL) activity, proliferation in an activated B cell, differentiation in an activated B cell, proliferation in a natural killer (NK) cell, differentiation in a NK cell, cytokine secretion by an activated T cell or an NK cell, and NK/lymphocyte activated killer (LAK) antitumor cytotoxicity.

In one embodiment the mutant IL-2 polypeptide has a reduced ability to induce IL-2 signaling in regulatory T cells, compared to a wild-type IL-2 polypeptide. In one embodiment the mutant IL-2 polypeptide induces less activation-induced cell death (AICD) in T cells, compared to a wild-type IL-2 polypeptide. In one embodiment the mutant IL-2 polypeptide has a reduced toxicity profile in vivo, compared to a wild-type IL-2 polypeptide. In one embodiment the mutant IL-2 polypeptide has a prolonged serum half-life, compared to a wild-type IL-2 polypeptide.

A particular mutant IL-2 polypeptide according to the invention comprises four amino acid substitutions at positions corresponding to residues 3, 42, 45 and 72 of human IL-2. Specific amino acid substitutions are T3A, F42A, Y45A and L72G. As demonstrated in the appended Examples, said quadruple mutant IL-2 polypeptide exhibits no detectable binding to CD25, 5 reduced ability to induce apoptosis in T cells, reduced ability to induce IL-2 signaling in T_{reg} cells, and a reduced toxicity profile in vivo. However, it retains ability to activate IL-2 signaling in effector cells, to induce proliferation of effector cells, and to generate IFN- γ as a secondary cytokine by NK cells.

Moreover, said mutant IL-2 polypeptide has further advantageous properties, such as reduced 10 surface hydrophobicity, good stability, and good expression yield, as described in the Examples. Unexpectedly, said mutant IL-2 polypeptide also provides a prolonged serum half-life, compared to wild-type IL-2.

IL-2 mutants of the invention, in addition to having mutations in the region of IL-2 that forms the interface of IL-2 with CD25 or the glycosylation site, also may have one or more mutations 15 in the amino acid sequence outside these regions. Such additional mutations in human IL-2 may provide additional advantages such as increased expression or stability. For example, the cysteine at position 125 may be replaced with a neutral amino acid such as serine, alanine, threonine or valine, yielding C125S IL-2, C125A IL-2, C125T IL-2 or C125V IL-2 respectively, as described in U.S. Patent no. 4,518,584. As described therein, one may also delete the N- 20 terminal alanine residue of IL-2 yielding such mutants as des-A1 C125S or des-A1 C125A. Alternatively or conjunctively, the IL-2 mutant may include a mutation whereby methionine normally occurring at position 104 of wild-type human IL-2 is replaced by a neutral amino acid such as alanine (see U.S. Patent no. 5,206,344). The resulting mutants, e. g., des-A1 M104A IL-2, des-A1 M104A C125S IL-2, M104A IL-2, M104A C125A IL-2, des-A1 M104A C125A IL-2, or 25 M104A C125S IL-2 (these and other mutants may be found in U.S. Patent No. 5,116,943 and in Weiger et al., Eur J Biochem 180, 295-300 (1989)) may be used in conjunction with the particular IL-2 mutations of the invention.

Thus, in certain embodiments the mutant IL-2 polypeptide according to the invention comprises an additional amino acid mutation at a position corresponding to residue 125 of human IL-2. In 30 one embodiment said additional amino acid mutation is the amino acid substitution C125A.

The skilled person will be able to determine which additional mutations may provide additional advantages for the purpose of the invention. For example, he will appreciate that amino acid mutations in the IL-2 sequence that reduce or abolish the affinity of IL-2 to the intermediate-affinity IL-2 receptor, such as D20T, N88R or Q126D (see e.g. US 2007/0036752), may not be
5 suitable to include in the mutant IL-2 polypeptide according to the invention.

In one embodiment the mutant IL-2 polypeptide of the invention comprises a sequence selected from the group of SEQ ID NO: 7, SEQ ID NO: 11, SEQ ID NO: 15, and SEQ ID NO: 19. In a specific embodiment the mutant IL-2 polypeptide of the invention comprises a sequence of SEQ ID NO: 15 or SEQ ID NO: 19. In an even more specific embodiment the mutant IL-2
10 polypeptide comprises a sequence of SEQ ID NO: 19.

Mutant IL-2 polypeptides of the invention are particularly useful in the context of IL-2 fusion proteins such as IL-2 bearing immunoconjugates. Such fusion proteins comprise a mutant IL-2 polypeptide of the invention fused to a non-IL-2 moiety. The non-IL-2 moiety can be a synthetic or natural protein or a portion or variant thereof. Exemplary non-IL-2 moieties include albumin,
15 or antibody domains such as Fc domains or antigen binding domains of immunoglobulins.

IL-2 bearing immunoconjugates are fusion proteins comprising an antigen binding moiety and an IL-2 moiety. They significantly increase the efficacy of IL-2 therapy by directly targeting IL-2 e.g. into a tumor microenvironment. According to the invention, an antigen binding moiety can be a whole antibody or immunoglobulin, or a portion or variant thereof that has a biological
20 function such as antigen specific binding affinity.

The benefits of immunoconjugate therapy are readily apparent. For example, an antigen binding moiety of an immunoconjugate recognizes a tumor-specific epitope and results in targeting of the immunoconjugate molecule to the tumor site. Therefore, high concentrations of IL-2 can be delivered into the tumor microenvironment, thereby resulting in activation and proliferation of a
25 variety of immune effector cells mentioned herein using a much lower dose of the immunoconjugate than would be required for unconjugated IL-2. Moreover, since application of IL-2 in form of immunoconjugates allows lower doses of the cytokine itself, the potential for undesirable side effects of IL-2 is restricted, and targeting the IL-2 to a specific site in the body by means of an immunoconjugate may also result in a reduction of systemic exposure and thus
30 less side effects than obtained with unconjugated IL-2. In addition, the increased circulating half-life of an immunoconjugate compared to unconjugated IL-2 contributes to the efficacy of the

immunoconjugate. However, this characteristic of IL-2 immunoconjugates may again aggravate potential side effects of the IL-2 molecule. Because of the significantly longer circulating half-life of IL-2 immunoconjugate in the bloodstream relative to unconjugated IL-2, the probability for IL-2 or other portions of the fusion protein molecule to activate components generally present in the vasculature is increased. The same concern applies to other fusion proteins that contain IL-2 fused to another moiety such as Fc or albumin, resulting in an extended half-life of IL-2 in the circulation. Therefore an immunoconjugate comprising a mutant IL-2 polypeptide according to the invention, with reduced toxicity compared to wild-type forms of IL-2, is particularly advantageous.

10 Accordingly, the invention further provides a mutant IL-2 polypeptide as described hereinbefore, linked to at least one non-IL-2 moiety. In one embodiment the mutant IL-2 polypeptide and the non-IL-2 moiety form a fusion protein, i.e. the mutant IL-2 polypeptide shares a peptide bond with the non-IL-2 moiety. In one embodiment the mutant IL-2 polypeptide is linked to a first and a second non-IL-2 moiety. In one embodiment the mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with the first antigen binding moiety, and the second antigen binding moiety shares an amino- or carboxy-terminal peptide bond with either i) the mutant IL-2 polypeptide or ii) the first antigen binding moiety. In a specific embodiment the mutant IL-2 polypeptide shares a carboxy-terminal peptide bond with said first non-IL-2 moiety and an amino-terminal peptide bond with said second non-IL-2 moiety. In one embodiment said non-IL-2 moiety is a targeting moiety. In a particular embodiment said non-IL-2 moiety is an antigen binding moiety (thus forming an immunoconjugate with the mutant IL-2 polypeptide, as described in more detail hereinbelow). In certain embodiments the antigen binding moiety is an antibody or an antibody fragment. In one embodiment the antigen binding moiety is a full-length antibody. In one embodiment the antigen binding moiety is an immunoglobulin molecule, particularly an IgG class immunoglobulin molecule, more particularly an IgG₁ subclass immunoglobulin molecule. In one such embodiment, the mutant IL-2 polypeptide shares an amino-terminal peptide bond with one of the immunoglobulin heavy chains. In another embodiment the antigen binding moiety is an antibody fragment. In some embodiments said antigen binding moiety comprises an antigen binding domain of an antibody comprising an antibody heavy chain variable region and an antibody light chain variable region. In a more specific embodiment the antigen binding moiety is a Fab molecule or a scFv molecule. In a particular embodiment the antigen binding moiety is a Fab molecule. In another embodiment the antigen binding moiety is a scFv molecule. In one embodiment said antigen binding moiety is

directed to an antigen presented on a tumor cell or in a tumor cell environment. In a preferred embodiment said antigen is selected from the group of Fibroblast Activation Protein (FAP), the A1 domain of Tenascin-C (TNC A1), the A2 domain of Tenascin-C (TNC A2), the Extra Domain B of Fibronectin (EDB), Carcinoembryonic Antigen (CEA) and the Melanoma-associated Chondroitin Sulfate Proteoglycan (MCSP). Where the mutant IL-2 polypeptide is linked to more than one antigen binding moiety, e.g. a first and a second antigen binding moiety, each antigen binding moiety can be independently selected from various forms of antibodies and antibody fragments. For example, the first antigen binding moiety can be a Fab molecule and the second antigen binding moiety can be a scFv molecule. In a specific embodiment each of said first and said second antigen binding moieties is a scFv molecule or each of said first and said second antigen binding moieties is a Fab molecule. In a particular embodiment each of said first and said second antigen binding moieties is a Fab molecule. Likewise, where the mutant IL-2 polypeptide is linked to more than one antigen binding moiety, e.g. a first and a second antigen binding moiety, the antigen to which each of the antigen binding moieties is directed can be independently selected. In one embodiment said first and said second antigen binding moieties are directed to different antigens. In another embodiment said first and said second antigen binding moieties are directed to the same antigen. As described above, the antigen is particularly an antigen presented on a tumor cell or in a tumor cell environment, more particularly an antigen selected from the group of Fibroblast Activation Protein (FAP), the A1 domain of Tenascin-C (TNC A1), the A2 domain of Tenascin-C (TNC A2), the Extra Domain B of Fibronectin (EDB), Carcinoembryonic Antigen (CEA) and the Melanoma-associated Chondroitin Sulfate Proteoglycan (MCSP). The antigen binding region may further incorporate any of the features, singly or in combination, described herein in relation to antigen binding domains of immunoconjugates.

Immunoconjugates

In a particular aspect the invention provides an immunoconjugate comprising a mutant IL-2 polypeptide comprising one or more amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, and at least one antigen binding moiety. In one embodiment according to the invention, the amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor and

preserves affinity of the mutant IL-2 polypeptide to the intermediate affinity IL-2 receptor is at a position selected from a position corresponding to residue 42, 45 and 72 of human IL-2. In one embodiment said amino acid mutation is an amino acid substitution. In one embodiment said amino acid mutation is an amino acid substitution selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, Y45K, L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K, more specifically an amino acid substitution selected from the group of F42A, Y45A and L72G. In one embodiment the amino acid mutation is at a position corresponding to residue 42 of human IL-2. In a specific embodiment said amino acid mutation is an amino acid substitution selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, and F42. In an even more specific embodiment said amino acid substitution is F42A. In another embodiment the amino acid mutation is at a position corresponding to residue 45 of human IL-2. In a specific embodiment said amino acid mutation is an amino acid substitution selected from the group of Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, and Y45K. In an even more specific embodiment said amino acid substitution is Y45A. In yet another embodiment the amino acid mutation is at a position corresponding to residue 72 of human IL-2. In a specific embodiment said amino acid mutation is an amino acid substitution selected from the group of L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In an even more specific embodiment said amino acid substitution is L72G. In certain embodiments, the mutant IL-2 polypeptide according to the invention does not comprise an amino acid mutation at a position corresponding to residue 38 of human IL-2. In a particular embodiment, the mutant IL-2 polypeptide comprised in the immunoconjugate of the invention comprises at least a first and a second amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the α -subunit of the IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate affinity IL-2 receptor. In one embodiment said first and second amino acid mutations are at two positions selected from the positions corresponding to residue 42, 45 and 72 of human IL-2. In one embodiment said first and second amino acid mutations are amino acid substitutions. In one embodiment said first and second amino acid mutations are amino acid substitutions selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, Y45K, L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K. In a particular embodiment said first and second amino acid mutations are amino acid substitutions selected from the group of F42A, Y45A and L72G. The mutant IL-2 polypeptide may further incorporate

any of the features, singly or in combination, described in the preceding paragraphs in relation to the mutant IL-2 polypeptides of the invention. In one embodiment said mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with said antigen binding moiety comprised in the immunoconjugate, i.e. the immunoconjugate is a fusion protein. In certain embodiments
5 said antigen binding moiety is an antibody or an antibody fragment. In some embodiments said antigen binding moiety comprises an antigen binding domain of an antibody comprising an antibody heavy chain variable region and an antibody light chain variable region. The antigen binding region may incorporate any of the features, singly or in combination, described hereinabove or below in relation to antigen binding domains.

10 **Immunoconjugate Formats**

Particularly suitable immunoconjugate formats are described in PCT publication no. WO 2011/020783, which is incorporated herein by reference in its entirety. These immunoconjugates comprise at least two antigen binding domains. Thus, in one embodiment, the immunoconjugate according to the present invention comprises at least a first mutant IL-2 polypeptide as described
15 herein, and at least a first and a second antigen binding moiety. In a particular embodiment, said first and second antigen binding moiety are independently selected from the group consisting of an Fv molecule, particularly a scFv molecule, and a Fab molecule. In a specific embodiment, said first mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with said first antigen binding moiety and said second antigen binding moiety shares an amino- or
20 carboxy-terminal peptide bond with either i) the first mutant IL-2 polypeptide or ii) the first antigen binding moiety. In a particular embodiment, the immunoconjugate consists essentially of a first mutant IL-2 polypeptide and first and second antigen binding moieties, joined by one or more linker sequences. Such formats have the advantage that they bind with high affinity to the target antigen (such as a tumor antigen), but only monomeric binding to the IL-2 receptor, thus
25 avoiding targeting the immunoconjugate to IL-2 receptor bearing immune cells at other locations than the target site. In a particular embodiment, a first mutant IL-2 polypeptide shares a carboxy-terminal peptide bond with a first antigen binding moiety and further shares an amino-terminal peptide bond with a second antigen binding moiety. In another embodiment, a first antigen binding moiety shares a carboxy-terminal peptide bond with a first mutant IL-2 polypeptide, and
30 further shares an amino-terminal peptide bond with a second antigen binding moiety. In another embodiment, a first antigen binding moiety shares an amino-terminal peptide bond with a first mutant IL-2 polypeptide, and further shares a carboxy-terminal peptide with a second antigen

binding moiety. In a particular embodiment, a mutant IL-2 polypeptide shares a carboxy-terminal peptide bond with a first heavy chain variable region and further shares an amino-terminal peptide bond with a second heavy chain variable region. In another embodiment a mutant IL-2 polypeptide shares a carboxy-terminal peptide bond with a first light chain variable
5 region and further shares an amino-terminal peptide bond with a second light chain variable region. In another embodiment, a first heavy or light chain variable region is joined by a carboxy-terminal peptide bond to a first mutant IL-2 polypeptide and is further joined by an amino-terminal peptide bond to a second heavy or light chain variable region. In another embodiment, a first heavy or light chain variable region is joined by an amino-terminal peptide
10 bond to a first mutant IL-2 polypeptide and is further joined by a carboxy-terminal peptide bond to a second heavy or light chain variable region. In one embodiment, a mutant IL-2 polypeptide shares a carboxy-terminal peptide bond with a first Fab heavy or light chain and further shares an amino-terminal peptide bond with a second Fab heavy or light chain. In another embodiment, a first Fab heavy or light chain shares a carboxy-terminal peptide bond with a first mutant IL-2
15 polypeptide and further shares an amino-terminal peptide bond with a second Fab heavy or light chain. In other embodiments, a first Fab heavy or light chain shares an amino-terminal peptide bond with a first mutant IL-2 polypeptide and further shares a carboxy-terminal peptide bond with a second Fab heavy or light chain. In one embodiment, the immunoconjugate comprises at least a first mutant IL-2 polypeptide sharing an amino-terminal peptide bond with one or more
20 scFv molecules and further sharing a carboxy-terminal peptide bond with one or more scFv molecules.

Other particularly suitable immunoconjugate formats comprise an immunoglobulin molecule as antigen binding moiety. In one such embodiment, the immunoconjugate comprises at least one mutant IL-2 polypeptide as described herein and an immunoglobulin molecule, particularly an
25 IgG molecule, more particularly an IgG₁ molecule. In one embodiment the immunoconjugate comprises not more than one mutant IL-2 polypeptide. In one embodiment the immunoglobulin molecule is human. In one embodiment the mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with the immunoglobulin molecule. In one embodiment, the immunoconjugate essentially consists of a mutant IL-2 polypeptide and an immunoglobulin
30 molecule, particularly an IgG molecule, more particularly an IgG₁ molecule, joined by one or more linker sequences. In a specific embodiment the mutant IL-2 polypeptide is joined at its amino-terminal amino acid to the carboxy-terminal amino acid of one of the immunoglobulin heavy chains. In certain embodiments, the immunoglobulin molecule comprises in the Fc

domain a modification promoting heterodimerization of two non-identical immunoglobulin heavy chains. The site of most extensive protein-protein interaction between the two polypeptide chains of a human IgG Fc domain is in the CH3 domain of the Fc domain. Thus, in one embodiment said modification is in the CH3 domain of the Fc domain. In a specific embodiment said modification is a knob-into-hole modification, comprising a knob modification in one of the immunoglobulin heavy chains and a hole modification in the other one of the immunoglobulin heavy chains. The knob-into-hole technology is described e.g. in US 5,731,168; US 7,695,936; Ridgway et al., *Prot Eng* 9, 617-621 (1996) and Carter, *J Immunol Meth* 248, 7-15 (2001). Generally, the method involves introducing a protuberance ("knob") at the interface of a first polypeptide and a corresponding cavity ("hole") in the interface of a second polypeptide, such that the protuberance can be positioned in the cavity so as to promote heterodimer formation and hinder homodimer formation. Protuberances are constructed by replacing small amino acid side chains from the interface of the first polypeptide with larger side chains (e.g. tyrosine or tryptophan). Compensatory cavities of identical or similar size to the protuberances are created in the interface of the second polypeptide by replacing large amino acid side chains with smaller ones (e.g. alanine or threonine). The protuberance and cavity can be made by altering the nucleic acid encoding the polypeptides, e.g. by site-specific mutagenesis, or by peptide synthesis. In a specific embodiment a knob modification comprises the amino acid substitution T366W in one of the two immunoglobulin heavy chains, and the hole modification comprises the amino acid substitutions T366S, L368A and Y407V in the other one of the two immunoglobulin heavy chains. In a further specific embodiment, immunoglobulin heavy chain comprising the knob modification additionally comprises the amino acid substitution S354C, and the immunoglobulin heavy chain comprising the hole modification additionally comprises the amino acid substitution Y349C. Introduction of these two cysteine residues results in formation of a disulfide bridge between the two heavy chains, further stabilizing the dimer (Carter, *J Immunol Methods* 248, 7-15 (2001)).

In a particular embodiment the mutant IL-2 polypeptide is joined to the carboxy-terminal amino acid of the immunoglobulin heavy chain comprising the knob modification.

In an alternative embodiment a modification promoting heterodimerization of two non-identical polypeptide chains comprises a modification mediating electrostatic steering effects, e.g. as described in PCT publication WO 2009/089004. Generally, this method involves replacement of one or more amino acid residues at the interface of the two polypeptide chains by charged amino

acid residues so that homodimer formation becomes electrostatically unfavorable but heterodimerization electrostatically favorable.

An Fc domain confers to the immunoconjugate favorable pharmacokinetic properties, including a long serum half-life which contributes to good accumulation in the target tissue and a favorable
5 tissue-blood distribution ratio. At the same time it may, however, lead to undesirable targeting of the immunoconjugate to cells expressing Fc receptors rather than to the preferred antigen-bearing cells. Moreover, the co-activation of Fc receptor signaling pathways may lead to cytokine release which, in combination with the IL-2 polypeptide and the long half-life of the immunoconjugate, results in excessive activation of cytokine receptors and severe side effects
10 upon systemic administration. In line with this, conventional IgG-IL-2 immunoconjugates have been described to be associated with infusion reactions (see e.g. King et al., J Clin Oncol 22, 4463-4473 (2004)).

Accordingly, in certain embodiments the immunoglobulin molecule comprised in the immunoconjugate according to the invention is engineered to have reduced binding affinity to an
15 Fc receptor. In one such embodiment the immunoglobulin comprises in its Fc domain one or more amino acid mutation that reduces the binding affinity of the immunoconjugate to an Fc receptor. Typically, the same one or more amino acid mutation is present in each of the two immunoglobulin heavy chains. In one embodiment said amino acid mutation reduces the binding affinity of the immunoconjugate to the Fc receptor by at least 2-fold, at least 5-fold, or at least
20 10-fold. In embodiments where there is more than one amino acid mutation that reduces the binding affinity of the immunoconjugate to the Fc receptor, the combination of these amino acid mutations may reduce the binding affinity of the Fc domain to the Fc receptor by at least 10-fold, at least 20-fold, or even at least 50-fold. In one embodiment the immunoconjugate comprising an engineered immunoglobulin molecule exhibits less than 20%, particularly less than 10%, more
25 particularly less than 5% of the binding affinity to an Fc receptor as compared to an immunoconjugate comprising a non-engineered immunoglobulin molecule. In one embodiment the Fc receptor is an activating Fc receptor. In a specific embodiment the Fc receptor is an Fcγ receptor, more specifically an FcγRIIIa, FcγRI or FcγRIIa receptor. Preferably, binding to each of these receptors is reduced. In some embodiments binding affinity to a complement component,
30 specifically binding affinity to C1q, is also reduced. In one embodiment binding affinity to neonatal Fc receptor (FcRn) is not reduced. Substantially similar binding to FcRn, i.e. preservation of the binding affinity of the immunoglobulin to said receptor, is achieved when the

immunoglobulin (or the immunoconjugate comprising said immunoglobulin) exhibits greater than about 70% of the binding affinity of a non-engineered form of the immunoglobulin (or the immunoconjugate comprising said non-engineered form of the immunoglobulin) to FcRn. Immunoglobulins, or immunoconjugates comprising said immunoglobulins, may exhibit greater than about 80% and even greater than about 90% of such affinity. In one embodiment the amino acid mutation is an amino acid substitution. In one embodiment the immunoglobulin comprises an amino acid substitution at position P329 of the immunoglobulin heavy chain (Kabat numbering). In a more specific embodiment the amino acid substitution is P329A or P329G, particularly P329G. In one embodiment the immunoglobulin comprises a further amino acid substitution at a position selected from S228, E233, L234, L235, N297 and P331 of the immunoglobulin heavy chain. In a more specific embodiment the further amino acid substitution is S228P, E233P, L234A, L235A, L235E, N297A, N297D or P331S. In a particular embodiment the immunoglobulin comprises amino acid substitutions at positions P329, L234 and L235 of the immunoglobulin heavy chain. In a more particular embodiment the immunoglobulin comprises the amino acid mutations L234A, L235A and P329G (LALA P329G). This combination of amino acid substitutions almost completely abolishes Fc γ receptor binding of a human IgG molecule, and hence decreases effector function including antibody-dependent cell-mediated cytotoxicity (ADCC).

In certain embodiments, the immunoconjugate comprises one or more proteolytic cleavage sites located between mutant IL-2 polypeptide and antigen binding moieties.

Components of the immunoconjugate (e.g. antigen binding moieties and/or mutant IL-2 polypeptide) may be linked directly or through various linkers, particularly peptide linkers comprising one or more amino acids, typically about 2-20 amino acids, that are described herein or are known in the art. Suitable, non-immunogenic linker peptides include, for example, (G4S)_n, (SG₄)_n or G₄(SG₄)_n linker peptides, wherein n is generally a number between 1 and 10, typically between 2 and 4.

Antigen Binding Moieties

The antigen binding moiety of the immunoconjugate of the invention is generally a polypeptide molecule that binds to a specific antigenic determinant and is able to direct the entity to which it is attached (e.g. a mutant IL-2 polypeptide or a second antigen binding moiety) to a target site, for example to a specific type of tumor cell or tumor stroma that bears the antigenic determinant. The immunoconjugate can bind to antigenic determinants found, for example, on the surfaces of

tumor cells, on the surfaces of virus-infected cells, on the surfaces of other diseased cells, free in blood serum, and/or in the extracellular matrix (ECM).

- Non-limiting examples of tumor antigens include MAGE, MART-1/Melan-A, gp100, Dipeptidyl peptidase IV (DPPIV), adenosine deaminase-binding protein (ADAbp), cyclophilin b, Colorectal associated antigen (CRC)-C017-1A/GA733, Carcinoembryonic Antigen (CEA) and its immunogenic epitopes CAP-1 and CAP-2, etv6, aml1, Prostate Specific Antigen (PSA) and its immunogenic epitopes PSA-1, PSA-2, and PSA-3, prostate-specific membrane antigen (PSMA), T-cell receptor/CD3-zeta chain, MAGE-family of tumor antigens (e.g., MAGE-A1, MAGE-A2, MAGE-A3, MAGE-A4, MAGE-A5, MAGE-A6, MAGE-A7, MAGE-A8, MAGE-A9, MAGE-A10, MAGE-A11, MAGE-A12, MAGE-Xp2 (MAGE-B2), MAGE-Xp3 (MAGE-B3), MAGE-Xp4 (MAGE-B4), MAGE-C1, MAGE-C2, MAGE-C3, MAGE-C4, MAGE-C5), GAGE-family of tumor antigens (e.g., GAGE-1, GAGE-2, GAGE-3, GAGE-4, GAGE-5, GAGE-6, GAGE-7, GAGE-8, GAGE-9), BAGE, RAGE, LAGE-1, NAG, GnT-V, MUM-1, CDK4, tyrosinase, p53, MUC family, HER2/neu, p21ras, RCAS1, α -fetoprotein, E-cadherin, α -catenin, β -catenin and γ -catenin, p120ctn, gp100 Pmel117, PRAME, NY-ESO-1, cdc27, adenomatous polyposis coli protein (APC), fodrin, Connexin 37, Ig-idiotype, p15, gp75, GM2 and GD2 gangliosides, viral products such as human papilloma virus proteins, Smad family of tumor antigens, Imp-1, P1A, EBV-encoded nuclear antigen (EBNA)-1, brain glycogen phosphorylase, SSX-1, SSX-2 (HOM-MEL-40), SSX-1, SSX-4, SSX-5, SCP-1 and CT-7, and c-erbB-2.
- Non-limiting examples of viral antigens include influenza virus hemagglutinin, Epstein-Barr virus LMP-1, hepatitis C virus E2 glycoprotein, HIV gp160, and HIV gp120.

Non-limiting examples of ECM antigens include syndecan, heparanase, integrins, osteopontin, link, cadherins, laminin, laminin type EGF, lectin, fibronectin, notch, tenascin, and matrixin.

- The immunoconjugates of the invention can bind to the following specific non-limiting examples of cell surface antigens: FAP, Her2, EGFR, IGF-1R, CD2 (T-cell surface antigen), CD3 (heteromultimer associated with the TCR), CD22 (B-cell receptor), CD23 (low affinity IgE receptor), CD30 (cytokine receptor), CD33 (myeloid cell surface antigen), CD40 (tumor necrosis factor receptor), IL-6R (IL6 receptor), CD20, MCSP, and PDGF β R (β platelet-derived growth factor receptor).

In one embodiment, the immunoconjugate of the invention comprises two or more antigen binding moieties, wherein each of these antigen binding moieties specifically binds to the same antigenic determinant. In another embodiment, the immunoconjugate of the invention comprises two or more antigen binding moieties, wherein each of these antigen binding moieties
5 specifically binds to different antigenic determinants.

The antigen binding moiety can be any type of antibody or fragment thereof that retains specific binding to an antigenic determinant. Antibody fragments include, but are not limited to, V_H fragments, V_L fragments, Fab fragments, F(ab')₂ fragments, scFv fragments, Fv fragments, minibodies, diabodies, triabodies, and tetrabodies (see e.g. Hudson and Souriau, Nature Med 9,
10 129-134 (2003)).

Particularly suitable antigen binding moieties are described in PCT publication no. WO 2011/020783, which is incorporated herein by reference in its entirety.

In one embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that are specific for the Extra Domain B of fibronectin (EDB). In another
15 embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that can compete with monoclonal antibody L19 for binding to an epitope of EDB. See, e.g., PCT publication WO 2007/128563 A1 (incorporated herein by reference in its entirety). In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain derived from the L19 monoclonal antibody shares a carboxy-terminal peptide
20 bond with a mutant IL-2 polypeptide which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain derived from the L19 monoclonal antibody. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab light chain derived from the L19 monoclonal antibody shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide which in turn shares a carboxy-terminal peptide bond with a second Fab
25 light chain derived from the L19 monoclonal antibody. In a further embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first scFv derived from the L19 monoclonal antibody shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide which in turn shares a carboxy-terminal peptide bond with a second scFv derived from the L19 monoclonal antibody.

30 In a more specific embodiment, the immunoconjugate comprises the polypeptide sequence of SEQ ID NO: 199 or a variant thereof that retains functionality. In another embodiment, the

immunoconjugate comprises a Fab light chain derived from the L19 monoclonal antibody. In a more specific embodiment, the immunoconjugate comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 201 or a variant thereof that retains functionality. In yet another embodiment, the immunoconjugate comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 199 and SEQ ID NO: 201 or variants thereof that retain functionality. In another specific embodiment, the polypeptides are covalently linked, e.g., by a disulfide bond.

In one embodiment, the immunoconjugate of the invention comprises at least one, typically two or more antigen binding moieties that are specific for the A1 domain of Tenascin (TNC-A1). In another embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that can compete with monoclonal antibody F16 for binding to an epitope of TNC-A1. See, e.g., PCT Publication WO 2007/128563 A1 (incorporated herein by reference in its entirety). In one embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that are specific for the A1 and/or the A4 domain of Tenascin (TNC-A1 or TNC-A4 or TNC-A1/A4). In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain specific for the A1 domain of Tenascin shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain specific for the A1 domain of Tenascin. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab light chain specific for the A1 domain of Tenascin shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide which in turn shares a carboxy-terminal peptide bond with a second Fab light chain specific for the A1 domain of Tenascin. In a further embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first scFv specific for the A1 domain of Tenascin shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide which in turn shares a carboxy-terminal peptide bond with a second scFv specific for the A1 domain of Tenascin. In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein an immunoglobulin heavy chain specific for TNC-A1 shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide.

In a specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 33 or SEQ ID NO: 35, or variants thereof

that retain functionality. In another specific embodiment, the antigen binding moieties of the immunoconjugate comprise a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 29 or SEQ ID NO: 31, or variants thereof that retain functionality. In a more specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 33 or SEQ ID NO: 35 or variants thereof that retain functionality, and a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 29 or SEQ ID NO: 31 or variants thereof that retain functionality.

10 In another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to either SEQ ID NO: 34 or SEQ ID NO: 36. In yet another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by the polynucleotide sequence of
15 either SEQ ID NO: 34 or SEQ ID NO: 36. In another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to either SEQ ID NO: 30 or SEQ ID NO: 32. In yet another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is
20 encoded by the polynucleotide sequence of either SEQ ID NO: 30 or SEQ ID NO: 32.

In a specific embodiment, the immunoconjugate comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 203 or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%,
25 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 205 or SEQ ID NO: 215, or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 207 or SEQ ID NO: 237 or variants thereof that retain functionality. In a more specific embodiment, the
30 immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 205 and SEQ ID NO: 207 or variants thereof that retain functionality. In another specific embodiment,

the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 215 and SEQ ID NO: 237 or variants thereof that retain functionality.

In a specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to SEQ ID NO: 204. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of SEQ ID NO: 204. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to either SEQ ID NO: 206 or SEQ ID NO: 216. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of either SEQ ID NO: 206 or SEQ ID NO: 216. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to either SEQ ID NO: 208 or SEQ ID NO: 238. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of either SEQ ID NO: 208 or SEQ ID NO: 238.

In one embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that are specific for the A2 domain of Tenascin (TNC-A2). In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain specific for the A2 domain of Tenascin shares a carboxy-terminal peptide bond with a IL mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain specific for the A2 domain of Tenascin. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab light chain specific for the A2 domain of Tenascin shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab light chain specific for the A2 domain of Tenascin. In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein an immunoglobulin heavy chain specific for TNC-A2 shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide.

In a specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 27, SEQ ID

NO: 159, SEQ ID NO: 163, SEQ ID NO: 167, SEQ ID NO: 171, SEQ ID NO: 175, SEQ ID NO: 179, SEQ ID NO: 183 and SEQ ID NO: 187, or variants thereof that retain functionality. In another specific embodiment, the antigen binding moieties of the immunoconjugate comprise a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 23, SEQ ID NO: 25; SEQ ID NO: 157, SEQ ID NO: 161, SEQ ID NO: 165, SEQ ID NO: 169, SEQ ID NO: 173, SEQ ID NO: 177, SEQ ID NO: 181 and SEQ ID NO: 185, or variants thereof that retain functionality. In a more specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 27, SEQ ID NO: 159, SEQ ID NO: 163, SEQ ID NO: 167, SEQ ID NO: 171, SEQ ID NO: 175, SEQ ID NO: 179, SEQ ID NO: 183 and SEQ ID NO: 187, or variants thereof that retain functionality, and a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 23, SEQ ID NO: 25; SEQ ID NO: 157, SEQ ID NO: 161, SEQ ID NO: 165, SEQ ID NO: 169, SEQ ID NO: 173, SEQ ID NO: 177, SEQ ID NO: 181 and SEQ ID NO: 185, or variants thereof that retain functionality.

In another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 28, SEQ ID NO: 160, SEQ ID NO: 164, SEQ ID NO: 168, SEQ ID NO: 172, SEQ ID NO: 176, SEQ ID NO: 180, SEQ ID NO: 184 and SEQ ID NO: 188. In yet another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence selected from the group of SEQ ID NO: 28, SEQ ID NO: 160, SEQ ID NO: 164, SEQ ID NO: 168, SEQ ID NO: 172, SEQ ID NO: 176, SEQ ID NO: 180, SEQ ID NO: 184 and SEQ ID NO: 188. In another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 158, SEQ ID NO: 162, SEQ ID NO: 166, SEQ ID NO: 170, SEQ ID NO: 174, SEQ ID NO: 178, SEQ ID NO: 182 and SEQ ID NO: 186. In yet another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence selected from the group of of

SEQ ID NO: 24, SEQ ID NO: 26, SEQ ID NO: 158, SEQ ID NO: 162, SEQ ID NO: 166, SEQ ID NO: 170, SEQ ID NO: 174, SEQ ID NO: 178, SEQ ID NO: 182 and SEQ ID NO: 186.

In a specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 241, SEQ ID NO: 243 and SEQ ID NO: 245, or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 247, SEQ ID NO: 249 and SEQ ID NO: 251, or variants thereof that retain functionality. In a more specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 241, SEQ ID NO: 243, and SEQ ID NO: 245 or variants thereof that retain functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 247, SEQ ID NO: 249 and SEQ ID NO: 251 or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 241 and either SEQ ID NO: 249 or SEQ ID NO: 251, or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 243 and either SEQ ID NO: 247 or SEQ ID NO: 249, or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 245 and SEQ ID NO: 247, or variants thereof that retain functionality.

In a specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 242, SEQ ID NO: 244 and SEQ ID NO: 246. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence selected from the group of of SEQ ID NO: 242, SEQ ID NO: 244 and SEQ ID NO: 246. In another specific embodiment, the immunoconjugate

comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 248, SEQ ID NO: 250 and SEQ ID NO: 252. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence selected from the group of of SEQ ID NO: 248, SEQ ID NO: 250 and SEQ ID NO: 252.

In one embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that are specific for the Fibroblast Activated Protein (FAP). In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain specific for FAP shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain specific for FAP. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab light chain specific for FAP shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab light chain specific for FAP. In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein an immunoglobulin heavy chain specific for FAP shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide.

In a specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group consisting of SEQ ID NO: 41, SEQ ID NO: 45, SEQ ID NO: 47, SEQ ID NO: 51, SEQ ID NO: 55, SEQ ID NO: 59, SEQ ID NO: 63, SEQ ID NO: 67, SEQ ID NO: 71, SEQ ID NO: 75, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 87, SEQ ID NO: 91, SEQ ID NO: 95, SEQ ID NO: 99, SEQ ID NO: 103, SEQ ID NO: 107, SEQ ID NO: 111, SEQ ID NO: 115, SEQ ID NO: 119, SEQ ID NO: 123, SEQ ID NO: 127, SEQ ID NO: 131, SEQ ID NO: 135, SEQ ID NO: 139, SEQ ID NO: 143, SEQ ID NO: 147, SEQ ID NO: 151 and SEQ ID NO: 155, or variants thereof that retain functionality. In another specific embodiment, the antigen binding moieties of the immunoconjugate comprise a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group consisting of: SEQ ID NO: 37, SEQ ID NO: 39, SEQ ID NO: 43, SEQ ID NO: 49, SEQ ID NO: 53, SEQ ID NO: 57, SEQ ID NO: 61, SEQ ID NO: 65, SEQ ID NO: 69, SEQ ID NO: 73, SEQ ID NO: 77, SEQ ID NO: 81, SEQ ID NO: 85, SEQ ID NO: 89, SEQ ID NO: 93, SEQ ID NO: 97, SEQ ID NO: 101, SEQ ID

NO: 105, SEQ ID NO: 109, SEQ ID NO: 113, SEQ ID NO: 117, SEQ ID NO: 121, SEQ ID NO: 125, SEQ ID NO: 129, SEQ ID NO: 133, SEQ ID NO: 137, SEQ ID NO: 141, SEQ ID NO: 145, SEQ ID NO: 149 and SEQ ID NO: 153, or variants thereof that retain functionality. In a more specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group consisting of SEQ ID NO: 41, SEQ ID NO: 45, SEQ ID NO: 47, SEQ ID NO: 51, SEQ ID NO: 55, SEQ ID NO: 59, SEQ ID NO: 63, SEQ ID NO: 67, SEQ ID NO: 71, SEQ ID NO: 75, SEQ ID NO: 79, SEQ ID NO: 83, SEQ ID NO: 87, SEQ ID NO: 91, SEQ ID NO: 95, SEQ ID NO: 99, SEQ ID NO: 103, SEQ ID NO: 107, SEQ ID NO: 111, SEQ ID NO: 115, SEQ ID NO: 119, SEQ ID NO: 123, SEQ ID NO: 127, SEQ ID NO: 131, SEQ ID NO: 135, SEQ ID NO: 139, SEQ ID NO: 143, SEQ ID NO: 147, SEQ ID NO: 151 and SEQ ID NO: 155, or variants thereof that retain functionality, and a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group consisting of: SEQ ID NO: 37, SEQ ID NO: 39, SEQ ID NO: 43, SEQ ID NO: 49, SEQ ID NO: 53, SEQ ID NO: 57, SEQ ID NO: 61, SEQ ID NO: 65, SEQ ID NO: 69, SEQ ID NO: 73, SEQ ID NO: 77, SEQ ID NO: 81, SEQ ID NO: 85, SEQ ID NO: 89, SEQ ID NO: 93, SEQ ID NO: 97, SEQ ID NO: 101, SEQ ID NO: 105, SEQ ID NO: 109, SEQ ID NO: 113, SEQ ID NO: 117, SEQ ID NO: 121, SEQ ID NO: 125, SEQ ID NO: 129, SEQ ID NO: 133, SEQ ID NO: 137, SEQ ID NO: 141, SEQ ID NO: 145, SEQ ID NO: 149 and SEQ ID NO: 153, or variants thereof that retain functionality. In one embodiment, antigen binding moieties of the immunoconjugate comprise the heavy chain variable region sequence of SEQ ID NO: 41 and the light chain variable region sequence of SEQ ID NO: 39. In one embodiment, antigen binding moieties of the immunoconjugate comprise the heavy chain variable region sequence of SEQ ID NO: 51 and the light chain variable region sequence of SEQ ID NO: 49. In one embodiment, antigen binding moieties of the immunoconjugate comprise the heavy chain variable region sequence of SEQ ID NO: 111 and the light chain variable region sequence of SEQ ID NO: 109. In one embodiment, antigen binding moieties of the immunoconjugate comprise the heavy chain variable region sequence of SEQ ID NO: 143 and the light chain variable region sequence of SEQ ID NO: 141. In one embodiment, antigen binding moieties of the immunoconjugate comprise the heavy chain variable region sequence of SEQ ID NO: 151 and the light chain variable region sequence of SEQ ID NO: 149.

In another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about

80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group consisting of: SEQ ID NO: 42, SEQ ID NO: 46, SEQ ID NO: 48, SEQ ID NO: 52, SEQ ID NO: 56, SEQ ID NO: 60, SEQ ID NO: 64, SEQ ID NO: 68, SEQ ID NO: 72, SEQ ID NO: 76, SEQ ID NO: 80, SEQ ID NO: 84, SEQ ID NO: 88, SEQ ID NO: 92, SEQ ID NO: 96, SEQ ID NO: 100, SEQ ID NO: 104, SEQ ID NO: 108, SEQ ID NO: 112, SEQ ID NO: 116, SEQ ID NO: 120, SEQ ID NO: 124, SEQ ID NO: 128, SEQ ID NO: 132, SEQ ID NO: 136, SEQ ID NO: 140, SEQ ID NO: 144, SEQ ID NO: 148, SEQ ID NO: 152, and SEQ ID NO: 156. In yet another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence selected from the group consisting of: SEQ ID NO: 42, SEQ ID NO: 46, SEQ ID NO: 48, SEQ ID NO: 52, SEQ ID NO: 56, SEQ ID NO: 60, SEQ ID NO: 64, SEQ ID NO: 68, SEQ ID NO: 72, SEQ ID NO: 76, SEQ ID NO: 80, SEQ ID NO: 84, SEQ ID NO: 88, SEQ ID NO: 92, SEQ ID NO: 96, SEQ ID NO: 100, SEQ ID NO: 104, SEQ ID NO: 108, SEQ ID NO: 112, SEQ ID NO: 116, SEQ ID NO: 120, SEQ ID NO: 124, SEQ ID NO: 128, SEQ ID NO: 132, SEQ ID NO: 136, SEQ ID NO: 140, SEQ ID NO: 144, SEQ ID NO: 148, SEQ ID NO: 152, and SEQ ID NO: 156. In another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to sequence selected from the group consisting of: SEQ ID NO: 38, SEQ ID NO: 40, SEQ ID NO: 44, SEQ ID NO: 50, SEQ ID NO: 54, SEQ ID NO: 58, SEQ ID NO: 62, SEQ ID NO: 66, SEQ ID NO: 70, SEQ ID NO: 74, SEQ ID NO: 78, SEQ ID NO: 82, SEQ ID NO: 86, SEQ ID NO: 90, SEQ ID NO: 94, SEQ ID NO: 98, SEQ ID NO: 102, SEQ ID NO: 106, SEQ ID NO: 110, SEQ ID NO: 114, SEQ ID NO: 118, SEQ ID NO: 122, SEQ ID NO: 126, SEQ ID NO: 130, SEQ ID NO: 134, SEQ ID NO: 138, SEQ ID NO: 142, SEQ ID NO: 146, SEQ ID NO: 150, and SEQ ID NO: 154. In yet another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence selected from the group consisting of: SEQ ID NO: 38, SEQ ID NO: 40, SEQ ID NO: 44, SEQ ID NO: 50, SEQ ID NO: 54, SEQ ID NO: 58, SEQ ID NO: 62, SEQ ID NO: 66, SEQ ID NO: 70, SEQ ID NO: 74, SEQ ID NO: 78, SEQ ID NO: 82, SEQ ID NO: 86, SEQ ID NO: 90, SEQ ID NO: 94, SEQ ID NO: 98, SEQ ID NO: 102, SEQ ID NO: 106, SEQ ID NO: 110, SEQ ID NO: 114, SEQ ID NO: 118, SEQ ID NO: 122, SEQ ID NO: 126, SEQ ID NO: 130, SEQ ID NO: 134, SEQ ID NO: 138, SEQ ID NO: 142, SEQ ID NO: 146, SEQ ID NO: 150, and SEQ ID NO: 154.

In another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 209, SEQ ID NO: 211, SEQ ID NO: 213, SEQ ID NO: 217, SEQ ID NO: 219, SEQ ID NO: 221, SEQ ID NO: 223, SEQ ID NO: 225, SEQ ID NO: 227, and SEQ ID NO: 229, or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 231, SEQ ID NO: 233, SEQ ID NO: 235 and SEQ ID NO: 239 or variants thereof that retain functionality. In a more specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 211 or SEQ ID NO: 219 or variants thereof that retain functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 233 or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 209, SEQ ID NO: 221, SEQ ID NO: 223, SEQ ID NO: 225, SEQ ID NO: 227 and SEQ ID NO: 229, or variants thereof that retain functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 231 or variants thereof that retain functionality. In a further specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 213 and SEQ ID NO: 235 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 217 and SEQ ID NO: 239 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 219 and SEQ ID NO: 233 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 221 and SEQ ID NO: 231 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present

invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 223 and SEQ ID NO: 231 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 225 and SEQ ID NO: 231 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 227 and SEQ ID NO: 231 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 229 and SEQ ID NO: 231 or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the present invention comprises two polypeptide sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 211 and SEQ ID NO: 233 or variants thereof that retain functionality.

In another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 297, SEQ ID NO: 301 and SEQ ID NO: 315, or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to a sequence selected from the group of SEQ ID NO: 299, SEQ ID NO: 303 and SEQ ID NO: 317, or variants thereof that retain functionality. In a more specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 297 or a variant thereof that retains functionality, a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 299 or a variant thereof that retains functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 233 or a variant thereof that retains functionality. In another specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 301 or a variant thereof that retains functionality, a polypeptide sequence that is at least about 80%, 85%,

90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 303 or a variant thereof that retains functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 231 or a variant thereof that retains functionality. In yet another specific embodiment, the immunoconjugate of the present invention
5 comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 315 or a variant thereof that retains functionality, a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 317 or a variant thereof that retains functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to
10 SEQ ID NO: 233 or a variant thereof that retains functionality.

In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 210, SEQ ID NO: 212, SEQ ID NO: 214, SEQ ID NO: 218, SEQ ID NO: 220, SEQ ID NO: 222, SEQ ID NO: 224,
15 SEQ ID NO: 226, SEQ ID NO: 228, and SEQ ID NO: 230. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence selected from the group of SEQ ID NO: 210, SEQ ID NO: 212, SEQ ID NO: 214, SEQ ID NO: 218, SEQ ID NO: 220, SEQ ID NO: 222, SEQ ID NO: 224, SEQ ID NO: 226, SEQ ID NO: 228, and SEQ ID NO: 230. In another specific embodiment, the immunoconjugate comprises a
20 polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 232, SEQ ID NO: 234, SEQ ID NO: 236, and SEQ ID NO: 240. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence selected from the group of SEQ ID NO: 232, SEQ ID NO: 234, SEQ ID
25 NO: 236, and SEQ ID NO: 240.

In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 298, SEQ ID NO: 302 and SEQ ID NO: 316. In yet another specific embodiment, the immunoconjugate comprises
30 a polypeptide sequence encoded by a polynucleotide sequence selected from the group of SEQ ID NO: 298, SEQ ID NO: 302 and SEQ ID NO: 316. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that

is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a sequence selected from the group of SEQ ID NO: 300, SEQ ID NO: 304 and SEQ ID NO: 318. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence selected from the group of SEQ ID NO: 300, SEQ ID NO: 304 and
5 SEQ ID NO: 318.

In one embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that are specific for the Melanoma Chondroitin Sulfate Proteoglycan (MCSP). In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain specific for MCSP shares a carboxy-terminal peptide bond with a mutant IL-2
10 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain specific for MCSP. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab light chain specific for MCSP shares a carboxy-terminal peptide bond with an IL-2 molecule, which in turn shares a carboxy-terminal peptide bond with a second Fab light chain specific for MCSP. In another embodiment, the
15 immunoconjugate comprises a polypeptide sequence wherein an immunoglobulin heavy chain specific for MCSP shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide.

In a specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of either SEQ ID NO: 189 or SEQ ID NO: 193 or
20 variants thereof that retain functionality. In another specific embodiment, the antigen binding moieties of the immunoconjugate comprise a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of either SEQ ID NO: 191 or SEQ ID NO: 197 or variants thereof that retain functionality. In a more specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy
25 chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of either SEQ ID NO: 189 or SEQ ID NO: 193, or variants thereof that retain functionality, and a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of either SEQ
ID NO: 191 or SEQ ID NO: 197, or variants thereof that retain functionality. In a more specific
30 embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 189, and a light chain variable region sequence

that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 191. In another specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 193, and a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 191.

In another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of either SEQ ID NO: 190 or SEQ ID NO: 194. In yet another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by the polynucleotide sequence of either SEQ ID NO: 190 or SEQ ID NO: 194. In another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of either SEQ ID NO: 192 or SEQ ID NO: 198. In yet another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by the polynucleotide sequence of either SEQ ID NO: 192 or SEQ ID NO: 198.

In a specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 253 or SEQ ID NO: 257, or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 255 or SEQ ID NO: 261, or variants thereof that retain functionality. In a more specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 253 or SEQ ID NO: 257 or variants thereof that retain functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to either SEQ ID NO: 255 or SEQ ID NO: 261, or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 253 or variants thereof that retain

functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 255 or variants thereof that retain functionality. In another specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 257 or variants thereof that retain functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 255 or variants thereof that retain functionality.

In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of either SEQ ID NO: 254 or SEQ ID NO: 258. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of either SEQ ID NO: 254 or SEQ ID NO: 258. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of either SEQ ID NO: 256 or SEQ ID NO: 262. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of either SEQ ID NO: 256 or SEQ ID NO: 262.

In one embodiment, the immunoconjugate comprises at least one, typically two or more antigen binding moieties that are specific for the Carcinoembryonic Antigen (CEA).

In another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain specific for CEA shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain specific for CEA. In yet another embodiment, the immunoconjugate comprises a polypeptide sequence wherein a first Fab heavy chain specific for CEA shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide, which in turn shares a carboxy-terminal peptide bond with a second Fab heavy chain specific for CEA. In one embodiment, the immunoconjugate comprises a polypeptide sequence wherein an immunoglobulin heavy chain specific for CEA shares a carboxy-terminal peptide bond with a mutant IL-2 polypeptide. In a specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 313 or a variant thereof that retains functionality. In another specific embodiment, the antigen binding moieties of the

immunoconjugate comprise a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 311 or a variant thereof that retains functionality. In a more specific embodiment, the antigen binding moieties of the immunoconjugate comprise a heavy chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 313, or a variant thereof that retains functionality, and a light chain variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 311, or a variant thereof that retains functionality.

In another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of SEQ ID NO: 314. In yet another specific embodiment, the heavy chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by the polynucleotide sequence of SEQ ID NO: 314. In another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of SEQ ID NO: 312. In yet another specific embodiment, the light chain variable region sequence of the antigen binding moieties of the immunoconjugate is encoded by the polynucleotide sequence of SEQ ID NO: 312.

In another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 319, or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 321, or variants thereof that retain functionality. In yet another specific embodiment, the immunoconjugate of the invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to the sequence of SEQ ID NO: 323, or variants thereof that retain functionality. In a more specific embodiment, the immunoconjugate of the present invention comprises a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 319 or a variant thereof that retains functionality, a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 321 or a variant thereof that

retains functionality, and a polypeptide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical to SEQ ID NO: 323 or a variant thereof that retains functionality.

In another specific embodiment, the immunoconjugate comprises a polypeptide sequence
5 encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of SEQ ID NO: 320. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of SEQ ID NO: 320. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%,
10 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of SEQ ID NO: 322. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of SEQ ID NO: 322. In another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by a polynucleotide sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the sequence of
15 SEQ ID NO: 324. In yet another specific embodiment, the immunoconjugate comprises a polypeptide sequence encoded by the polynucleotide sequence of SEQ ID NO: 324.

Antigen binding moieties of the invention include those that have sequences that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99%, or 100% identical to the peptide sequences set forth in SEQ ID NOs 23-261 (uneven numbers), 297-303 (uneven numbers), 311 and 313,
20 including functional fragments or variants thereof. The invention also encompasses antigen binding moieties comprising sequences of SEQ ID NOs 23-261 (uneven numbers), 297-303 (uneven numbers), 311 and 313 with conservative amino acid substitutions.

Polynucleotides

25 The invention further provides isolated polynucleotides encoding a mutant IL-2 polypeptide or an immunoconjugate comprising a mutant IL-2 polypeptide as described herein.

Polynucleotides of the invention include those that are at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99%, or 100% identical to the sequences set forth in SEQ ID NOs 2, 4, 5, 6, 8, 9, 10, 12, 13, 14, 16, 17, 18, 20, 21, 22, 24-262 (even numbers), 293-296, and 298-324 (even numbers)
30 including functional fragments or variants thereof.

The polynucleotides encoding mutant IL-2 polypeptides not linked to a non-IL-2 moiety are generally expressed as single polynucleotide that encodes the entire polypeptide.

In one embodiment, the present invention is directed to an isolated polynucleotide encoding a mutant IL-2 polypeptide, wherein the polynucleotide comprises a sequence that encodes a mutant IL-2 sequence of SEQ ID NO: 7, 11, 15 or 19. The invention also encompasses an isolated polynucleotide encoding a mutant IL-2 polypeptide, wherein the polynucleotide comprises a sequence that encodes a mutant IL-2 polypeptide of SEQ ID NO: 7, 11, 15 or 19 with conservative amino acid substitutions.

In another embodiment, the invention is directed to an isolated polynucleotide encoding a mutant IL-2 polypeptide, wherein the polynucleotide comprises a sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a nucleotide sequence selected from the group of SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 17, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, SEQ ID NO: 293, SEQ ID NO: 294, SEQ ID NO: 295 and SEQ ID NO: 296. In another embodiment, the invention is directed to an isolated polynucleotide encoding a mutant IL-2 polypeptide, wherein the polynucleotide comprises a nucleotide sequence selected from the group of SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 17, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, SEQ ID NO: 293, SEQ ID NO: 294, SEQ ID NO: 295 and SEQ ID NO: 296. In another embodiment, the invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a nucleic acid sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a nucleotide sequence selected from the group of SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 17, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, SEQ ID NO: 293, SEQ ID NO: 294, SEQ ID NO: 295 and SEQ ID NO: 296. In another embodiment, the invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a nucleic acid sequence selected from the group of SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 13, SEQ ID NO: 14, SEQ ID NO: 16, SEQ ID NO: 17, SEQ ID NO: 18, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, SEQ ID NO: 293, SEQ ID NO: 294, SEQ ID NO: 295 and SEQ ID NO: 296.

The polynucleotides encoding immunoconjugates of the invention may be expressed as a single polynucleotide that encodes the entire immunoconjugate or as multiple (e.g., two or more) polynucleotides that are co-expressed. Polypeptides encoded by polynucleotides that are co-expressed may associate through, e.g., disulfide bonds or other means to form a functional immunoconjugate. For example, the heavy chain portion of an antigen binding moiety may be encoded by a separate polynucleotide from the portion of the immunoconjugate comprising the light chain portion of the antigen binding moiety and the mutant IL-2 polypeptide. When co-expressed, the heavy chain polypeptides will associate with the light chain polypeptides to form the antigen binding moiety. Alternatively, in another example, the light chain portion of the antigen binding moiety could be encoded by a separate polynucleotide from the portion of the immunoconjugate comprising the heavy chain portion of the antigen binding moiety and the mutant IL-2 polypeptide. In one embodiment, an isolated polynucleotide of the invention encodes a fragment of an immunoconjugate comprising a mutant IL-2 polypeptide and an antigen binding moiety. In one embodiment, an isolated polynucleotide of the invention encodes the heavy chain of an antigen binding moiety and a mutant IL-2 polypeptide. In another embodiment, an isolated polynucleotide of the invention encodes the light chain of an antigen binding moiety and a mutant IL-2 polypeptide.

In a specific embodiment, an isolated polynucleotide of the invention encodes a fragment of an immunoconjugate comprising at least one mutant IL-2 polypeptide, and at least one, preferably two or more antigen binding moieties, wherein a first mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with a first antigen binding moiety and a second antigen binding moiety shares an amino- or carboxy-terminal peptide bond with either the first mutant IL-2 polypeptide or the first antigen binding moiety. In a one embodiment, the antigen binding moieties are independently selected from the group consisting of a Fv molecule, particularly a scFv molecule, and a Fab molecule. In another specific embodiment, the polynucleotide encodes the heavy chains of two of the antigen binding moieties and one mutant IL-2 polypeptide. In another specific embodiment, the polynucleotide encodes the light chains of two of the antigen binding moieties and one mutant IL-2 polypeptide. In another specific embodiment, the polynucleotide encodes one light chain of one of the antigen binding moieties, one heavy chain of a second antigen binding moiety and one mutant IL-2 polypeptide.

In another specific embodiment, an isolated polynucleotide of the invention encodes a fragment of an immunoconjugate, wherein the polynucleotide encodes the heavy chains of two Fab

molecules and a mutant IL-2 polypeptide. In another specific embodiment, an isolated polynucleotide of the invention encodes a fragment of an immunoconjugate, wherein the polynucleotide encodes the light chains of two Fab molecules and a mutant IL-2 polypeptide. In another specific embodiment an isolated polynucleotide of the invention encodes a fragment of
5 an immunoconjugate, wherein the polynucleotide encodes the heavy chain of one Fab molecule, the light chain of second Fab molecule and a mutant IL-2 polypeptide.

In one embodiment, an isolated polynucleotide of the invention encodes an immunoconjugate comprising at least one mutant IL-2 polypeptide, joined at its amino- and carboxy-terminal amino acids to one or more scFv molecules.

10 In one embodiment, an isolated polynucleotide of the invention encodes a fragment of an immunoconjugate, wherein the polynucleotide encodes the heavy chain of an immunoglobulin molecule, particularly an IgG molecule, more particularly an IgG₁ molecule, and a mutant IL-2 polypeptide. In a more specific embodiment, the isolated polynucleotide encodes a the heavy chain of an immunoglobulin molecule and a mutant IL-2 polypeptide, wherein the mutant IL-2
15 polypeptide shares a amino-terminal peptide bond with the immunoglobulin heavy chain.

In another embodiment, the present invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a sequence that encodes a variable region sequence as shown in SEQ ID NO: 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 77, 79, 81, 83, 85, 87, 89, 91,
20 93, 95, 97, 99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 231, 133, 135, 137, 139, 141, 143, 145, 147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169, 171, 173, 175, 177, 179, 181, 183, 185, 187, 189, 191, 193, 195, 197, 311 or 313. In another embodiment, the present invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a sequence that
25 encodes a polypeptide sequence as shown in SEQ ID NO: 199, 201, 203, 205, 207, 209, 211, 213, 215, 217, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 249, 251, 253, 255, 257, 259, 261, 297, 299, 301, 303, 315, 317, 319, 321 or 323. In another embodiment, the invention is further directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a sequence that is
30 at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to a nucleotide sequence shown in SEQ ID NO: 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108,

110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250, 252, 254, 256, 258, 260, 262, 298, 300, 302, 304, 312, 314, 316, 318, 320, 322 or 324. In another embodiment, the invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a nucleic acid sequence shown in SEQ ID NO: 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250, 252, 254, 256, 258, 260, 262, 298, 300, 302, 304, 312, 314, 316, 318, 320, 322 or 324. In another embodiment, the invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a sequence that encodes a variable region sequence that is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to an amino acid sequence of SEQ ID NO: 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 77, 79, 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 231, 133, 135, 137, 139, 141, 143, 145, 147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169, 171, 173, 175, 177, 179, 181, 183, 185, 187, 189, 191, 193, 195, 197, 311 or 313. In another embodiment, the invention is directed to an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a sequence that encodes a polypeptide sequence that is at least 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identical to an amino acid sequence of SEQ ID NO: 199, 201, 203, 205, 207, 209, 211, 213, 215, 217, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 249, 251, 253, 255, 257, 259, 261, 297, 299, 301, 303, 315, 317, 319, 321 or 323. The invention encompasses an isolated polynucleotide encoding an immunoconjugate or fragment thereof, wherein the polynucleotide comprises a sequence that encodes the variable region sequences of SEQ ID NO: 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 77, 79, 81, 83, 85, 87, 89, 91, 93, 95, 97, 99, 101, 103, 105, 107, 109, 111, 113, 115, 117, 119, 121, 123, 125, 127, 129, 231, 133, 135, 137, 139, 141, 143, 145, 147, 149, 151, 153, 155, 157, 159, 161, 163, 165, 167, 169, 171, 173,

175, 177, 179, 181, 183, 185, 187, 189, 191, 193, 195, 197, 311 or 313 with conservative amino acid substitutions. The invention also encompasses an isolated polynucleotide encoding an immunoconjugate of the invention or fragment thereof, wherein the polynucleotide comprises a sequence that encodes the polypeptide sequences of SEQ ID NO: 199, 201, 203, 205, 207, 209,
5 211, 213, 215, 217, 219, 221, 223, 225, 227, 229, 231, 233, 235, 237, 239, 241, 243, 245, 247, 249, 251, 253, 255, 257, 259, 261, 297, 299, 301, 303, 315, 317, 319, 321 or 323 with conservative amino acid substitutions.

In certain embodiments the polynucleotide or nucleic acid is DNA. In other embodiments, a polynucleotide of the present invention is RNA, for example, in the form of messenger RNA
10 (mRNA). RNA of the present invention may be single stranded or double stranded.

Recombinant Methods

Mutant IL-2 polypeptides of the invention can be prepared by deletion, substitution, insertion or modification using genetic or chemical methods well known in the art. Genetic methods may
15 include site-specific mutagenesis of the encoding DNA sequence, PCR, gene synthesis, and the like. The correct nucleotide changes can be verified for example by sequencing. In this regard, the nucleotide sequence of native IL-2 has been described by Taniguchi et al. (Nature 302, 305-10 (1983)) and nucleic acid encoding human IL-2 is available from public depositories such as the American Type Culture Collection (Rockville MD). The sequence of native human IL-2 is
20 shown in SEQ ID NO: 1. Substitution or insertion may involve natural as well as non-natural amino acid residues. Amino acid modification includes well known methods of chemical modification such as the addition of glycosylation sites or carbohydrate attachments, and the like.

Mutant IL-2 polypeptides and immunoconjugates of the invention may be obtained, for example, by solid-state peptide synthesis or recombinant production. For recombinant production one or
25 more polynucleotide encoding said mutant IL-2 polypeptide or immunoconjugate (fragment), e.g., as described above, is isolated and inserted into one or more vectors for further cloning and/or expression in a host cell. Such polynucleotide may be readily isolated and sequenced using conventional procedures. In one embodiment a vector, preferably an expression vector, comprising one or more of the polynucleotides of the invention is provided. Methods which are
30 well known to those skilled in the art can be used to construct expression vectors containing the coding sequence of a mutant IL-2 polypeptide or immunoconjugate (fragment) along with

appropriate transcriptional/translational control signals. These methods include *in vitro* recombinant DNA techniques, synthetic techniques and *in vivo* recombination/genetic recombination. See, for example, the techniques described in Maniatis *et al.*, MOLECULAR CLONING: A LABORATORY MANUAL, Cold Spring Harbor Laboratory, N.Y. (1989); and Ausubel *et al.*, CURRENT PROTOCOLS IN MOLECULAR BIOLOGY, Greene Publishing Associates and Wiley Interscience, N.Y (1989). The expression vector can be part of a plasmid, virus, or may be a nucleic acid fragment. The expression vector includes an expression cassette into which the polynucleotide encoding the IL-2 mutant or the immunoconjugate (fragment) (i.e. the coding region) is cloned in operable association with a promoter and/or other transcription or translation control elements. As used herein, a "coding region" is a portion of nucleic acid which consists of codons translated into amino acids. Although a "stop codon" (TAG, TGA, or TAA) is not translated into an amino acid, it may be considered to be part of a coding region, if present, but any flanking sequences, for example promoters, ribosome binding sites, transcriptional terminators, introns, 5' and 3' untranslated regions, and the like, are not part of a coding region.

Two or more coding regions can be present in a single polynucleotide construct, *e.g.* on a single vector, or in separate polynucleotide constructs, *e.g.* on separate (different) vectors. Furthermore, any vector may contain a single coding region, or may comprise two or more coding regions, *e.g.* a vector of the present invention may encode one or more polypeptides, which are post- or co-translationally separated into the final proteins via proteolytic cleavage. In addition, a vector, polynucleotide, or nucleic acid of the invention may encode heterologous coding regions, either fused or unfused to a first or second polynucleotide encoding the polypeptides of the invention, or variant or derivative thereof. Heterologous coding regions include without limitation specialized elements or motifs, such as a secretory signal peptide or a heterologous functional domain. An operable association is when a coding region for a gene product, *e.g.* a polypeptide, is associated with one or more regulatory sequences in such a way as to place expression of the gene product under the influence or control of the regulatory sequence(s). Two DNA fragments (such as a polypeptide coding region and a promoter associated therewith) are "operably associated" if induction of promoter function results in the transcription of mRNA encoding the desired gene product and if the nature of the linkage between the two DNA fragments does not interfere with the ability of the expression regulatory sequences to direct the expression of the gene product or interfere with the ability of the DNA template to be transcribed. Thus, a promoter region would be operably associated with a nucleic acid encoding a polypeptide if the promoter was capable of effecting transcription of that nucleic acid. The promoter may be a cell-

specific promoter that directs substantial transcription of the DNA only in predetermined cells. Other transcription control elements, besides a promoter, for example enhancers, operators, repressors, and transcription termination signals, can be operably associated with the polynucleotide to direct cell-specific transcription. Suitable promoters and other transcription control regions are disclosed herein. A variety of transcription control regions are known to those skilled in the art. These include, without limitation, transcription control regions, which function in vertebrate cells, such as, but not limited to, promoter and enhancer segments from cytomegaloviruses (*e.g.* the immediate early promoter, in conjunction with intron-A), simian virus 40 (*e.g.* the early promoter), and retroviruses (such as, *e.g.* Rous sarcoma virus). Other transcription control regions include those derived from vertebrate genes such as actin, heat shock protein, bovine growth hormone and rabbit β -globin, as well as other sequences capable of controlling gene expression in eukaryotic cells. Additional suitable transcription control regions include tissue-specific promoters and enhancers as well as inducible promoters (*e.g.* promoters inducible tetracyclins). Similarly, a variety of translation control elements are known to those of ordinary skill in the art. These include, but are not limited to ribosome binding sites, translation initiation and termination codons, and elements derived from viral systems (particularly an internal ribosome entry site, or IRES, also referred to as a CITE sequence). The expression cassette may also include other features such as an origin of replication, and/or chromosome integration elements such as retroviral long terminal repeats (LTRs), or adeno-associated viral (AAV) inverted terminal repeats (ITRs).

Polynucleotide and nucleic acid coding regions of the present invention may be associated with additional coding regions which encode secretory or signal peptides, which direct the secretion of a polypeptide encoded by a polynucleotide of the present invention. For example, if secretion of the mutant IL-2 polypeptide is desired, DNA encoding a signal sequence may be placed upstream of the nucleic acid encoding the mature amino acids of the mutant IL-2. The same applies to immunoconjugates of the invention or fragments thereof. According to the signal hypothesis, proteins secreted by mammalian cells have a signal peptide or secretory leader sequence which is cleaved from the mature protein once export of the growing protein chain across the rough endoplasmic reticulum has been initiated. Those of ordinary skill in the art are aware that polypeptides secreted by vertebrate cells generally have a signal peptide fused to the N-terminus of the polypeptide, which is cleaved from the translated polypeptide to produce a secreted or "mature" form of the polypeptide. For example, human IL-2 is translated with a 20 amino acid signal sequence at the N-terminus of the polypeptide, which is subsequently cleaved

off to produce the mature, 133 amino acid human IL-2. In certain embodiments, the native signal peptide, *e.g.* the IL-2 signal peptide or an immunoglobulin heavy chain or light chain signal peptide is used, or a functional derivative of that sequence that retains the ability to direct the secretion of the polypeptide that is operably associated with it. Alternatively, a heterologous
5 mammalian signal peptide, or a functional derivative thereof, may be used. For example, the wild-type leader sequence may be substituted with the leader sequence of human tissue plasminogen activator (TPA) or mouse β -glucuronidase. Exemplary amino acid and polynucleotide sequences of secretory signal peptides are shown in SEQ ID NOs 236-273.

DNA encoding a short protein sequence that could be used to facilitate later purification (*e.g.* a
10 histidine tag) or assist in labeling the IL-2 mutant or immunoconjugate may be included within or at the ends of the IL-2 mutant or immunoconjugate (fragment) encoding polynucleotide.

In a further embodiment, a host cell comprising one or more polynucleotides of the invention is provided. In certain embodiments a host cell comprising one or more vectors of the invention is provided. The polynucleotides and vectors may incorporate any of the features, singly or in
15 combination, described herein in relation to polynucleotides and vectors, respectively. In one such embodiment a host cell comprises (*e.g.* has been transformed or transfected with) a vector comprising a polynucleotide that encodes an amino acid sequence comprising the mutant IL-2 polypeptide of the invention. As used herein, the term "host cell" refers to any kind of cellular system which can be engineered to generate the mutant IL-2 polypeptides or immunoconjugates
20 of the invention or fragments thereof. Host cells suitable for replicating and for supporting expression of mutant IL-2 polypeptides or immunoconjugates are well known in the art. Such cells may be transfected or transduced as appropriate with the particular expression vector and large quantities of vector containing cells can be grown for seeding large scale fermenters to obtain sufficient quantities of the IL-2 mutant or immunoconjugate for clinical applications.
25 Suitable host cells include prokaryotic microorganisms, such as *E. coli*, or various eukaryotic cells, such as Chinese hamster ovary cells (CHO), insect cells, or the like. For example, polypeptides may be produced in bacteria in particular when glycosylation is not needed. After expression, the polypeptide may be isolated from the bacterial cell paste in a soluble fraction and can be further purified. In addition to prokaryotes, eukaryotic microbes such as filamentous fungi
30 or yeast are suitable cloning or expression hosts for polypeptide-encoding vectors, including fungi and yeast strains whose glycosylation pathways have been "humanized," resulting in the production of a polypeptide with a partially or fully human glycosylation pattern. See Gerngross,

Nat Biotech 22, 1409-1414 (2004), and Li et al., Nat Biotech 24, 210-215 (2006). Suitable host cells for the expression of (glycosylated) polypeptides are also derived from multicellular organisms (invertebrates and vertebrates). Examples of invertebrate cells include plant and insect cells. Numerous baculoviral strains have been identified which may be used in conjunction with
5 insect cells, particularly for transfection of *Spodoptera frugiperda* cells. Plant cell cultures can also be utilized as hosts. See e.g. US Patent Nos. 5,959,177, 6,040,498, 6,420,548, 7,125,978, and 6,417,429 (describing PLANTIBODIESTM technology for producing antibodies in transgenic plants). Vertebrate cells may also be used as hosts. For example, mammalian cell lines that are adapted to grow in suspension may be useful. Other examples of useful mammalian host
10 cell lines are monkey kidney CV1 line transformed by SV40 (COS-7); human embryonic kidney line (293 or 293T cells as described, e.g., in Graham et al., J Gen Virol 36, 59 (1977)), baby hamster kidney cells (BHK), mouse sertoli cells (TM4 cells as described, e.g., in Mather, Biol Reprod 23, 243-251 (1980)), monkey kidney cells (CV1), African green monkey kidney cells (VERO-76), human cervical carcinoma cells (HELA), canine kidney cells (MDCK), buffalo rat
15 liver cells (BRL 3A), human lung cells (W138), human liver cells (Hep G2), mouse mammary tumor cells (MMT 060562), TRI cells (as described, e.g., in Mather et al., Annals N.Y. Acad Sci 383, 44-68 (1982)), MRC 5 cells, and FS4 cells. Other useful mammalian host cell lines include Chinese hamster ovary (CHO) cells, including dhfr⁻ CHO cells (Urlaub et al., Proc Natl Acad Sci USA 77, 4216 (1980)); and myeloma cell lines such as YO, NS0, P3X63 and Sp2/0. For a
20 review of certain mammalian host cell lines suitable for protein production, see, e.g., Yazaki and Wu, Methods in Molecular Biology, Vol. 248 (B.K.C. Lo, ed., Humana Press, Totowa, NJ), pp. 255-268 (2003). Host cells include cultured cells, e.g., mammalian cultured cells, yeast cells, insect cells, bacterial cells and plant cells, to name only a few, but also cells comprised within a transgenic animal, transgenic plant or cultured plant or animal tissue. In one embodiment, the
25 host cell is a eukaryotic cell, preferably a mammalian cell, such as a Chinese Hamster Ovary (CHO) cell, a human embryonic kidney (HEK) cell or lymphoid cell (e.g., YO, NS0, Sp20 cell).

Standard technologies are known in the art to express foreign genes in these systems. Cells expressing a mutant-IL-2 polypeptide fused to either the heavy or the light chain of an antigen binding domain such as an antibody, may be engineered so as to also express the other of the
30 antibody chains such that the expressed mutant IL-2 fusion product is an antibody that has both a heavy and a light chain.

In one embodiment, a method of producing a mutant IL-2 polypeptide or an immunoconjugate according to the invention is provided, wherein the method comprises culturing a host cell comprising a polynucleotide encoding the mutant IL-2 polypeptide or immunoconjugate, as provided herein, under conditions suitable for expression of the mutant IL-2 polypeptide or
5 immunoconjugate, and optionally recovering the mutant IL-2 polypeptide or immunoconjugate from the host cell (or host cell culture medium).

In certain embodiments according to the invention the mutant IL-2 polypeptide is linked to at least one non-IL-2 moiety. An IL-2 mutant can be prepared where the mutant IL-2 polypeptide segment is linked to one or more molecules such as a polypeptide, protein, carbohydrate, lipid,
10 nucleic acid, polynucleotide or molecules that are combinations of these molecules (e.g. glycoproteins, glycolipids etc.). The mutant IL-2 polypeptide also may be linked to an organic moiety, inorganic moiety or pharmaceutical drug. As used herein, a pharmaceutical drug is an organic containing compound of about 5,000 daltons or less. The mutant IL-2 polypeptide also may be linked to any biological agent including therapeutic compounds such as anti-neoplastic
15 agents, anti-microbial agents, hormones, immunomodulators, anti-inflammatory agents and the like. Also included are radioisotopes such as those useful for imaging as well as for therapy.

The mutant IL-2 polypeptide may also be linked to multiple molecules of the same type or to more than one type of molecule. In certain embodiments, the molecule that is linked to IL-2 can confer the ability to target the IL-2 to specific tissues or cells in an animal, and is referred to
20 herein as a "targeting moiety". In these embodiments, the targeting moiety may have affinity for a ligand or receptor in the target tissue or cell, thereby directing the IL-2 to the target tissue or cell. In a particular embodiment the targeting moiety directs the IL-2 to a tumor. Targeting moieties include, for example, antigen binding moieties (e.g. antibodies and fragments thereof) specific for cell surface or intracellular proteins, ligands of biological receptors, and the like.
25 Such antigen binding moieties may be specific for tumor associated antigens such as the ones described herein.

A mutant IL-2 polypeptide may be genetically fused to another polypeptide, e.g. a single chain antibody, or (part of) an antibody heavy or light chains, or may be chemically conjugated to another molecule. Fusion of a mutant IL-2 polypeptide to part of an antibody heavy chain is
30 described in the Examples. An IL-2 mutant which is a fusion between a mutant IL-2 polypeptide and another polypeptide can be designed such that the IL-2 sequence is fused directly to the polypeptide or indirectly through a linker sequence. The composition and length of the linker

may be determined in accordance with methods well known in the art and may be tested for efficacy. An example of a linker sequence between IL-2 and an antibody heavy chain is found in the sequences shown e.g. in SEQ ID NOs 209, 211, 213 etc. Additional sequences may also be included to incorporate a cleavage site to separate the individual components of the fusion if
5 desired, for example an endopeptidase recognition sequence. In addition, an IL-2 mutant or fusion protein thereof may also be synthesized chemically using methods of polypeptide synthesis as is well known in the art (e.g. Merrifield solid phase synthesis). Mutant IL-2 polypeptides may be chemically conjugated to other molecules, e.g. another polypeptide, using well known chemical conjugation methods. Bi-functional cross-linking reagents such as
10 homofunctional and heterofunctional cross-linking reagents well known in the art can be used for this purpose. The type of cross-linking reagent to use depends on the nature of the molecule to be coupled to IL-2 and can readily be identified by those skilled in the art. Alternatively, or in addition, mutant IL-2 and/or the molecule to which it is intended to be conjugated may be chemically derivatized such that the two can be conjugated in a separate reaction as is also well
15 known in the art.

In certain embodiments the mutant IL-2 polypeptide is linked to one or more antigen binding moieties (i.e. is part of an immunoconjugate) comprising at least an antibody variable region capable of binding an antigenic determinant. Variable regions can form part of and be derived from naturally or non-naturally occurring antibodies and fragments thereof. Methods to produce
20 polyclonal antibodies and monoclonal antibodies are well known in the art (see e.g. Harlow and Lane, "Antibodies, a laboratory manual", Cold Spring Harbor Laboratory, 1988). Non-naturally occurring antibodies can be constructed using solid phase-peptide synthesis, can be produced recombinantly (e.g. as described in U.S. patent No. 4,186,567) or can be obtained, for example, by screening combinatorial libraries comprising variable heavy chains and variable light chains
25 (see e.g. U.S. Patent. No. 5,969,108 to McCafferty). Immunoconjugates, antigen binding moieties and methods for producing the same are also described in detail in PCT publication no. WO 2011/020783, the entire content of which is incorporated herein by reference.

Any animal species of antibody, antibody fragment, antigen binding domain or variable region can be linked to a mutant IL-2 polypeptide. Non-limiting antibodies, antibody fragments, antigen
30 binding domains or variable regions useful in the present invention can be of murine, primate, or human origin. If the mutant IL-2/antibody conjugate or fusion is intended for human use, a chimeric form of the antibody may be used wherein the constant regions of the antibody are from

a human. A humanized or fully human form of the antibody can also be prepared in accordance with methods well known in the art (see e. g. U.S. Patent No. 5,565,332 to Winter). Humanization may be achieved by various methods including, but not limited to (a) grafting the non-human (e.g., donor antibody) CDRs onto human (e.g. recipient antibody) framework and
5 constant regions with or without retention of critical framework residues (e.g. those that are important for retaining good antigen binding affinity or antibody functions), (b) grafting only the non-human specificity-determining regions (SDRs or a-CDRs; the residues critical for the antibody-antigen interaction) onto human framework and constant regions, or (c) transplanting the entire non-human variable domains, but "cloaking" them with a human-like section by
10 replacement of surface residues. Humanized antibodies and methods of making them are reviewed, e.g., in Almagro and Fransson, *Front Biosci* 13, 1619-1633 (2008), and are further described, e.g., in Riechmann et al., *Nature* 332, 323-329 (1988); Queen et al., *Proc Natl Acad Sci USA* 86, 10029-10033 (1989); US Patent Nos. 5,821,337, 7,527,791, 6,982,321, and 7,087,409; Jones et al., *Nature* 321, 522-525 (1986); Morrison et al., *Proc Natl Acad Sci* 81,
15 6851-6855 (1984); Morrison and Oi, *Adv Immunol* 44, 65-92 (1988); Verhoeyen et al., *Science* 239, 1534-1536 (1988); Padlan, *Molec Immun* 31(3), 169-217 (1994); Kashmiri et al., *Methods* 36, 25-34 (2005) (describing SDR (a-CDR) grafting); Padlan, *Mol Immunol* 28, 489-498 (1991) (describing "resurfacing"); Dall'Acqua et al., *Methods* 36, 43-60 (2005) (describing "FR shuffling"); and Osbourn et al., *Methods* 36, 61-68 (2005) and Klimka et al., *Br J Cancer* 83,
20 252-260 (2000) (describing the "guided selection" approach to FR shuffling). Human antibodies and human variable regions can be produced using various techniques known in the art. Human antibodies are described generally in van Dijk and van de Winkel, *Curr Opin Pharmacol* 5, 368-74 (2001) and Lonberg, *Curr Opin Immunol* 20, 450-459 (2008). Human variable regions can form part of and be derived from human monoclonal antibodies made by the hybridoma method
25 (see e.g. *Monoclonal Antibody Production Techniques and Applications*, pp. 51-63 (Marcel Dekker, Inc., New York, 1987)). Human antibodies and human variable regions may also be prepared by administering an immunogen to a transgenic animal that has been modified to produce intact human antibodies or intact antibodies with human variable regions in response to antigenic challenge (see e.g. Lonberg, *Nat Biotech* 23, 1117-1125 (2005). Human antibodies and
30 human variable regions may also be generated by isolating Fv clone variable region sequences selected from human-derived phage display libraries (see e.g., Hoogenboom et al. in *Methods in Molecular Biology* 178, 1-37 (O'Brien et al., ed., Human Press, Totowa, NJ, 2001); and McCafferty et al., *Nature* 348, 552-554; Clackson et al., *Nature* 352, 624-628 (1991)). Phage

typically display antibody fragments, either as single-chain Fv (scFv) fragments or as Fab fragments. A detailed description of the preparation of antigen binding moieties for immunoconjugates by phage display can be found in the Examples appended to PCT publication no. WO 2011/020783.

5 In certain embodiments, the antigen binding moieties useful in the present invention are engineered to have enhanced binding affinity according to, for example, the methods disclosed in PCT publication no. WO 2011/020783 (see Examples relating to affinity maturation) or U.S. Pat. Appl. Publ. No. 2004/0132066, the entire contents of which are hereby incorporated by reference. The ability of the immunoconjugate of the invention to bind to a specific antigenic determinant
10 can be measured either through an enzyme-linked immunosorbent assay (ELISA) or other techniques familiar to one of skill in the art, e.g. surface plasmon resonance technique (analyzed on a BIACORE T100 system) (Liljeblad, et al., Glyco J 17, 323-329 (2000)), and traditional binding assays (Heeley, Endocr Res 28, 217-229 (2002)). Competition assays may be used to identify an antibody, antibody fragment, antigen binding domain or variable domain that
15 competes with a reference antibody for binding to a particular antigen, e.g. an antibody that competes with the L19 antibody for binding to the Extra Domain B of fibronectin (EDB). In certain embodiments, such a competing antibody binds to the same epitope (e.g. a linear or a conformational epitope) that is bound by the reference antibody. Detailed exemplary methods for mapping an epitope to which an antibody binds are provided in Morris (1996) "Epitope Mapping
20 Protocols," in Methods in Molecular Biology vol. 66 (Humana Press, Totowa, NJ). In an exemplary competition assay, immobilized antigen (e.g. EDB) is incubated in a solution comprising a first labeled antibody that binds to the antigen (e.g. L19 antibody) and a second unlabeled antibody that is being tested for its ability to compete with the first antibody for binding to the antigen. The second antibody may be present in a hybridoma supernatant. As a
25 control, immobilized antigen is incubated in a solution comprising the first labeled antibody but not the second unlabeled antibody. After incubation under conditions permissive for binding of the first antibody to the antigen, excess unbound antibody is removed, and the amount of label associated with immobilized antigen is measured. If the amount of label associated with immobilized antigen is substantially reduced in the test sample relative to the control sample,
30 then that indicates that the second antibody is competing with the first antibody for binding to the antigen. See Harlow and Lane (1988) Antibodies: A Laboratory Manual ch.14 (Cold Spring Harbor Laboratory, Cold Spring Harbor, NY).

Further chemical modification of the mutant IL-2 mutant or immunoconjugate of the invention may be desirable. For example, problems of immunogenicity and short half-life may be improved by conjugation to substantially straight chain polymers such as polyethylene glycol (PEG) or polypropylene glycol (PPG) (see e.g. WO 87/00056).

- 5 IL-2 mutants and immunoconjugates prepared as described herein may be purified by art-known techniques such as high performance liquid chromatography, ion exchange chromatography, gel electrophoresis, affinity chromatography, size exclusion chromatography, and the like. The actual conditions used to purify a particular protein will depend, in part, on factors such as net charge, hydrophobicity, hydrophilicity etc., and will be apparent to those having skill in the art.
- 10 For affinity chromatography purification an antibody, ligand, receptor or antigen can be used to which the mutant IL-2 polypeptide or immunoconjugate binds. For example, an antibody which specifically binds the mutant IL-2 polypeptide may be used. For affinity chromatography purification of immunoconjugates of the invention, a matrix with protein A or protein G may be used. For example, sequential Protein A or G affinity chromatography and size exclusion
- 15 chromatography can be used to isolate an immunoconjugate essentially as described in the Examples. The purity of the mutant IL-2 polypeptides and fusion proteins thereof can be determined by any of a variety of well known analytical methods including gel electrophoresis, high pressure liquid chromatography, and the like. For example, the heavy chain fusion proteins expressed as described in the Examples were shown to be intact and properly assembled as
- 20 demonstrated by reducing SDS-PAGE (see e.g. Figure 14). Two bands were resolved at approximately Mr 25,000 and Mr 60,000, corresponding to the predicted molecular weights of the immunoglobulin light chain and heavy chain/IL-2 fusion protein.

Assays

- 25 Mutant IL-2 polypeptides and immunoconjugates provided herein may be identified, screened for, or characterized for their physical/chemical properties and/or biological activities by various assays known in the art.

Affinity assays

- The affinity of the mutant or wild-type IL-2 polypeptide for various forms of the IL-2 receptor
- 30 can be determined in accordance with the method set forth in the Examples by surface plasmon

resonance (SPR), using standard instrumentation such as a BIAcore instrument (GE Healthcare), and receptor subunits such as may be obtained by recombinant expression (see e.g. Shanafelt et al., *Nature Biotechnol* 18, 1197-1202 (2000)). A recombinant IL-2 receptor β/γ -subunit heterodimer can be generated by fusing each of the subunits to an antibody Fc domain monomer modified by the knobs-into-holes technology (see e.g. U.S. Pat. No. 5,731,168) to promote heterodimerization of the appropriate receptor subunit/Fc fusion proteins (see SEQ ID NOs 102 and 103). Alternatively, binding affinity of IL-2 mutants for different forms of the IL-2 receptor may be evaluated using cell lines known to express one or the other such form of the receptor. A specific illustrative and exemplary embodiment for measuring binding affinity is described in the following and in the Examples below. According to one embodiment, K_D is measured by surface plasmon resonance using a BIACORE® T100 machine (GE Healthcare) at 25°C with IL-2 receptors immobilized on CM5 chips. Briefly, carboxymethylated dextran biosensor chips (CM5, GE Healthcare) are activated with N-ethyl-N'-(3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and N-hydroxysuccinimide (NHS) according to the supplier's instructions. Recombinant IL-2 receptor is diluted with 10 mM sodium acetate, pH 5.5, to 0.5-30 $\mu\text{g/ml}$ before injection at a flow rate of 10 $\mu\text{l/minute}$ to achieve approximately 200 - 1000 (for IL-2R α -subunit) or 500-3000 (for IL-2R $\beta\gamma$ knobs-into-holes heterodimer) response units (RU) of coupled protein. Following the injection of IL-2 receptor, 1 M ethanolamine is injected to block unreacted groups. For kinetics measurements, three-fold serial dilutions of mutant IL-2 polypeptide or immunoconjugate (range between ~ 0.3 nM to 300 nM) are injected in HBS-EP+ (GE Healthcare, 10 mM HEPES, 150 mM NaCl, 3 mM EDTA, 0.05% Surfactant P20, pH 7.4) at 25°C at a flow rate of approximately 30 $\mu\text{l/min}$. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIACORE® T100 Evaluation Software version 1.1.1) by simultaneously fitting the association and dissociation sensorgrams. The equilibrium dissociation constant (K_D) is calculated as the ratio $k_{\text{off}}/k_{\text{on}}$. See, e.g., Chen et al., *J Mol Biol* 293, 865-881 (1999).

Binding of immunoconjugates of the invention to Fc receptors can be easily determined e.g. by ELISA, or by Surface Plasmon Resonance (SPR) using standard instrumentation such as a BIAcore instrument (GE Healthcare), and Fc receptors such as may be obtained by recombinant expression. Alternatively, binding affinity of Fc domains or immunoconjugates comprising an Fc domain for Fc receptors may be evaluated using cell lines known to express particular Fc receptors, such as NK cells expressing Fc γ IIIa receptor. According to one embodiment, K_D is measured by surface plasmon resonance using a BIACORE® T100 machine (GE Healthcare) at

25°C with Fc receptors immobilized on CM5 chips. Briefly, carboxymethylated dextran biosensor chips (CM5, GE Healthcare) are activated with N-ethyl-N'-(3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and N-hydroxysuccinimide (NHS) according to the supplier's instructions. Recombinant Fc receptor is diluted with 10 mM sodium acetate, pH 5.5, to 0.5-30 µg/ml before injection at a flow rate of 10 µl/minute to achieve approximately 100-5000 response units (RU) of coupled protein. Following the injection of the Fc receptor, 1 M ethanolamine is injected to block unreacted groups. For kinetics measurements, three- to five-fold serial dilutions of immunoconjugate (range between ~0.01 nM to 300 nM) are injected in HBS-EP+ (GE Healthcare, 10 mM HEPES, 150 mM NaCl, 3 mM EDTA, 0.05% Surfactant P20, pH 7.4) at 25°C at a flow rate of approximately 30-50 µl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIAcore® T100 Evaluation Software version 1.1.1) by simultaneously fitting the association and dissociation sensorgrams. The equilibrium dissociation constant (K_D) is calculated as the ratio k_{off}/k_{on} . See, e.g., Chen et al., J Mol Biol 293, 865-881 (1999).

15 Activity assays

The ability of an IL-2 mutant to bind to IL-2 receptors may be indirectly measured by assaying the effects of immune activation that occur downstream of receptor binding.

In one aspect, assays are provided for identifying mutant IL-2 polypeptides having biological activity. Biological activities may include, e.g., the ability to induce proliferation of IL-2 receptor-bearing T and/or NK cells, the ability to induce IL-2 signaling in IL-2 receptor-bearing T and/or NK cells, the ability to generate interferon (IFN)- γ as a secondary cytokine by NK cells, a reduced ability to induce elaboration of secondary cytokines, particularly IL-10 and TNF- α , by peripheral blood mononuclear cells (PBMCs), a reduced ability to induce apoptosis in T cells, the ability to induce tumor regression and/or improve survival, and a reduced toxicity profile, particularly reduced vasopermeability, in vivo. Mutant IL-2 polypeptides having such biological activity in vivo and/or in vitro are also provided.

In certain embodiments, a mutant IL-2 polypeptide of the invention is tested for such biological activity. A variety of methods are well known the art for determining biological activities of IL-2, and also details for many of these methods are disclosed in the Examples appended herewith. The Examples provide a suitable assay for testing IL-2 mutants of the invention for their ability to generate IFN- γ by NK cells. Cultured NK cells are incubated with the mutant IL-2

polypeptide or immunoconjugates of the invention, and IFN- γ concentration in the culture medium is subsequently measured by ELISA.

IL-2 induced signaling induces several signaling pathways, and involves JAK (Janus kinase) and STAT (signal transducer and activator of transcription) signaling molecules. The interaction of
5 IL-2 with the receptor β - and γ -subunits leads to phosphorylation of the receptor and of JAK1 and JAK3, which are associated with the β - and γ -subunit, respectively. STAT5 then associates with the phosphorylated receptor and is phosphorylated itself on a crucial tyrosin residue. This results in the dissociation of STAT5 from the receptor, dimerization of STAT5 and translocation of the STAT5 dimers to the nucleus where they promote the transcription of target genes. The
10 ability of mutant IL-2 polypeptides to induce signaling through the IL-2 receptor can thus be assessed, for example, by measuring phosphorylation of STAT5. Details of this method are disclosed in the Examples. PBMCs are treated with mutant IL-2 polypeptides or immunoconjugates of the invention and levels of phosphorylated STAT5 are determined by flow cytometry.

15 Proliferation of T cells or NK cells in response to IL-2 may be measured by incubating T cells or NK cells isolated from blood with mutant IL-2 polypeptides or immunoconjugates of the invention, followed by determination of the ATP content in lysates of the treated cells. Before treatment, T cells may be pre-stimulated with phytohemagglutinin (PHA-M). This assay, described in the Examples, allows sensitive quantitation of the number of viable cells, however
20 there are numerous suitable alternative assays known in the art (e.g. [3 H]-thymidine incorporation assay, Cell Titer Glo ATP assays, Alamar Blue assay, WST-1 assay, MTT assay).

An assay for determination of apoptosis of T cells and AICD is also provided in the Examples, wherein T cells are treated with an apoptosis-inducing antibody after the incubation with the mutant IL-2 polypeptides or immunoconjugates of the invention and apoptotic cells are
25 quantified by flow cytometric detection of phosphatidyl serine/annexin exposure. Other assays are known in the art.

The effects of mutant IL-2 on tumor growth and survival can be assessed in a variety of animal tumor models known in the art. For example, xenografts of human cancer cell lines can be implanted to immunodeficient mice, and treated with mutant IL-2 polypeptides or
30 immunoconjugates of the invention, as described in the Examples.

Toxicity of mutant IL-2 polypeptides and immunoconjugates of the invention in vivo can be determined based on mortality, in-life observations (visible symptoms of adverse effects, e.g. behaviour, body weight, body temperature) and clinical and anatomical pathology (e.g. measurements of blood chemistry values and/or histopathological analyses).

- 5 Vasopermeability induced by treatment with IL-2 can be examined in a pretreatment vasopermeability animal model. In general, the IL-2 mutant or immunoconjugate of the invention is administered to a suitable animal, e.g. a mouse, and at a later time the animal is injected with a vascular leak reporter molecule whose dissemination from the vasculature reflects the extent of vascular permeability. The vascular leak reporter molecule is preferably
- 10 large enough to reveal permeability with the wild-type form of IL-2 used for pretreatment. An example of a vascular leak reporter molecule can be a serum protein such as albumin or an immunoglobulin. The vascular leak reporter molecule preferably is detectably labeled such as with a radioisotope to facilitate quantitative determination of the molecule's tissue distribution. Vascular permeability may be measured for vessels present in any of a variety of internal body
- 15 organs such as liver, lung, and the like, as well as a tumor, including a tumor that is xenografted. Lung is a preferred organ for measuring vasopermeability of full-length IL-2 mutants.

Compositions, Formulations, and Routes of Administration

- In a further aspect, the invention provides pharmaceutical compositions comprising any of the
- 20 mutant IL-2 polypeptides or immunoconjugates provided herein, e.g., for use in any of the below therapeutic methods. In one embodiment, a pharmaceutical composition comprises any of the mutant IL-2 polypeptides or immunoconjugates provided herein and a pharmaceutically acceptable carrier. In another embodiment, a pharmaceutical composition comprises any of the mutant IL-2 polypeptides or immunoconjugates provided herein and at least one additional
- 25 therapeutic agent, e.g., as described below.

Further provided is a method of producing a mutant IL-2 polypeptide or an immunoconjugate of the invention in a form suitable for administration in vivo, the method comprising (a) obtaining a mutant IL-2 polypeptide or immunoconjugate according to the invention, and (b) formulating the mutant IL-2 polypeptide or immunoconjugate with at least one pharmaceutically acceptable

carrier, whereby a preparation of mutant IL-2 polypeptide or immunoconjugate is formulated for administration in vivo.

Pharmaceutical compositions of the present invention comprise a therapeutically effective amount of one or more mutant IL-2 polypeptide or immunoconjugate dissolved or dispersed in a pharmaceutically acceptable carrier. The phrases "pharmaceutical or pharmacologically acceptable" refers to molecular entities and compositions that are generally non-toxic to recipients at the dosages and concentrations employed, i.e. do not produce an adverse, allergic or other untoward reaction when administered to an animal, such as, for example, a human, as appropriate. The preparation of a pharmaceutical composition that contains at least one mutant IL-2 polypeptide or immunoconjugate and optionally an additional active ingredient will be known to those of skill in the art in light of the present disclosure, as exemplified by Remington's Pharmaceutical Sciences, 18th Ed. Mack Printing Company, 1990, incorporated herein by reference. Moreover, for animal (e.g., human) administration, it will be understood that preparations should meet sterility, pyrogenicity, general safety and purity standards as required by FDA Office of Biological Standards or corresponding authorities in other countries. Preferred compositions are lyophilized formulations or aqueous solutions. Exemplary IL-2 compositions are described in U.S. Patent Nos. 4,604,377 and 4,766,106. As used herein, "pharmaceutically acceptable carrier" includes any and all solvents, buffers, dispersion media, coatings, surfactants, antioxidants, preservatives (e.g. antibacterial agents, antifungal agents), isotonic agents, absorption delaying agents, salts, preservatives, antioxidants, proteins, drugs, drug stabilizers, polymers, gels, binders, excipients, disintegration agents, lubricants, sweetening agents, flavoring agents, dyes, such like materials and combinations thereof, as would be known to one of ordinary skill in the art (see, for example, Remington's Pharmaceutical Sciences, 18th Ed. Mack Printing Company, 1990, pp. 1289-1329, incorporated herein by reference). Except insofar as any conventional carrier is incompatible with the active ingredient, its use in the therapeutic or pharmaceutical compositions is contemplated.

The composition may comprise different types of carriers depending on whether it is to be administered in solid, liquid or aerosol form, and whether it need to be sterile for such routes of administration as injection. Mutant IL-2 polypeptides or immunoconjugates of the present invention (and any additional therapeutic agent) can be administered intravenously, intradermally, intraarterially, intraperitoneally, intralesionally, intracranially, intraarticularly, intraprostatically, intrasplenically, intrarenally, intrapleurally, intratracheally, intranasally,

intravitreally, intravaginally, intrarectally, intratumorally, intramuscularly, intraperitoneally, subcutaneously, subconjunctivally, intravesicularly, mucosally, intrapericardially, intraumbilically, intraocularly, orally, topically, locally, by inhalation (e.g. aerosol inhalation), injection, infusion, continuous infusion, localized perfusion bathing target cells directly, via a catheter, via a lavage, in cremes, in lipid compositions (e.g. liposomes), or by other method or any combination of the forgoing as would be known to one of ordinary skill in the art (see, for example, Remington's Pharmaceutical Sciences, 18th Ed. Mack Printing Company, 1990, incorporated herein by reference). Parenteral administration, in particular intravenous injection, is most commonly used for administering polypeptide molecules such as the mutant IL-2 polypeptides and immunoconjugates of the invention.

Parenteral compositions include those designed for administration by injection, e.g. subcutaneous, intradermal, intralesional, intravenous, intraarterial intramuscular, intrathecal or intraperitoneal injection. For injection, the mutant IL-2 polypeptides and immunoconjugates of the invention may be formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hanks' solution, Ringer's solution, or physiological saline buffer. The solution may contain formulatory agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the mutant IL-2 polypeptides and immunoconjugates may be in powder form for constitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use. Sterile injectable solutions are prepared by incorporating the IL-2 polypeptides or immunoconjugates of the invention in the required amount in the appropriate solvent with various of the other ingredients enumerated below, as required. Sterility may be readily accomplished, e.g., by filtration through sterile filtration membranes. Generally, dispersions are prepared by incorporating the various sterilized active ingredients into a sterile vehicle which contains the basic dispersion medium and/or the other ingredients. In the case of sterile powders for the preparation of sterile injectable solutions, suspensions or emulsion, the preferred methods of preparation are vacuum-drying or freeze-drying techniques which yield a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered liquid medium thereof. The liquid medium should be suitably buffered if necessary and the liquid diluent first rendered isotonic prior to injection with sufficient saline or glucose. The composition must be stable under the conditions of manufacture and storage, and preserved against the contaminating action of microorganisms, such as bacteria and fungi. It will be appreciated that endotoxin contamination should be kept minimally at a safe level, for example, less than 0.5 ng/mg protein. Suitable pharmaceutically acceptable carriers include, but are not limited to: buffers such as phosphate, citrate, and other

organic acids; antioxidants including ascorbic acid and methionine; preservatives (such as octadecyldimethylbenzyl ammonium chloride; hexamethonium chloride; benzalkonium chloride; benzethonium chloride; phenol, butyl or benzyl alcohol; alkyl parabens such as methyl or propyl paraben; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); low molecular weight
5 (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, histidine, arginine, or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrins; chelating agents such as EDTA; sugars such as sucrose, mannitol, trehalose or sorbitol; salt-forming counter-ions such as sodium;
10 metal complexes (e.g. Zn-protein complexes); and/or non-ionic surfactants such as polyethylene glycol (PEG). Aqueous injection suspensions may contain compounds which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, dextran, or the like. Optionally, the suspension may also contain suitable stabilizers or agents which increase the solubility of the compounds to allow for the preparation of highly concentrated solutions.
15 Additionally, suspensions of the active compounds may be prepared as appropriate oily injection suspensions. Suitable lipophilic solvents or vehicles include fatty oils such as sesame oil, or synthetic fatty acid esters, such as ethyl cleats or triglycerides, or liposomes.

Active ingredients may be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-
20 microcapsules and poly-(methylmethacrylate) microcapsules, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nanoparticles and nanocapsules) or in macroemulsions. Such techniques are disclosed in Remington's Pharmaceutical Sciences (18th Ed. Mack Printing Company, 1990). Sustained-release preparations may be prepared. Suitable examples of sustained-release preparations include
25 semipermeable matrices of solid hydrophobic polymers containing the polypeptide, which matrices are in the form of shaped articles, e.g. films, or microcapsules. In particular embodiments, prolonged absorption of an injectable composition can be brought about by the use in the compositions of agents delaying absorption, such as, for example, aluminum monostearate, gelatin or combinations thereof.

30 In addition to the compositions described previously, the immunoconjugates may also be formulated as a depot preparation. Such long acting formulations may be administered by implantation (for example subcutaneously or intramuscularly) or by intramuscular injection.

Thus, for example, the mutant IL-2 polypeptides and immunoconjugates may be formulated with suitable polymeric or hydrophobic materials (for example as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt.

Pharmaceutical compositions comprising the mutant IL-2 polypeptides and immunoconjugates
5 of the invention may be manufactured by means of conventional mixing, dissolving, emulsifying, encapsulating, entrapping or lyophilizing processes. Pharmaceutical compositions may be formulated in conventional manner using one or more physiologically acceptable carriers, diluents, excipients or auxiliaries which facilitate processing of the proteins into preparations that can be used pharmaceutically. Proper formulation is dependent upon the route
10 of administration chosen.

The mutant IL-2 polypeptides and immunoconjugates may be formulated into a composition in a free acid or base, neutral or salt form. Pharmaceutically acceptable salts are salts that substantially retain the biological activity of the free acid or base. These include the acid addition salts, e.g., those formed with the free amino groups of a proteinaceous composition, or which are
15 formed with inorganic acids such as for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric or mandelic acid. Salts formed with the free carboxyl groups can also be derived from inorganic bases such as for example, sodium, potassium, ammonium, calcium or ferric hydroxides; or such organic bases as isopropylamine, trimethylamine, histidine or procaine. Pharmaceutical salts tend to be more soluble in aqueous
20 and other protic solvents than are the corresponding free base forms.

Therapeutic Methods and Compositions

Any of the mutant IL-2 polypeptides and immunoconjugates provided herein may be used in therapeutic methods. Mutant IL-2 polypeptides and immunoconjugates of the invention can be
25 used as immunotherapeutic agents, for example in the treatment of cancers.

For use in therapeutic methods, mutant IL-2 polypeptides and immunoconjugates of the invention would be formulated, dosed, and administered in a fashion consistent with good medical practice. Factors for consideration in this context include the particular disorder being treated, the particular mammal being treated, the clinical condition of the individual patient, the

cause of the disorder, the site of delivery of the agent, the method of administration, the scheduling of administration, and other factors known to medical practitioners.

Mutant IL-2 polypeptides and immunoconjugates of the invention are useful in treating disease states where stimulation of the immune system of the host is beneficial, in particular conditions
5 where an enhanced cellular immune response is desirable. These may include disease states where the host immune response is insufficient or deficient. Disease states for which the mutant IL-2 polypeptides or immunoconjugates of the invention can be administered comprise, for example, a tumor or infection where a cellular immune response would be a critical mechanism for specific immunity. Specific disease states for which IL-2 mutants of the present invention can
10 be employed include cancer, for example renal cell carcinoma or melanoma; immune deficiency, specifically in HIV-positive patients, immunosuppressed patients, chronic infection and the like. The mutant IL-2 polypeptides or immunoconjugates of the invention may be administered per se or in any suitable pharmaceutical composition.

In one aspect, mutant IL-2 polypeptides and immunoconjugates of the invention for use as a
15 medicament are provided. In further aspects, mutant IL-2 polypeptides and immunoconjugates of the invention for use in treating a disease are provided. In certain embodiments, mutant IL-2 polypeptides and immunoconjugates of the invention for use in a method of treatment are provided. In one embodiment, the invention provides a mutant IL-2 polypeptide or an immunoconjugate as described herein for use in the treatment of a disease in an individual in
20 need thereof. In certain embodiments, the invention provides a mutant IL-2 polypeptide or an immunoconjugate for use in a method of treating an individual having a disease comprising administering to the individual a therapeutically effective amount of the mutant IL-2 polypeptide or the immunoconjugate. In certain embodiments the disease to be treated is a proliferative disorder. In a preferred embodiment the disease is cancer. In certain embodiments the method
25 further comprises administering to the individual a therapeutically effective amount of at least one additional therapeutic agent, e.g., an anti-cancer agent if the disease to be treated is cancer. In further embodiments, the invention provides a mutant IL-2 polypeptide or an immunoconjugate for use in stimulating the immune system. In certain embodiments, the invention provides a mutant IL-2 polypeptide or an immunoconjugate for use in a method of
30 stimulating the immune system in an individual comprising administering to the individual an effective amount of the mutant IL-2 polypeptide or immunoconjugate to stimulate the immune system. An "individual" according to any of the above embodiments is a mammal, preferably a

human. "Stimulation of the immune system" according to any of the above embodiments may include any one or more of a general increase in immune function, an increase in T cell function, an increase in B cell function, a restoration of lymphocyte function, an increase in the expression of IL-2 receptors, an increase in T cell responsiveness, an increase in natural killer cell activity or lymphokine-activated killer (LAK) cell activity, and the like.

In a further aspect, the invention provides for the use of a mutant IL-2 polypeptide or an immunconjugate of the invention in the manufacture or preparation of a medicament for the treatment of a disease in an individual in need thereof. In one embodiment, the medicament is for use in a method of treating a disease comprising administering to an individual having the disease a therapeutically effective amount of the medicament. In certain embodiments the disease to be treated is a proliferative disorder. In a preferred embodiment the disease is cancer. In one such embodiment, the method further comprises administering to the individual a therapeutically effective amount of at least one additional therapeutic agent, e.g., an anti-cancer agent if the disease to be treated is cancer. In a further embodiment, the medicament is for stimulating the immune system. In a further embodiment, the medicament is for use in a method of stimulating the immune system in an individual comprising administering to the individual an amount effective of the medicament to stimulate the immune system. An "individual" according to any of the above embodiments may be a mammal, preferably a human. "Stimulation of the immune system" according to any of the above embodiments may include any one or more of a general increase in immune function, an increase in T cell function, an increase in B cell function, a restoration of lymphocyte function, an increase in the expression of IL-2 receptors, an increase in T cell responsiveness, an increase in natural killer cell activity or lymphokine-activated killer (LAK) cell activity, and the like.

In a further aspect, the invention provides a method for treating a disease in an individual, comprising administering to said individual a therapeutically effective amount of a mutant IL-2 polypeptide or an immunoconjugate of the invention. In one embodiment a composition is administered to said individual, comprising the mutant IL-2 polypeptide or the immunoconjugate of the invention in a pharmaceutically acceptable form. In certain embodiments the disease to be treated is a proliferative disorder. In a preferred embodiment the disease is cancer. In certain embodiments the method further comprises administering to the individual a therapeutically effective amount of at least one additional therapeutic agent, e.g., an anti-cancer agent if the disease to be treated is cancer. In a further aspect, the invention provides a method for

stimulating the immune system in an individual, comprising administering to the individual an effective amount of a mutant IL-2 polypeptide or an immunoconjugate to stimulate the immune system. An "individual" according to any of the above embodiments may be a mammal, preferably a human. "Stimulation of the immune system" according to any of the above
5 embodiments may include any one or more of a general increase in immune function, an increase in T cell function, an increase in B cell function, a restoration of lymphocyte function, an increase in the expression of IL-2 receptors, an increase in T cell responsiveness, an increase in natural killer cell activity or lymphokine-activated killer (LAK) cell activity, and the like.

It is understood that any of the above therapeutic methods may be carried out using an
10 immunoconjugate of the invention in place of or in addition to a mutant IL-2 polypeptide.

In certain embodiments the disease to be treated is a proliferative disorder, preferably cancer. Non-limiting examples of cancers include bladder cancer, brain cancer, head and neck cancer, pancreatic cancer, lung cancer, breast cancer, ovarian cancer, uterine cancer, cervical cancer, endometrial cancer, esophageal cancer, colon cancer, colorectal cancer, rectal cancer, gastric
15 cancer, prostate cancer, blood cancer, skin cancer, squamous cell carcinoma, bone cancer, and kidney cancer. Other cell proliferation disorders that can be treated using a mutant IL-2 polypeptide or an immunoconjugate of the present invention include, but are not limited to neoplasms located in the: abdomen, bone, breast, digestive system, liver, pancreas, peritoneum, endocrine glands (adrenal, parathyroid, pituitary, testicles, ovary, thymus, thyroid), eye, head and
20 neck, nervous system (central and peripheral), lymphatic system, pelvic, skin, soft tissue, spleen, thoracic region, and urogenital system. Also included are pre-cancerous conditions or lesions and cancer metastases. In certain embodiments the cancer is chosen from the group consisting of renal cell cancer, skin cancer, lung cancer, colorectal cancer, breast cancer, brain cancer, head and neck cancer. Similarly, other cell proliferation disorders can also be treated by the mutant
25 IL-2 polypeptides and immunoconjugates of the present invention. Examples of such cell proliferation disorders include, but are not limited to: hypergammaglobulinemia, lymphoproliferative disorders, paraproteinemias, purpura, sarcoidosis, Sezary Syndrome, Waldenström's Macroglobulinemia, Gaucher's Disease, histiocytosis, and any other cell proliferation disease, besides neoplasia, located in an organ system listed above. In another
30 embodiment, the disease is related to autoimmunity, transplantation rejection, post-traumatic immune responses and infectious diseases (e.g. HIV). More specifically, the mutant IL-2 polypeptides and immunoconjugates may be used in eliminating cells involved in immune cell-

mediated disorders, including lymphoma; autoimmunity, transplantation rejection, graft-versus-host disease, ischemia and stroke. A skilled artisan readily recognizes that in many cases the mutant IL-2 polypeptides or immunoconjugates may not provide a cure but may only provide partial benefit. In some embodiments, a physiological change having some benefit is also
5 considered therapeutically beneficial. Thus, in some embodiments, an amount of mutant IL-2 polypeptide or immunoconjugate that provides a physiological change is considered an "effective amount" or a "therapeutically effective amount". The subject, patient, or individual in need of treatment is typically a mammal, more specifically a human.

The immunoconjugates of the invention are also useful as diagnostic reagents. The binding of an
10 immunoconjugate to an antigenic determinant can be readily detected by using a secondary antibody specific for the IL-2 polypeptide. In one embodiment, the secondary antibody and the immunoconjugate facilitate the detection of binding of the immunoconjugate to an antigenic determinant located on a cell or tissue surface.

In some embodiments, an effective amount of the mutant IL-2 polypeptides or
15 immunoconjugates of the invention is administered to a cell. In other embodiments, a therapeutically effective amount of the mutant IL-2 polypeptides or immunoconjugates of the invention is administered to an individual for the treatment of disease.

For the prevention or treatment of disease, the appropriate dosage of a mutant IL-2 polypeptide or immunoconjugate of the invention (when used alone or in combination with one or more other
20 additional therapeutic agents) will depend on the type of disease to be treated, the route of administration, the body weight of the patient, the type of polypeptide (e.g. unconjugated IL-2 or immunoconjugate), the severity and course of the disease, whether the antibody is administered for preventive or therapeutic purposes, previous or concurrent therapeutic interventions, the patient's clinical history and response to the mutant IL-2 polypeptide or immunoconjugate, and
25 the discretion of the attending physician.. The practitioner responsible for administration will, in any event, determine the concentration of active ingredient(s) in a composition and appropriate dose(s) for the individual subject. Various dosing schedules including but not limited to single or multiple administrations over various time-points, bolus administration, and pulse infusion are contemplated herein.

30 A single administration of unconjugated IL-2 can range from about 50,000 IU/kg to about 1,000,000 IU/kg or more, more typically about 600,000 IU/kg of IL-2. This may be repeated

several times a day (e.g. 2-3 x), for several days (e.g. about 3-5 consecutive days) and then may be repeated one or more times following a period of rest (e.g., about 7-14 days). Thus, a therapeutically effective amount may comprise only a single administration or many administrations over a period of time (e.g. about 20-30 individual administrations of about 5 600,000 IU/kg of IL-2 each given over about a 10-20 day period). When administered in the form of an immunconjugate, a therapeutically effective of the mutant IL-2 polypeptide may be lower than for unconjugated mutant IL-2 polypeptide.

Similarly, the immunoconjugate is suitably administered to the patient at one time or over a series of treatments. Depending on the type and severity of the disease, about 1 µg/kg to 15 10 mg/kg (e.g. 0.1 mg/kg – 10 mg/kg) of immunoconjugate can be an initial candidate dosage for administration to the patient, whether, for example, by one or more separate administrations, or by continuous infusion. One typical daily dosage might range from about 1 µg/kg to 100 mg/kg or more, depending on the factors mentioned above. For repeated administrations over several days or longer, depending on the condition, the treatment would generally be sustained until a 15 desired suppression of disease symptoms occurs. One exemplary dosage of the immunoconjugate would be in the range from about 0.005 mg/kg to about 10 mg/kg. In other non-limiting examples, a dose may also comprise from about 1 microgram/kg/body weight, about 5 microgram/kg/body weight, about 10 microgram/kg/body weight, about 50 microgram/kg/body weight, about 100 microgram/kg/body weight, about 200 20 microgram/kg/body weight, about 350 microgram/kg/body weight, about 500 microgram/kg/body weight, about 1 milligram/kg/body weight, about 5 milligram/kg/body weight, about 10 milligram/kg/body weight, about 50 milligram/kg/body weight, about 100 milligram/kg/body weight, about 200 milligram/kg/body weight, about 350 milligram/kg/body weight, about 500 milligram/kg/body weight, to about 1000 mg/kg/body weight or more per 25 administration, and any range derivable therein. In non-limiting examples of a derivable range from the numbers listed herein, a range of about 5 mg/kg/body weight to about 100 mg/kg/body weight, about 5 microgram/kg/body weight to about 500 milligram/kg/body weight, etc., can be administered, based on the numbers described above. Thus, one or more doses of about 0.5 mg/kg, 2.0 mg/kg, 5.0 mg/kg or 10 mg/kg (or any combination thereof) may be administered to 30 the patient. Such doses may be administered intermittently, e.g. every week or every three weeks (e.g. such that the patient receives from about two to about twenty, or e.g. about six doses of the immunoconjugate). An initial higher loading dose, followed by one or more lower doses may be

administered. However, other dosage regimens may be useful. The progress of this therapy is easily monitored by conventional techniques and assays.

The mutant IL-2 polypeptides and immunoconjugates of the invention will generally be used in an amount effective to achieve the intended purpose. For use to treat or prevent a disease condition, the mutant IL-2 polypeptides and immunoconjugates of the invention, or pharmaceutical compositions thereof, are administered or applied in a therapeutically effective amount. Determination of a therapeutically effective amount is well within the capabilities of those skilled in the art, especially in light of the detailed disclosure provided herein.

For systemic administration, a therapeutically effective dose can be estimated initially from *in vitro* assays, such as cell culture assays. A dose can then be formulated in animal models to achieve a circulating concentration range that includes the IC₅₀ as determined in cell culture. Such information can be used to more accurately determine useful doses in humans.

Initial dosages can also be estimated from *in vivo* data, *e.g.*, animal models, using techniques that are well known in the art. One having ordinary skill in the art could readily optimize administration to humans based on animal data.

Dosage amount and interval may be adjusted individually to provide plasma levels of the mutant IL-2 polypeptides or immunoconjugates which are sufficient to maintain therapeutic effect. Usual patient dosages for administration by injection range from about 0.1 to 50 mg/kg/day, typically from about 0.5 to 1 mg/kg/day. Therapeutically effective plasma levels may be achieved by administering multiple doses each day. Levels in plasma may be measured, for example, by HPLC.

In cases of local administration or selective uptake, the effective local concentration of the immunoconjugates may not be related to plasma concentration. One having skill in the art will be able to optimize therapeutically effective local dosages without undue experimentation.

A therapeutically effective dose of the mutant IL-2 polypeptides or immunoconjugates described herein will generally provide therapeutic benefit without causing substantial toxicity. Toxicity and therapeutic efficacy of an IL-2 mutant or immunoconjugate can be determined by standard pharmaceutical procedures in cell culture or experimental animals (see, *e.g.* Examples 8 and 9). Cell culture assays and animal studies can be used to determine the LD₅₀ (the dose lethal to 50% of a population) and the ED₅₀ (the dose therapeutically effective in 50% of a population). The

dose ratio between toxic and therapeutic effects is the therapeutic index, which can be expressed as the ratio LD_{50}/ED_{50} . IL-2 mutants and immunoconjugates that exhibit large therapeutic indices are preferred. In one embodiment, the mutant IL-2 polypeptide or the immunoconjugate according to the present invention exhibits a high therapeutic index. The data obtained from cell culture assays and animal studies can be used in formulating a range of dosages suitable for use in humans. The dosage lies preferably within a range of circulating concentrations that include the ED_{50} with little or no toxicity. The dosage may vary within this range depending upon a variety of factors, e.g., the dosage form employed, the route of administration utilized, the condition of the subject, and the like. The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. (See, e.g., Fingl et al., 1975, In: The Pharmacological Basis of Therapeutics, Ch. 1, p. 1, incorporated herein by reference in its entirety).

The attending physician for patients treated with IL-2 mutants or immunoconjugates of the invention would know how and when to terminate, interrupt, or adjust administration due to toxicity, organ dysfunction, and the like. Conversely, the attending physician would also know to adjust treatment to higher levels if the clinical response were not adequate (precluding toxicity). The magnitude of an administered dose in the management of the disorder of interest will vary with the severity of the condition to be treated, with the route of administration, and the like. The severity of the condition may, for example, be evaluated, in part, by standard prognostic evaluation methods. Further, the dose and perhaps dose frequency will also vary according to the age, body weight, and response of the individual patient.

The maximum therapeutic dose of a mutant IL-2 polypeptide or immunoconjugate comprising said polypeptide may be increased from those used for wild-type IL-2 or an immunoconjugate comprising wild-type IL-2, respectively.

Other Agents and Treatments

The mutant IL-2 polypeptides and the immunoconjugates according to the invention may be administered in combination with one or more other agents in therapy. For instance, a mutant IL-2 polypeptide or immunoconjugate of the invention may be co-administered with at least one additional therapeutic agent. The term "therapeutic agent" encompasses any agent administered

to treat a symptom or disease in an individual in need of such treatment. Such additional therapeutic agent may comprise any active ingredients suitable for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. In certain embodiments, an additional therapeutic agent is an immunomodulatory agent, a cytostatic agent, an inhibitor of cell adhesion, a cytotoxic agent, an activator of cell apoptosis, or an agent that increases the sensitivity of cells to apoptotic inducers. In a particular embodiment, the additional therapeutic agent is an anti-cancer agent, for example a microtubule disruptor, an antimetabolite, a topoisomerase inhibitor, a DNA intercalator, an alkylating agent, a hormonal therapy, a kinase inhibitor, a receptor antagonist, an activator of tumor cell apoptosis, or an antiangiogenic agent.

Such other agents are suitably present in combination in amounts that are effective for the purpose intended. The effective amount of such other agents depends on the amount of mutant IL-2 polypeptide or immunoconjugate used, the type of disorder or treatment, and other factors discussed above. The mutant IL-2 polypeptides and immunoconjugates are generally used in the same dosages and with administration routes as described herein, or about from 1 to 99% of the dosages described herein, or in any dosage and by any route that is empirically/clinically determined to be appropriate.

Such combination therapies noted above encompass combined administration (where two or more therapeutic agents are included in the same or separate compositions), and separate administration, in which case, administration of the mutant IL-2 polypeptide or immunoconjugate of the invention can occur prior to, simultaneously, and/or following, administration of the additional therapeutic agent and/or adjuvant. Mutant IL-2 polypeptides and immunoconjugates of the invention can also be used in combination with radiation therapy.

Articles of Manufacture

In another aspect of the invention, an article of manufacture containing materials useful for the treatment, prevention and/or diagnosis of the disorders described above is provided. The article of manufacture comprises a container and a label or package insert on or associated with the container. Suitable containers include, for example, bottles, vials, syringes, IV solution bags, etc. The containers may be formed from a variety of materials such as glass or plastic. The container

holds a composition which is by itself or combined with another composition effective for treating, preventing and/or diagnosing the condition and may have a sterile access port (for example the container may be an intravenous solution bag or a vial having a stopper pierceable by a hypodermic injection needle). At least one active agent in the composition is a mutant IL-2 polypeptide of the invention. The label or package insert indicates that the composition is used for treating the condition of choice. Moreover, the article of manufacture may comprise (a) a first container with a composition contained therein, wherein the composition comprises a mutant IL-2 polypeptide of the invention; and (b) a second container with a composition contained therein, wherein the composition comprises a further cytotoxic or otherwise therapeutic agent. The article of manufacture in this embodiment of the invention may further comprise a package insert indicating that the compositions can be used to treat a particular condition. Alternatively, or additionally, the article of manufacture may further comprise a second (or third) container comprising a pharmaceutically-acceptable buffer, such as bacteriostatic water for injection (BWFI), phosphate-buffered saline, Ringer's solution and dextrose solution. It may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, and syringes.

It is understood that any of the above articles of manufacture may include an immunoconjugate of the invention in place of or in addition to a mutant IL-2 polypeptide.

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Short Description of the Figures

Figure 1. Schematic representation of the Fab-IL-2-Fab (A) and IgG-IL-2 (B) immunoconjugate formats, comprising mutant IL-2 polypeptide.

Figure 2. Purification of the naked IL-2 wild-type construct. (A) Chromatogram of the His tag purification for the wild-type naked IL-2; (B) SDS PAGE of purified protein (8-12% Bis-Tris (NuPage, Invitrogen), MES running buffer).

Figure 3. Purification of the naked IL-2 wild-type construct. (A) Chromatogram of the size exclusion chromatography for the wild-type IL-2; (B) SDS PAGE of purified protein (8-12% Bis-Tris (NuPage, Invitrogen), MES running buffer).

Figure 4. Analytical size exclusion chromatography for the wild-type IL-2 as determined on a Superdex 75, 10/300 GL. Pool 1 comprises 74% of the 23 kDa species and 26% of the 20 kDa species, Pool 2 comprises 40% of the 22 kDa species and 60% of the 20 kDa species.

Figure 5. Purification of the naked IL-2 quadruple mutant construct. (A) Chromatogram of the His tag purification for the IL-2 quadruple mutant; (B) SDS PAGE of purified protein (8-12% Bis-Tris (NuPage, Invitrogen), MES running buffer).

Figure 6. Purification of the naked IL-2 quadruple mutant construct. (A) Chromatogram of the size exclusion chromatography for the IL-2 quadruple mutant; (B) SDS PAGE of purified protein (8-12% Bis-Tris (NuPage, Invitrogen), MES running buffer).

Figure 7. Analytical size exclusion chromatography for the IL-2 quadruple mutant as determined on a Superdex 75, 10/300 GL (Pool 2, 20 kDa).

Figure 8. Simultaneous binding to IL-2R and human FAP by FAP-targeted 29B11-based Fab-IL-2-Fab comprising wild-type or quadruple mutant IL-2. (A) Setup of the SPR assay; (B) SPR sensorgram.

Figure 9. Induction of IFN- γ release by NK92 cells by FAP-targeted 4G8-based Fab-IL-2-Fab comprising wild-type or mutant IL-2, compared to Proleukin, in solution.

Figure 10. Induction of proliferation of isolated NK cells (bottom) by FAP-targeted 4G8-based Fab-IL-2-Fab comprising wild-type or mutant IL-2, compared to Proleukin, in solution.

Figure 11. Induction of proliferation of activated CD3⁺ T cells by FAP-targeted 4G8-based Fab-IL-2-Fab comprising wild-type or mutant IL-2, compared to Proleukin, in solution.

Figure 12. Induction of activation induced cell death (AICD) of over-stimulated T cells by FAP-targeted 4G8-based Fab-IL-2-Fab comprising wild-type or mutant IL-2, compared to Proleukin, in solution.

Figure 13. Phospho-STAT5 FACS assay in solution with FAP-targeted 4G8-based Fab-IL-2-Fab comprising wild-type or quadruple mutant IL-2, compared to Proleukin, in solution. (A) regulatory T cells (CD4⁺CD25⁺FOXP3⁺); (B) CD8⁺ T cells (CD3⁺CD8⁺); (C) CD4⁺ T cells (CD4⁺CD25⁻CD127⁺); (D) NK cells (CD3⁻CD56⁺).

Figure 14. Purification of the FAP-targeted 28H1-based Fab-IL-2 qm-Fab immunoconjugate. (A) Elution profile of Protein G column. (B) Elution profile of Superdex 200 size exclusion column. (C) Novex Tris-Glycine 4-20% SDS-PAGE of the end-product with non-reduced and reduced sample.

- 5 Figure 15. Purification of the 4G8-based FAP-targeted Fab-IL-2 qm-Fab immunoconjugate. (A) Elution profile of Protein A column. (B) Elution profile of Superdex 200 size exclusion column. (C) NuPAGE Novex Bis-Tris Mini Gel (Invitrogen), MOPS running buffer of the end-product with non-reduced and reduced sample.

Figure 16. Purification of the MHLG1 KV9 MCSP-targeted Fab-IL2QM-Fab immunoconjugate.

- 10 (A) Elution profile of Protein A column, B) Elution profile of Superdex 200 size exclusion column. C) NuPAGE Novex Bis-Tris Mini Gel, Invitrogen, MOPS running buffer of the end-product with non-reduced and reduced sample.

Figure 17. Target binding of Fab-IL-2-Fab constructs on HEK 293-human FAP cells.

Figure 18. Target binding of Fab-IL-2-Fab constructs on HEK 293-human FAP cells.

- 15 Figure 19. Binding specificity of Fab-IL-2-Fab constructs as determined on HEK 293-human DPPiV and HEK 293 mock-transfected cells. Binding of a specific DPPiV (CD26) antibody is shown on the right.

Figure 20. Analysis of FAP internalization upon binding of Fab-IL-2-Fab constructs to FAP on GM05389 fibroblasts.

- 20 Figure 21. IL-2 induced IFN- γ release by NK92 cells in solution.

Figure 22. IL-2 induced IFN- γ release by NK92 cells in solution.

Figure 23. IL-2 induced proliferation of NK92 cells in solution.

- Figure 24. Assessment of Fab-IL-2-Fab clones 28H1 vs. 29B11 vs. 4G8 in STAT5 phosphorylation assay with PBMCs in solution. (A) NK cells (CD3⁻CD56⁺); (B) CD8⁺ T cells (CD3⁺CD8⁺); (C) CD4⁺ T cells (CD3⁺CD4⁺CD25⁻CD127⁺); (D) regulatory T cells (CD4⁺CD25⁺FOXP3⁺).
- 25

Figure 25. Efficacy of the FAP-targeted 4G8 Fab-IL-2 wt-Fab and 4G8 Fab-IL-2 qm-Fab immunoconjugates in the human renal cell adenocarcinoma cell line ACHN.

Figure 26. Efficacy of the FAP-targeted 4G8 FAP-IL-2 qm-Fab and 28H1 Fab-IL-2 qm-Fab immunoconjugates in the mouse Lewis lung carcinoma cell line LLC1.

5 Figure 27. Efficacy of the FAP-targeted 28H1 Fab-IL-2 wt-Fab and 28H1 Fab-IL-2 qm-Fab immunoconjugates in the mouse Lewis lung carcinoma cell line LLC1.

Figure 28. Low magnification (100x) of lungs of mice treated with vehicle control (A) or 9 µg/g wt IL-2 (B) or qm IL-2 (C). Lungs of mice treated with 9 µg/g wt IL-2 show vasocentric mononuclear infiltrate that has moved into the alveolar spaces. Edema and hemorrhage is also
10 present. Marginal infiltrate is noted in the mice treated with qm IL-2 around few vessels.

Figure 29. Higher magnification (200x) of lungs shown in Figure 28. Margination and infiltration of mononuclear cells in and around blood vessels is more severe in mice treated with wt IL-2 (A) than in mice treated with qm IL-2 (B and C).

Figure 30. Low magnification (100x) of livers of mice treated with vehicle control (A) or 9 µg/g
15 wt IL-2 (B) or qm IL-2 (C). Vasocentric infiltration is seen in mice treated with wt IL-2.

Figure 31. IFN-γ secretion by NK92 cells upon incubation with different IL-2 wild-type (wt) and quadruple mutant (qm) preparations for 24 (A) or 48 hours (B).

Figure 32. Proliferation of NK92 cells upon incubation with different IL-2 wild-type (wt) and quadruple mutant (qm) preparations for 48 hours.

20 Figure 33. Proliferation of NK92 cells upon incubation with different IL-2 wild-type (wt) and quadruple mutant (qm) preparations for 48 hours.

Figure 34. Proliferation of NK cells upon incubation with different FAP-targeted 28H1 IL-2 immunoconjugates or Proleukin for 4 (A), 5 (B) or 6 (C) days.

Figure 35. Proliferation of CD4 T-cells upon incubation with different FAP-targeted 28H1 IL-2
25 immunoconjugates or Proleukin for 4 (A), 5 (B) or 6 (C) days.

Figure 36. Proliferation of CD8 T-cells upon incubation with different FAP-targeted 28H1 IL-2 immunoconjugates or Proleukin for 4 (A), 5 (B) or 6 (C) days.

Figure 37. Proliferation of NK cells (A), CD4 T-cells (B) and CD8 T-cells (C) upon incubation with different IL-2 immunoconjugates or Proleukin for 6 days.

Figure 38. STAT phosphorylation in NK cells (A), CD8 T-cells (B), CD4 T-cells (C) and regulatory T-cells (D) after 30 min incubation with Proleukin, in-house produced wild-type IL-2
5 and quadruple mutant IL-2.

Figure 39. STAT phosphorylation in NK cells (A), CD8 T-cells (B), CD4 T-cells (C) and regulatory T-cells (D) after 30 min incubation with Proleukin, IgG-IL-2 comprising wild-type IL-2 or IgG-IL-2 comprising quadruple mutant IL-2.

Figure 40. Survival of Black 6 mice after administration (once daily for seven days) of different
10 doses of IL-2 immunoconjugates comprising wild-type or quadruple mutant IL-2.

Figure 41. Serum concentrations of IL-2 immunoconjugates after a single i.v. administration of FAP-targeted (A) and untargeted (B) IgG-IL-2 constructs comprising either wild-type (wt) or quadruple mutant (qm) IL-2.

Figure 42. Serum concentrations of IL-2 immunoconjugates after a single i.v. administration of
15 untargeted Fab-IL-2-Fab constructs comprising either wild-type (wt) or quadruple mutant (qm) IL-2.

Figure 43. Purification of quadruple mutant IL-2. (A) Immobilized metal ion chromatography; (B) size exclusion chromatography; (C) SDS PAGE under non-reducing conditions (NuPAGE Novex Bis-Tris gel (Invitrogen), MES running buffer); (D) analytical size exclusion
20 chromatography (Superdex 75 10/300 GL).

Figure 44. Proliferation of pre-activated CD8 (A) and CD4 (B) T cells after six days incubation with different IL-2 immunoconjugates.

Figure 45. Activation induced cell death of CD3⁺ T cells after six days incubation with different IL-2 immunoconjugates and overnight treatment with anti-Fas antibody.

25 Figure 46. Purification of FAP-targeted 4G8-based IgG-IL-2 quadruple mutant (qm) immunoconjugate. A) Elution profile of the Protein A affinity chromatography step. B) Elution profile of the size exclusion chromatography step. C) Analytical SDS-PAGE (NuPAGE Novex Bis-Tris Mini Gel, Invitrogen, MOPS running buffer) of the final product. D) Analytical size

exclusion chromatography of the final product on a Superdex 200 column (97% monomer content).

Figure 47. Purification of FAP-targeted 28H1-based IgG-IL-2 qm immunoconjugate. A) Elution profile of the Protein A affinity chromatography step. B) Elution profile of the size exclusion chromatography step. C) Analytical SDS-PAGE (reduced: NuPAGE Novex Bis-Tris Mini Gel, Invitrogen, MOPS running buffer; non-reduced: NuPAGE Tris-Acetate, Invitrogen, Tris-Acetate running buffer) of the final product. D) Analytical size exclusion chromatography of the final product on a Superdex 200 column (100% monomer content).

Figure 48. Binding of FAP-targeted 4G8-based IgG-IL-2 qm immunoconjugate to human FAP expressed on stably transfected HEK 293 cells as measured by FACS, compared to the corresponding Fab-IL-2 qm-Fab construct.

Figure 49. Interferon (IFN)- γ release on NK92 cells induced by FAP-targeted 4G8-based IgG-IL-2 qm immunoconjugate in solution, compared to the 28H1-based Fab-IL-2 qm-Fab construct.

Figure 50. Detection of phosphorylated STAT5 by FACS in different cell types after stimulation for 20 min with FAP-targeted 4G8-based IgG-IL-2 qm immunoconjugate in solution, compared to the 28H1-based Fab-IL-2-Fab and Fab-IL-2 qm-Fab constructs as well as Proleukin. A) NK cells (CD3⁻CD56⁺); B) CD8⁺ T cells (CD3⁺CD8⁺); C) CD4⁺ T cells (CD3⁺CD4⁺CD25⁻CD127⁺); D) regulatory T cells (CD4⁺CD25⁺FOXP3⁺).

Examples

The following are examples of methods and compositions of the invention. It is understood that various other embodiments may be practiced, given the general description provided above.

Example 1

General methods

Recombinant DNA Techniques

Standard methods were used to manipulate DNA as described in Sambrook et al., Molecular cloning: A laboratory manual; Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, 1989. The molecular biological reagents were used according to the manufacturer's instructions. General information regarding the nucleotide sequences of human immunoglobulins light and heavy chains is given in: Kabat, E.A. et al., (1991) Sequences of Proteins of Immunological Interest, Fifth Ed., NIH Publication No 91-3242.

DNA Sequencing

DNA sequences were determined by double strand sequencing.

Gene Synthesis

Desired gene segments where required were either generated by PCR using appropriate templates or were synthesized by Geneart AG (Regensburg, Germany) from synthetic oligonucleotides and PCR products by automated gene synthesis. In cases where no exact gene sequence was available, oligonucleotide primers were designed based on sequences from closest homologues and the genes were isolated by RT-PCR from RNA originating from the appropriate tissue. The gene segments flanked by singular restriction endonuclease cleavage sites were cloned into standard cloning / sequencing vectors. The plasmid DNA was purified from transformed bacteria and concentration determined by UV spectroscopy. The DNA sequence of the subcloned gene fragments was confirmed by DNA sequencing. Gene segments were designed with suitable restriction sites to allow sub-cloning into the respective expression vectors. All constructs were designed with a 5'-end DNA sequence coding for a leader peptide which targets proteins for secretion in eukaryotic cells. SEQ ID NOs 263-273 give exemplary leader peptides and polynucleotide sequences encoding them.

Preparation of IL-2R $\beta\gamma$ subunit-Fc fusions and IL-2R α subunit Fc fusion

To study IL-2 receptor binding affinity, a tool was generated that allowed for the expression of a heterodimeric IL-2 receptor; the β -subunit of the IL-2 receptor was fused to an Fc molecule that was engineered to heterodimerize (Fc(hole)) (see SEQ ID NOs 274 and 275) using the "knobs-into-holes" technology (Merchant et al., Nat Biotech. 16, 677-681 (1998)). The γ -subunit of the IL-2 receptor was then fused to the Fc(knob) variant (see SEQ ID NOs 276 and 277), which heterodimerized with Fc(hole). This heterodimeric Fc-fusion protein was then used as a substrate for analyzing the IL-2/IL-2 receptor interaction. The IL-2R α -subunit was expressed as monomeric chain with an AcTev cleavage site and an Avi His tag (SEQ ID NOs 278 and 279). The respective IL-2R subunits were transiently expressed in HEK EBNA 293 with serum for the

IL-2R $\beta\gamma$ subunit construct and without serum for the α -subunit construct. The IL-2R $\beta\gamma$ subunit construct was purified on protein A (GE Healthcare), followed by size exclusion chromatography (GE Healthcare, Superdex 200). The IL-2R α -subunit was purified via His tag on a NiNTA column (Qiagen) followed by size exclusion chromatography (GE Healthcare, Superdex 75).

Preparation of Immunoconjugates

Details about the preparation and purification of Fab-IL-2-Fab immunoconjugates, including generation and affinity maturation of antigen binding moieties can be found in the Examples appended to PCT publication no. WO 2011/020783, which is incorporated herein by reference in its entirety. As described therein, various antigen binding domains directed to FAP have been generated by phage display, including the ones designated 4G8, 3F2, 28H1, 29B11, 14B3, and 4B9 used in the following examples. Clone 28H1 is an affinity matured antibody based on parental clone 4G8, while clones 29B11, 14B3 and 4B9 are affinity matured antibodies based on parental clone 3F2. The antigen binding domain designated MHLG1 KV9 used herein is directed to MCSP.

The sequences of immunoconjugates comprising wild-type IL-2 that were used in the following examples can also be found in PCT publication no. WO 2011/020783. The sequences corresponding to the immunoconjugates comprising quadruple mutant IL-2 that were used in the following examples are: 4G8: SEQ ID NOs 211 and 233; 3F2: SEQ ID NOs 209 and 231; 28H1: SEQ ID NOs 219 and 233; 29B11: SEQ ID NOs 221 and 231; 14B3: SEQ ID NOs 229 and 231; 4B9: SEQ ID NOs 227 and 231; MHLG1-KV9: SEQ ID NOs 253 and 255. The DNA sequences were generated by gene synthesis and/or classical molecular biology techniques and subcloned into mammalian expression vectors (one for the light chain and one for the heavy chain/IL-2 fusion protein) under the control of an MPSV promoter and upstream of a synthetic polyA site, each vector carrying an EBV OriP sequence. Immunoconjugates as applied in the examples below were produced by co-transfecting exponentially growing HEK293-EBNA cells with the mammalian expression vectors using calcium phosphate-transfection. Alternatively, HEK293 cells growing in suspension were transfected by polyethylenimine (PEI) with the respective expression vectors. Alternatively, stably transfected CHO cell pools or CHO cell clones were used for production in serum-free media. While 4G8-based FAP-targeted Fab-IL-2-Fab constructs comprising wild-type or (quadruple) mutant IL-2 can be purified by affinity

chromatography using a protein A matrix, affinity matured 28H1-based FAP-targeted Fab-IL-2-Fab constructs were purified by affinity chromatography on a protein G matrix in small scale.

Briefly, FAP-targeted 28H1 Fab-IL-2-Fab, comprising wild-type or (quadruple) mutant IL-2, was purified from cell supernatants by one affinity step (protein G) followed by size exclusion chromatography (Superdex 200, GE Healthcare). The protein G column was equilibrated in 20 mM sodium phosphate, 20 mM sodium citrate pH 7.5, supernatant was loaded, and the column was washed with 20 mM sodium phosphate, 20 mM sodium citrate pH 7.5. Fab-IL-2-Fab was eluted with 8.8 mM formic acid pH 3. The eluted fractions were pooled and polished by size exclusion chromatography in the final formulation buffer: 25 mM potassium phosphate, 125 mM sodium chloride, 100 mM glycine pH 6.7. Exemplary results from purification and analytics are given below.

FAP-targeted 3F2 Fab-IL-2-Fab or 4G8 Fab-IL-2-Fab, comprising wild-type or (quadruple) mutant IL-2, were purified by a similar method composed of one affinity step using protein A followed by size exclusion chromatography (Superdex 200, GE Healthcare). The protein A column was equilibrated in 20 mM sodium phosphate, 20 mM sodium citrate pH 7.5, supernatant was loaded, and the column was washed with 20 mM sodium phosphate, 20 mM sodium citrate, 500 mM sodium chloride pH 7.5, followed by a wash with 13.3 mM sodium phosphate, 20 mM sodium citrate, 500 mM sodium chloride pH 5.45. A third wash with 10 mM MES, 50 mM sodium chloride pH 5 was optionally performed. Fab-IL-2-Fab was eluted with 20 mM sodium citrate, 100 mM sodium chloride, 100 mM glycine, pH 3. The eluted fractions were pooled and polished by size exclusion chromatography in the final formulation buffer: 25 mM potassium phosphate, 125 mM sodium chloride, 100 mM glycine pH 6.7. Exemplary detailed purification procedures and results are given for selected constructs below.

FAP-targeted IgG-IL-2 qm fusion proteins were generated based on the FAP-antibodies 4G8, 4B9 and 28H1, wherein one single IL-2 quadruple mutant (qm) was fused to the C-terminus of one heterodimeric heavy chain as shown in Figure 1B. Targeting to the tumor stroma where FAP is selectively expressed is achieved via the bivalent antibody Fab region (avidity effect). Heterodimerization resulting in the presence of a single IL-2 quadruple mutant is achieved by application of the knob-into-hole technology. In order to minimize the generation of homodimeric IgG-cytokine fusions the cytokine was fused to the C-terminus (with deletion of the C-terminal Lys residue) of the knob-containing IgG heavy chain via a $G_4-(SG_4)_2$ - or $(G_4S)_3$ -linker. The antibody-cytokine fusion has IgG-like properties. To reduce FcγR binding/effector

function and prevent FcR co-activation, P329G L234A L235A (LALA) mutations were introduced in the Fc domain. The sequences of these immunoconjugates are given in SEQ ID NOs 297, 299 and 233 (28H1), SEQ ID NOs 301, 303 and 231 (4B9), and SEQ ID NOs 315, 317 and 233 (4G8)). In addition, a CEA-targeted IgG-IL-2 qm fusion protein and a control DP47GS non-targeted IgG-IL-2 qm fusion protein wherein the IgG does not bind to a specified target was generated. The sequences of these immunoconjugates are given in SEQ ID NOs 305, 307 and 309 (DP47GS), and SEQ ID NOs 319, 321 and 323 (CH1A1A).

The IgG-IL-2 constructs were generated by transient expression in HEK293 EBNA cells and purified essentially as described above for the Fab-IL-2-Fab constructs. Briefly, IgG-IL-2 fusion proteins were purified by one affinity step with protein A (HiTrap ProtA, GE Healthcare) equilibrated in 20 mM sodium phosphate, 20 mM sodium citrate pH 7.5. After loading of the supernatant, the column was first washed with 20 mM sodium phosphate, 20 mM sodium citrate, pH 7.5 and subsequently washed with 13.3 mM sodium phosphate, 20 mM sodium citrate, 500 mM sodium chloride, pH 5.45. The IgG-cytokine fusion protein was eluted with 20 mM sodium citrate, 100 mM sodium chloride, 100 mM glycine, pH 3. Fractions were neutralized and pooled and purified by size exclusion chromatography (HiLoad 16/60 Superdex 200, GE Healthcare) in final formulation buffer: 25 mM potassium phosphate, 125 mM sodium chloride, 100 mM glycine pH 6.7. Exemplary detailed purification procedures and results are given for selected constructs below. The protein concentration of purified protein samples was determined by measuring the optical density (OD) at 280 nm, using the molar extinction coefficient calculated on the basis of the amino acid sequence. Purity and molecular weight of immunoconjugates were analyzed by SDS-PAGE in the presence and absence of a reducing agent (5 mM 1,4-dithiotreitol) and stained with Coomassie blue (SimpleBlue™ SafeStain, Invitrogen). The NuPAGE® Pre-Cast gel system (Invitrogen) was used according to the manufacturer's instructions (4-20% Tris-glycine gels or 3-12% Bis-Tris). The aggregate content of immunoconjugate samples was analyzed using a Superdex 200 10/300GL analytical size-exclusion column (GE Healthcare) in 2 mM MOPS, 150 mM NaCl, 0.02% NaN₃, pH 7.3 running buffer at 25°C.

FAP binding affinity

The FAP binding activity of the cleaved Fab fragments used in these examples as antigen binding moieties was determined by surface plasmon resonance (SPR) on a Biacore machine. Briefly, an anti-His antibody (Penta-His, Qiagen 34660) was immobilized on CM5 chips to capture 10 nM human, murine or cynomolgus FAP-His (20 s). Temperature was 25°C and HBS-EP was used as buffer. Fab analyte concentration was 100 nM down to 0.41 nM (duplicates) at a

flow rate of 50 μ l/min (association: 300 s, dissociation: 600 s (4B9, 14B3, 29B11, 3F2) or 1200 s (28H1, 4G8), regeneration: 60 s 10 mM glycine pH 2). Fitting was performed based on a 1:1 binding model, RI=0, Rmax=local (because of capture format). Table 2 gives the monovalent affinities as determined by SPR.

5 TABLE 2. Affinity (K_D) of FAP-targeted Fab fragments to FAP as determined by SPR.

K_D in nM	Human FAP	Cynomolgus FAP	Murine FAP
4B9 Fab	0.3 0.31	0.23 0.24	5 5.2
14B3 Fab	0.47 0.47	0.61 0.59	4.7 4.7
29B11 Fab	0.19 0.19	0.21 0.2	1.3 1.2
3F2 Fab	6 6	4.7 5.3	8.9 9.5
28H1 Fab	2.6 2.6	3.7 3.7	0.13 0.18
4G8 Fab	53 (48 steady state) 51 (48 steady state)	33 (33 steady state) 35 (34 steady state)	0.07 0.07

Biological Activity Assays with Targeted IL-2 Immunoconjugates

The biological activity of FAP- or MCSP-targeted Fab-IL-2-Fab immunoconjugates and of FAP-targeted IgG-IL-2 immunoconjugates, comprising wild-type or (quadruple) mutant IL-2, was
 10 investigated in several cellular assays in comparison to commercially available IL-2 (Proleukin, Novartis, Chiron).

IFN- γ release by NK cells (in solution)

IL-2 starved NK92 cells (100000 cells/well in 96-U-well plate) were incubated with different concentrations of IL-2 immunoconjugates, comprising wild-type or (quadruple) mutant IL-2, for
 15 24 h in NK medium (MEM alpha from Invitrogen (#22561-021) supplemented with 10% FCS, 10% horse serum, 0.1 mM 2-mercaptoethanol, 0.2 mM inositol and 0.02 mM folic acid). Supernatants were harvested and the IFN- γ release was analysed using the anti-human IFN- γ ELISA Kit II from Becton Dickinson (#550612). Proleukin (Novartis) served as positive control for IL-2-mediated activation of the cells.

20 NK cell proliferation

Blood from healthy volunteers was taken in heparin-containing syringes and PBMCs were isolated. Untouched human NK cells were isolated from the PBMCs using the Human NK Cell Isolation Kit II from Miltenyi Biotec (#130-091-152). The CD25 expression of the cells was checked by flow cytometry. For proliferation assays, 20000 isolated human NK cells were incubated for 2 days in a humidified incubator at 37°C, 5 % CO₂ in the presence of different IL-2 immunoconjugates, comprising wild-type or (quadruple) mutant IL-2. Proleukin (Novartis) served as control. After 2 days, the ATP content of the cell lysates was measured using the CellTiter-Glo Luminescent Cell Viability Assay from Promega (#G7571/2/3). The percentage of growth was calculated setting the highest Proleukin concentration to 100 % proliferation and untreated cells without IL-2 stimulus to 0 % proliferation.

STAT5 Phosphorylation Assay

Blood from healthy volunteers was taken in heparin-containing syringes and PBMCs were isolated. PBMCs were treated with IL-2 immunoconjugates, comprising wild-type or (quadruple) mutant IL-2, at the indicated concentrations or with Proleukin (Novartis) as control. After 20 min incubation at 37°C, PBMCs were fixed with pre-warmed Cytofix buffer (Becton Dickinson #554655) for 10 min at 37°C, followed by permeabilization with Phosflow Perm Buffer III (Becton Dickinson #558050) for 30 min at 4°C. Cells were washed twice with PBS containing 0.1 % BSA before FACS staining was performed using mixtures of flow cytometry antibodies for detection of different cell populations and phosphorylation of STAT5. Samples were analysed using a FACSCantoII with HTS from Becton Dickinson.

NK cells were defined as CD3⁻CD56⁺, CD8 positive T cells were defined as CD3⁺CD8⁺, CD4 positive T cells were defined as CD4⁺CD25⁻CD127⁺ and T_{reg} cells were defined as CD4⁺CD25⁺FoxP3⁺.

Proliferation and AICD of T cells

Blood from healthy volunteers was taken in heparin-containing syringes and PBMCs were isolated. Untouched T cells were isolated using the Pan T Cell Isolation Kit II from Miltenyi Biotec (#130-091-156). T cells were pre-stimulated with 1 µg/ml PHA-M (Sigma Aldrich #L8902) for 16 h before adding Proleukin or Fab-IL-2-Fab immunoconjugates, comprising wild-type or (quadruple) mutant IL-2, to the washed cells for another 5 days. After 5 days, the ATP content of the cell lysates was measured using the CellTiter-Glo Luminescent Cell Viability Assay from Promega (#G7571/2/3). The relative proliferation was calculated setting the highest Proleukin concentration to 100 % proliferation.

Phosphatidylserine (PS) exposure and cell death of T cells were assayed by flow cytometric analysis (FACSCantoII, BD Biosciences) of annexin V (Annexin-V-FLUOS Staining Kit, Roche Applied Science) and propidium iodide (PI)-stained cells. To induce activation-induced cell death (AICD), the T cells were treated with an apoptosis-inducing anti-Fas antibody (Millipore clone Ch11) for 16 h after the 16 h PHA-M and 5 days treatment with Fab-IL-2-Fab immunoconjugates. Annexin V staining was performed according to the manufacturer's instructions. Briefly, cells were washed with Ann-V Binding Buffer (1x stock: 0.01 M Hepes/NaOH pH7.4, 0.14 M NaCl, 2.5 mM CaCl₂) and stained for 15 min at RT in the dark with Annexin V FITC (Roche). Cells were washed again in Ann-V-Binding buffer before addition of 200 µl/well Ann-V-Binding Buffer containing PI (0.3 µg/ml). The cells were analysed immediately by flow cytometry.

Binding to FAP expressing cells

Binding of FAP-targeted IgG-IL-2 qm and Fab-IL-2 qm-Fab immunoconjugates to human FAP expressed on stably transfected HEK293 cells was measured by FACS. Briefly, 250 000 cells per well were incubated with the indicated concentration of the immunoconjugates in a round-bottom 96-well plate, incubated for 30 min at 4°C, and washed once with PBS/0.1 % BSA. Bound immunoconjugates were detected after incubation for 30 min at 4°C with FITC-conjugated AffiniPure F(ab')₂ Fragment goat anti-human F(ab')₂ Specific (Jackson Immuno Research Lab #109-096-097, working solution: 1:20 diluted in PBS/0.1% BSA, freshly prepared) using a FACS CantoII (Software FACS Diva).

Analysis of FAP Internalization upon binding by FACS

For several FAP antibodies known in the art it is described that they induce FAP internalization upon binding (described e.g. in Baum et al., J Drug Target 15, 399-406 (2007); Bauer et al., Journal of Clinical Oncology, 2010 ASCO Annual Meeting Proceedings (Post-Meeting Edition), vol. 28 (May 20 Supplement), abstract no. 13062 (2010); Ostermann et al., Clin Cancer Res 14, 4584-4592 (2008)). Thus, we analyzed the internalization properties of our Fab-IL-2-Fab immunoconjugates. Briefly, GM05389 cells (human lung fibroblasts,) cultured in EMEM medium with 15% FCS, were detached, washed, counted, checked for viability and seeded at a density of 2×10^5 cells/well in 12-well plates. The next day, FAP-targeted Fab-IL-2-Fab immunoconjugates were diluted in cold medium and allowed to bind to cell surface for 30 min on ice. The excess of unbound antibody was washed away using cold PBS and cells were further incubated in 0.5 ml complete pre-warmed medium at 37°C for the indicated time periods. When

the different time points were reached, cells were transferred on ice, washed once with cold PBS and incubated with the secondary antibody (FITC-conjugated AffiniPure F(ab')₂ Fragment goat anti-human F(ab')₂ specific, Jackson Immuno Research Lab # 109-096-097, 1:20 dilution) for 30 min at 4°C. Cells were then washed twice with PBS/0.1 % BSA, transferred to a 96-well plate, centrifuged for 4 min at 4°C, 400 x g and cell pellets were resuspended by vortexing. Cells were fixed using 100 µl 2% PFA. For FACS measurement, cells were re-suspended in 200 µl/sample PBS/0.1% BSA and measured with the plate protocol in FACS CantoII (Software FACS Diva).

10

Example 2

We designed mutated versions of IL-2 that comprised one or more of the following mutations (compared to the wild-type IL-2 sequence shown in SEQ ID NO: 1):

15

1. T3A - knockout of predicted O-glycosylation site
2. F42A - knockout of IL-2/IL-2R α interaction
3. Y45A - knockout of IL-2/IL-2R α interaction
4. L72G - knockout of IL-2/IL-2R α interaction
5. C125A - previously described mutation to avoid disulfide-bridged IL-2 dimers

A mutant IL-2 polypeptide comprising all of mutations 1-4 is denoted herein as IL-2 quadruple mutant (qm). It may further comprise mutation 5 (see SEQ ID NO: 19).

20 In addition to the three mutations F42A, Y45A and L72G designed to interfere with the binding to CD25, the T3A mutation was chosen to eliminate the O-glycosylation site and obtain a protein product with higher homogeneity and purity when the IL-2 qm polypeptide or immunoconjugate is expressed in eukaryotic cells such as CHO or HEK293 cells.

For purification purposes a His6 tag was introduced at the C-terminus linked via a VD sequence.

25 For comparison a non-mutated analogous version of IL-2 was generated that only contained the C145A mutation to avoid undesired inter-molecular disulfide bridges (SEQ ID NO: 3). The respective molecular weights without signal sequence were 16423 D for naked IL-2 and 16169 D for the naked IL-2 qm. The wild-type and quadruple mutant IL-2 with His tag were transfected in HEK EBNA cells in serum-free medium (F17 medium) The filtered supernatant was buffer

exchanged over a cross-flow, before loading it on a NiNTA Superflow Cartridge (5 ml, Qiagen). The column was washed with wash buffer: 20 mM sodium phosphate, 0.5 M sodium chloride pH 7.4 and eluted with elution buffer: 20 mM sodium phosphate, 0.5 M sodium chloride 0.5 M imidazole pH 7.4. After loading the column was washed with 8 column volumes (CV) wash
5 buffer, 10 CV 5% elution buffer (corresponds to 25 mM imidazole), then eluted with a gradient to 0.5 M imidazole. The pooled eluate was polished by size exclusion chromatography on a HiLoad 16/60 Superdex75 (GE Healthcare) column in 2 mM MOPS, 150 mM sodium chloride, 0.02% sodium azide pH 7.3. Figure 2 shows the chromatogram of the His tag purification for the wild-type naked IL-2. Pool 1 was made from fractions 78-85, pool 2 from fractions 86-111.
10 Figure 3 shows the chromatogram of the size exclusion chromatography for the wild-type IL-2, for each pool the fractions 12 to 14 were pooled. Figure 4 shows the analytical size exclusion chromatography for wild-type IL-2 as determined on a Superdex 75, 10/300 GL (GE Healthcare) column in 2 mM MOPS, 150 mM sodium chloride, 0.02% sodium azide pH 7.3. Pool 1 and 2 contained 2 proteins of ca. 22 and 20 kDa. Pool 1 had more of the large protein, and pool 2 had
15 more of the small protein, putatively this difference is due to differences in O-glycosylation. Yields were ca. 0.5 mg/L supernatant for pool 1 and ca. 1.6 mg/L supernatant for pool 2. Figure 5 shows the chromatogram of the His tag purification for the quadruple mutant IL-2. Pool 1 was made from fractions 59-91, pool 2 from fractions 92-111. Figure 6 shows the chromatogram of the size exclusion chromatography for the quadruple mutant IL-2, here only pool 2 fractions 12
20 to 14 were kept. Figure 7 shows the analytical size exclusion chromatography for the quadruple mutant IL-2 as determined on a Superdex 75, 10/300 GL (GE Healthcare) column in 2 mM MOPS, 150 mM sodium chloride, 0.02% sodium azide pH 7.3. The preparation for the naked quadruple mutant IL-2 contained only one protein of 20 kD. This protein has the O-glycosylation site knocked out. Aliquots of the naked IL-2 wild-type and quadruple mutant were stored frozen
25 at -80°C. Yields were ca 0.9 mg/L supernatant.

A second batch of His-tagged quadruple mutant IL-2 was purified as described above by immobilized metal ion affinity chromatography (IMAC) and followed by size exclusion chromatography (SEC). The buffers used for IMAC were 50 mM Tris, 20 mM imidazole, 0.5M NaCl pH 8 for column equilibration and washing, and 50 mM Tris, 0.5 M imidazole, 0.5 M NaCl
30 pH 8 for elution. The buffer used for SEC and final formulation buffer was 20 mM histidine, 140 mM NaCl pH 6. Figure 43 shows the result of that purification. The yield was 2.3 ml/L supernatant.

Subsequently, affinity for the IL-2R $\beta\gamma$ heterodimer and the IL-2R α -subunit were determined by surface plasmon resonance (SPR). Briefly, the ligand – either human IL-2R α -subunit (Fc2) or human IL-2R β knob γ hole heterodimer (Fc3) – was immobilized on a CM5 chip. Subsequently, naked wild-type (pool 1 and 2) or quadruple mutant IL-2, and Proleukin (Novartis/Chiron) were applied to the chip as analytes at 25°C in HBS-EP buffer in concentrations ranging from 300 nM down to 1.2 nM (1:3 dil.). Flow rate was 30 μ l/min and the following conditions were applied for association: 180s, dissociation: 300 s, and regeneration: 2 x 30 s 3M MgCl₂ for IL-2R β knob γ hole heterodimer, 10 s 50 mM NaOH for IL-2R α -subunit. 1:1 binding was applied for fitting (1:1 binding RI $\neq$ 0, Rmax=local for IL-2R $\beta\gamma$, apparent K_D, 1:1 binding RI=0, Rmax=local for IL-2R α). Table 3 shows the respective K_D values for binding of human wild-type and quadruple mutant IL-2 as well as of Proleukin to IL-2R $\beta\gamma$ and IL-2R α -subunit.

TABLE 3. Affinity of mutant IL-2 polypeptides to the intermediate affinity IL-2R and the IL-2R α -subunit.

K _D in nM T = 25°C	Hu IL-2R $\beta\gamma$ (kinetic)	Hu IL-2R α (kinetic)	Hu IL-2R α (steady state)
Naked IL-2 wt, pool 1	5.6 5	17.4 16.6	30.3 23.9
Naked IL-2 wt, pool 2	2.8 1.8	10.6 10	19.7 17.6
Naked IL-2 qm	2.7 2	no binding	no binding
Proleukin	2.4 2.8	7.5 12.5	19 17.8

The data show that the naked IL-2 quadruple mutant shows the desired behaviour and has lost binding for the IL-2R α -subunit whereas binding to IL-2R $\beta\gamma$ is retained and comparable to the respective wild type IL-2 construct and Proleukin. Differences between pools 1 and 2 of the wild-type IL-2 can probably be attributed to differences in O-glycosylation. This variability and heterogeneity has been overcome in the IL-2 quadruple mutant by introduction of the T23A mutation.

Example 3

The three mutations F42A, Y45A and L72G and the mutation T3A were introduced in the Fab-IL-2-Fab format (Figure 1A) using the anti-FAP antibody 4G8 as model targeting domain either

as single mutants: 1) 4G8 IL-2 T3A, 2) 4G8 IL-2 F42A, 3) 4G8 IL-2 Y45A, 4) 4G8 IL-2 L72G, or they were combined in Fab-IL-2 mt-Fab constructs as: 5) triple mutant F42A/Y45A/L72G, or as: 6) quadruple mutant T3A/F42A/Y45A/L72G to inactivate the O-glycosylation site as well. The 4G8-based Fab-IL-2 wt-Fab served for comparison. All constructs contained the C145A mutation to avoid disulfide-bridged IL-2 dimers. The different Fab-IL-2 Fab constructs were expressed in HEK 293 cells and purified as described above via protein A and size exclusion chromatography as specified above. Subsequently, the affinity of the selected IL-2 variants for the human and murine IL-2R $\beta\gamma$ heterodimer and for the human and murine IL-2R α -subunit was determined by surface plasmon resonance (SPR) (Biacore) using recombinant IL-2R $\beta\gamma$ heterodimer and monomeric IL-2R α -subunit under the following conditions: The IL-2R α -subunit was immobilized in two densities and the flow cell with higher immobilization was used for the mutants that have lost CD25 binding. The following conditions were used: chemical immobilization: human IL-2R $\beta\gamma$ heterodimer 1675 RU; mouse IL-2R $\beta\gamma$ heterodimer 5094 RU; human IL-2R α -subunit 1019 RU; human IL-2R α -subunit 385 RU, murine IL-2R α -subunit 1182 RU; murine IL-2R α -subunit 378 RU, temperature: 25°C, analytes: 4G8 Fab-IL-2 variants-Fab constructs 3.1 nM to 200 nM, flow 40 μ l/min, association: 180 s, dissociation: 180 s, regeneration: 10 mM glycine pH 1.5, 60 s, 40 μ l/min. Fitting: two state reaction model (conformational change), RI=0 Rmax=local. Results of the kinetic analysis are given in Table 4.

TABLE 4. Affinity of FAP-targeted immunoconjugates comprising mutant IL-2 polypeptides to the intermediate affinity IL-2R and the IL-2R α -subunit (K_D).

Construct Fab-IL-2-Fab	Hu IL-2R $\beta\gamma$	Hu IL-2R α	Mu IL-2R $\beta\gamma$	Mu IL-2R α
4G8 IL-2 wt	3.8 nM	4.5 nM	45.6 nM	29 nM
4G8 IL-2 T3A	1.6 nM	4.9 nM	15.6 nM	15 nM
4G8 IL-2 F42A	4.7 nM	149 nM	57 nM	363 nM
4G8 IL-2 Y45A	3.9 nM	22.5 nM	41.8 nM	369 nM
4G8 IL-2 L72G	ND	45.3 nM	ND	ND
4G8 IL-2 triple mutant F42A/Y45A/L72G	5.6 nM	no binding	68.8 nM	ND
4G8 IL-2 quadruple mutant T3A/F42A/Y45A/L72G	5.2 nM	no binding	56.2 nM	no binding

Simultaneous binding to the IL-2R $\beta\gamma$ heterodimer and FAP was shown by SPR. Briefly, the human IL-2R $\beta\gamma$ knob-into-hole construct was immobilized on a CM5 chip chemically and 10

nM Fab-IL-2-Fab constructs were captured for 90 s. Human FAP served as analyte at concentrations of 200 nM down to 0.2 nM. Conditions were: temperature: 25°C, buffer: HBS-EP, flow: 30 µl/min, association: 90 s, dissociation: 120 s. Regeneration was done for 60 s with 10 mM glycine pH 2. Fitting was performed with a model for 1:1 binding, $RI \neq 0$, $R_{max} = \text{global}$.

- 5 The SPR bridging assay showed that the Fab-IL-2-Fab constructs, both as wild-type and as quadruple mutant, as well as based on the affinity matured FAP binder 28H1 or the parental 3F2 or 4G8 antibodies, was able to bind at a concentration of 10 nM simultaneously to the IL 2R $\beta\gamma$ heterodimer immobilized on the chip as well as to human FAP used as analyte (Figure 8). The determined affinities are shown in Table 5.

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TABLE 5. Affinity of FAP-targeted immunoconjugates, comprising mutant IL-2 polypeptides and bound to the intermediate affinity IL-2R, to FAP (K_D).

Construct Fab-IL-2-Fab	K_D
4G8 Fab-IL-2 wt-Fab	5.0 nM
4G8 Fab-IL-2 qm-Fab	5.6 nM
29B11 Fab-IL-2 wt-Fab	0.32 nM
29B11 Fab-IL-2 qm-Fab	0.89 nM
3F2 Fab-IL-2 wt-Fab	1.2 nM

- Taken together the SPR data showed that i) the T3A mutation does not influence binding to
 15 CD25, ii) the three mutations F42A, Y45A and L72G do not influence the affinity for the IL 2R $\beta\gamma$ heterodimer while they reduce the affinity for CD25 in this order: wt = T3A > Y45A (ca. 5x lower) > L72G (ca. 10x lower) > F42A (ca. 33x lower); iii) the combination of the three mutations F42A, Y45A and L72G with or without the O-glycosylation site mutant T3A results in a complete loss of CD25 binding as determined under SPR conditions, iv) although affinity of
 20 human IL-2 for murine IL-2R $\beta\gamma$ heterodimer and IL-2R α -subunit is reduced approximately by a factor of 10 compared to human IL-2 receptors the selected mutations do not influence affinity for the murine IL-2R $\beta\gamma$ heterodimer, but abolish binding to murine IL-2R α -subunit accordingly. This indicates that the mouse represents a valid model for the study of pharmacological and toxicological effects of IL-2 mutants, although overall IL-2 exhibits less toxicity in rodents than
 25 in humans.

Apart from the loss of O-glycosylation one additional advantage of the combination of the four mutations T3A, F42A, Y45A, L72G is a lower surface hydrophobicity of the IL-2 quadruple mutant due to the exchange of surface exposed hydrophobic residues such as phenylalanine, tyrosine or leucine by alanine. An analysis of the aggregation temperature by dynamic light scattering showed that the aggregation temperature for the FAP-targeted Fab-IL-2-Fab immunoconjugates comprising wild-type or quadruple mutant IL-2 were in the same range: ca. 57-58°C for the 3F2 parental Fab-IL-2-Fab and for the affinity matured 29B11 3F2-derivative; and in the range of 62-63°C for the 4G8 parental Fab-IL-2-Fab and the affinity matured 28H1, 4B9 and 14B3 4G8-derivatives, indicating that the combination of the four mutations had no negative impact on protein stability. In support of the favorable properties of the selected IL-2 quadruple mutant, transient expression yields indicated that the quadruple mutant in the Fab-IL-2 qm-Fab format may even result in higher expression yields than those observed for the respective Fab-IL-2 wt-Fab constructs. Finally, pharmacokinetic analysis shows that both 4G8-based Fab-IL-2 qm-Fab and Fab-IL-2 wt-Fab have comparable PK properties (see example 9 below). Based on these data and the cellular data described in example 4 below the quadruple mutant T3A, F42A, Y45A, L72G was selected as ideal combination of mutations to abolish CD25 binding of IL-2 in the targeted Fab-IL-2-Fab immunoconjugate.

Example 4

The 4G8-based FAP-targeted Fab-IL 2-Fab immunoconjugates, comprising wild-type IL-2 or the single mutants 4G8 IL-2 T3A, 4G8 IL-2 F42A, 4G8 IL-2 Y45A, 4G8 IL-2 L72G or the respective triple (F42A/Y45A/L72G) or quadruple mutant (T3A/F42A/Y45A/L72G) IL-2, were subsequently tested in cellular assays in comparison to Proleukin as described above.

IL-2 induced IFN- γ release was measured following incubation of the NK cell line NK92 with the constructs (Figure 9). NK92 cells express CD25 on their surface. The results show that the Fab-IL-2-Fab immunoconjugate comprising wild-type IL-2 was less potent in inducing IFN- γ release than Proleukin as could be expected from the ca. 10-fold lower affinity of the Fab-IL-2 wt-Fab for the IL-2R $\beta\gamma$ heterodimer. The introduction of single mutations interfering with CD25 binding as well as the combination of the three mutations interfering with CD25 binding in the IL-2 triple mutant resulted in Fab-IL-2-Fab constructs that were comparable to the wild-type IL-

2 construct in terms of potency and absolute induction of IFN- γ release within the error of the method.

TABLE 6. Induction of IFN- γ release from NK cells by Fab-IL-2-Fab immunoconjugates comprising mutant IL-2 polypeptides.

Construct	EC ₅₀ [nM]
Proleukin	4.1
4G8 Fab-IL 2 wt-Fab	23.0
4G8Fab-IL-2 (T3A)-Fab	16.2
4G8 Fab-IL-2 (F42A)-Fab	15.4
4G8 Fab-IL-2(Y45A)-Fab	20.9
4G8 Fab-IL-2 (L72G)-Fab	16.3
4G8 Fab-IL-2 (triple mutant 42/45/72)-Fab	24.4

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Subsequently, induction of proliferation of isolated human NK cells by Fab-IL-2-Fab immunoconjugates was assessed in a proliferation assay (Cell Titer Glo, Promega) (Figure 10). In contrast to NK92 cells, freshly isolated NK cells do not express CD25 (or only very low amounts). The results show that the Fab-IL-2-Fab immunoconjugate comprising wild-type IL-2 was ca. 10-fold less potent in inducing NK cell proliferation than Proleukin, as could be expected from the ca. 10-fold lower affinity of the Fab-IL-2 wt-Fab immunoconjugate for the IL-2R $\beta\gamma$ heterodimer. The introduction of single mutations interfering with CD25 binding as well as the combination of the three mutations interfering with CD25 in the IL-2 triple mutant resulted in Fab-IL-2-Fab constructs that were comparable to the wild-type IL-2 construct in terms of potency and absolute induction of proliferation; there was only a very small shift in potency observed for the Fab-IL-2-Fab triple mutant. In a second experiment the induction of proliferation of PHA-activated T cells was assessed following incubation with different amounts of Proleukin and Fab-IL-2-Fab immunoconjugates (Figure 11). As activated T cells express CD25, a clear reduction in T cell proliferation could be observed upon incubation with the immunoconjugates comprising IL-2 single mutants F42A, L72G or Y45A; with F42A showing the strongest reduction followed by L72G and Y45A, whereas when using Fab-IL-2 wt-Fab or Fab-IL-2 (T3A)-Fab the activation was almost retained compared to Proleukin. These data reflect the reduction in affinity for CD25 as determined by SPR (example above). The combination of the three mutations interfering with CD25 binding in the IL-2 triple mutant

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resulted in an immunoconjugate that mediated significantly reduced induction of T cell proliferation in solution. In line with these findings we measured cell death of T cells as determined by Annexin V/PI staining following over-stimulation induced by a first stimulation for 16 h with 1 µg/ml PHA, a second stimulation for 5 days with Proleukin or the respective Fab-IL-2-Fab immunoconjugates, followed by a third stimulation with 1 µg/ml PHA. In this setting we observed that activation induced cell death (AICD) in over-stimulated T cells was strongly reduced with the Fab-IL-2-Fab immunoconjugates comprising the IL-2 single mutants F42A, L72G and Y45A interfering with CD25 binding, with F42A and L72G showing the strongest reduction, which was similar to the reduction achieved by the combination of the three mutations in the immunoconjugate comprising the IL-2 triple mutant (Figure 12). In a last set of experiments we studied the effects of the Fab-IL-2 qm-Fab on the induction of STAT5 phosphorylation compared to Fab-IL-2 wt-Fab and Proleukin on human NK cells, CD4⁺ T cells, CD8⁺ T cells and T_{reg} cells from human PBMCs (Figure 13). For NK cells and CD8⁺ T cells that show no or very low CD25 expression (meaning that IL-2R signaling is mediated via the IL-2R βγ heterodimer) the results show that the Fab-IL-2-Fab format comprising wildtype IL-2 was ca. 10-fold less potent in inducing STAT5 phosphorylation than Proleukin, and that the Fab-IL-2 qm-Fab was comparable to the Fab-IL-2 wt-Fab construct. On CD4⁺ T cells, that show a rapid up-regulation of CD25 upon stimulation, the Fab-IL-2 qm-Fab was less potent than the Fab-IL-2 wt-Fab immunoconjugate, but still showed comparable induction of IL-2R signaling at saturating concentrations. This is in contrast to T_{reg} cells where the potency of the Fab-IL-2 qm-Fab was significantly reduced compared to the Fab-IL-2 wt-Fab immunoconjugate due to the high CD25 expression on T_{reg} cells and the subsequent high binding affinity of the Fab-IL-2 wt-Fab immunoconjugate to CD25 on T_{reg} cells. As a consequence of the abolishment of CD25 binding in the Fab-IL-2 qm-Fab immunoconjugate, IL-2 signaling in T_{reg} cells is only activated via the IL-2R βγ heterodimer at concentrations where IL-2R signaling is activated on CD25-negative effector cells through the IL-2R βγ heterodimer. Taken together the IL-2 quadruple mutant described here is able to activate IL-2R signaling through the IL-2R βγ heterodimer, but does neither result in AICD nor in a preferential stimulation of T_{reg} cells over other effector cells.

Example 5

Based on the data described in examples 2 and 3 affinity matured FAP-targeted Fab-IL-2 qm-Fab immunoconjugates based on clones 28H1 or 29B11 were generated and purified as

described above in the general methods section. In more detail, the FAP-targeted 28H1 targeted Fab-IL-2 qm-Fab was purified by one affinity step (protein G) followed by size exclusion chromatography (Superdex 200). Column equilibration was performed in PBS and supernatant from a stable CHO pool (CDCHO medium) was loaded onto a protein G column (GE Healthcare), the column was washed with PBS and samples were subsequently eluted with 2.5 mM HCl and fractions were immediately neutralized with 10x PBS. Size exclusion chromatography was performed in the final formulation buffer: 25 mM sodium phosphate, 125 mM sodium chloride, 100 mM glycine pH 6.7 on a Superdex 200 column. Figure 14 shows the elution profiles from the purification and the results from the analytical characterization of the product by SDS-PAGE (NuPAGE Novex Bis-Tris Mini Gel 4-20%, Invitrogen, MOPS running buffer, reduced and non-reduced). Given the low binding capacity of the 28H1 Fab fragment to protein G and protein A additional capture steps may result in higher yields.

FAP-targeted 4G8, 3F2 and 29B11 Fab-IL-2 qm-Fab and MCSP-targeted MHLG1 KV9 Fab-IL-2 qm-Fab immunoconjugates were purified by one affinity step (protein A) followed by size exclusion chromatography (Superdex 200). Column equilibration was performed in 20 mM sodium phosphate, 20 mM sodium citrate pH 7.5 and supernatant was loaded onto the protein A column. A first wash was performed in 20 mM sodium phosphate, 20 mM sodium citrate, pH 7.5 followed by a second wash: 13.3 mM sodium phosphate, 20 mM sodium citrate, 500 mM sodium chloride, pH 5.45. The Fab-IL-2 qm-Fab immunoconjugates were eluted in 20 mM sodium citrate, 100 mM sodium chloride, 100 mM glycine pH 3. Size exclusion chromatography was performed in the final formulation buffer: 25 mM potassium phosphate, 125 mM sodium chloride, 100 mM glycine pH 6.7. Figure 15 shows the elution profiles from the purification and the results from the analytical characterization of the product by SDS-PAGE (NuPAGE Novex Bis-Tris Mini Gel 4-20%, Invitrogen, MOPS running buffer, reduced and non-reduced) for the 4G8 Fab-IL-2 qm-Fab and Figure 16 for the MHLG1 KV9 Fab-IL-2 qm-Fab immunoconjugate.

FAP-targeted IgG-IL-2 qm fusion proteins based on the FAP-antibodies 4G8, 4B9 and 28H1, and a control DP47GS non-targeted IgG-IL-2 qm fusion protein were generated as described above in the general methods section. Figures 46 and 47 show the respective chromatograms and elution profiles of the purification (A, B) as well as the analytical SDS-PAGE and size exclusion chromatographies of the final purified constructs (C, D) for the 4G8- and 28H1-based constructs. Transient expression yields were 42 mg/L for the 4G8-based and 20 mg/L for the 28H1-based IgG-IL-2 qm immunoconjugate.

The FAP binding activity of the IgG-IL-2 qm immunoconjugates based on 4G8 and 28H1 anti-FAP antibodies were determined by surface plasmon resonance (SPR) on a Biacore machine in comparison to the corresponding unmodified IgG antibodies. Briefly, an anti-His antibody (Penta-His, Qiagen 34660) was immobilized on CM5 chips to capture 10 nM His-tagged human FAP (20 s). Temperature was 25°C and HBS-EP was used as buffer. Analyte concentration was 50 nM down to 0.05 nM at a flow rate of 50 µl/min (association: 300 s, dissociation: 900 s, regeneration: 60 s with 10 mM glycine pH 2). Fitting was performed based on a 1:1 binding model, RI=0, Rmax=local (because of capture format). Table 7 gives the estimated apparent bivalent affinities (pM avidity) as determined by SPR fitted with 1:1 binding RI=0, Rmax=local.

TABLE 7.

K_D [pM]	Hu FAP
4G8 IgG-IL-2 qm	100
4G8 IgG	50
28H1 IgG-IL-2 qm	175
28H1 IgG	200

The data show that within the error of the method affinity for human FAP is retained for the 28H1-based immunoconjugate or only slightly decreased for the 4G8-based immunoconjugate as compared to the corresponding unmodified antibodies.

Example 6

The affinity of the FAP-targeted, affinity matured 28H1 and 29B11-based Fab-IL-2-Fab immunoconjugates, each comprising wild-type or quadruple mutant IL-2, and of the 3F2-based Fab-IL-2 wt-Fab were determined by surface plasmon resonance (SPR) for the human, murine and cynomolgus IL-2R βγ heterodimer using recombinant IL-2R βγ heterodimer under the following conditions: ligand: human, murine and cynomolgus IL-2R β knob γ hole heterodimer immobilized on CM5 chip, analyte: 28H1 or 29B11 Fab-IL-2-Fab (comprising wild-type or quadruple mutant IL-2), 3F2 Fab-IL-2-Fab (comprising wild-type IL-2), temperature: 25°C or 37°C, buffer: HBS-EP, analyte concentration: 200 nM down to 2.5 nM, flow: 30 µl/min, association: 300 s, dissociation: 300 s, regeneration: 60 s 3M MgCl₂, fitting: 1:1 binding, RI≠0, Rmax=global. The affinity of the FAP-targeted affinity matured 28H1 and 29B11-based Fab-IL-

2-Fab immunoconjugate, each containing wildtype or quadruple mutant IL-2, and of the 3F2-based Fab-IL-2 wt-Fab were determined by surface plasmon resonance (SPR) for the human, murine and cynomolgus IL-2R α -subunit using recombinant monomeric IL-2R α -subunit under the following conditions: ligand: human, murine and cynomolgus IL-2R α -subunit immobilized on a CM5 chip, analyte: 28H1 or 29B11 Fab-IL-2-Fab (comprising wild-type or mutant IL-2), 3F2 Fab-IL-2-Fab (comprising wild-type IL-2), temperature: 25°C or 37°C, buffer: HBS-EP, analyte concentration 25 nM down to 0.3 nM, flow: 30 μ l/min, association: 120 s, dissociation: 600 s, regeneration: none, fitting: 1:1 binding, RI=0, Rmax=global.

Results of the kinetic analysis with the IL-2R $\beta\gamma$ heterodimer are given in Table 8.

TABLE 8. Binding of Fab-IL-2-Fab immunoconjugates comprising affinity matured Fab and mutant IL-2 to IL-2R $\beta\gamma$ heterodimers.

K_D in nM	Hu IL-2R $\beta\gamma$ (25°C)	Hu IL-2R $\beta\gamma$ (37°C)	Cyno IL-2R $\beta\gamma$ (25°C)	Cyno IL-2R $\beta\gamma$ (37°C)	Mu IL-2R $\beta\gamma$ (25°C)	Mu IL-2R $\beta\gamma$ (37°C)
28H1 Fab-IL-2 wt-Fab	9.7 9	19 22	11.5 11.6	29.2 30.4	112 79	186 219
28H1 Fab-IL-2 qm-Fab	7.5 6.9	14.3 14.7	8.9 8.4	21.3 21.2	66 54	142 106
29B11 Fab-IL-2 wt-Fab	6.5 5.7	9.5 12.4	6.9 6.7	14 19	93 74	71 74
29B11 Fab-IL-2 qm-Fab	7.2 7.4	13.1 13	7.8 8.4	16.7 18.1	60 63	44 42
3F2 Fab-IL-2 wt-Fab	5 4.8	ND	6.4 6.1	ND	40 40	ND

Whereas the affinity of human IL-2 to the human IL 2R $\beta\gamma$ heterodimer is described to be around 1 nM, the Fab-IL-2-Fab immunoconjugates (comprising wild-type or quadruple mutant IL-2) both have a reduced affinity between 6 and 10 nM, and as shown for the naked IL-2 above the affinity to the murine IL-2R is around 10 times weaker than for the human and cynomolgous IL-2R.

Results of the kinetic analysis with the IL-2R α -subunit are given in Table 9. Under the chosen conditions there is no binding detectable of the immunoconjugates comprising the IL-2 quadruple mutant to the human, murine or cyno IL-2R α -subunit.

TABLE 9. Binding of Fab-IL-2-Fab immunoconjugates comprising affinity matured Fab and mutant IL-2 to IL-2R α -subunits.

K_D in nM	Hu IL-2R α (25°C)	Hu IL-2R α (37°C)	Cyno IL-2R α (25°C)	Cyno IL-2R α (37°C)	Mu IL-2R α (25°C)	Mu IL-2R α (37°C)
28H1 Fab-IL-2 wt-Fab	16 16.2	28.8 28.2	16 16.2	36.5 35.6	43.3 44	67.5 61.1
28H1 Fab-IL-2 qm-Fab	no binding	no binding	no binding	no binding	no binding	no binding
29B11 Fab-IL-2 wt-Fab	5 4.6	7.6 7.7	4.8 4.3	7.3 7.4	11.4 9.6	13.3 13.8
29B11 Fab-IL-2 qm-Fab	no binding	no binding	no binding	no binding	no binding	no binding
3F2 Fab-IL-2 wt-Fab	5.7 6.1	ND	5 5.4	ND	12.3 12.1	ND

The affinity of the MCSP-targeted MHLG1-KV9 Fab-IL-2-Fab immunoconjugates, comprising the wild-type or quadruple mutant IL-2, were determined by surface plasmon resonance (SPR) for the human IL-2R $\beta\gamma$ heterodimer using recombinant IL-2R $\beta\gamma$ heterodimer under the following conditions: human IL-2R β knob γ hole heterodimer was immobilized on a CM5 chip (1600 RU). MHLG1-KV9 Fab-IL-2 wt-Fab and Fab-IL-2 qm-Fab were used as analyte at 25°C in HBS-P buffer. Analyte concentration was 300 nM down to 0.4 nM (1:3 dil.) for IL-2R $\beta\gamma$ at a flow of 30 μ l/min (association time 180 s, dissociation time 300 s). Regeneration was done for 2x30 s with 3M MgCl₂ for IL-2R $\beta\gamma$. Data were fitted using a 1:1 binding, RI $\neq$ 0, Rmax=local for IL-2R $\beta\gamma$.

The affinity of the MCSP-targeted MHLG1-KV9 Fab-IL-2-Fab immunoconjugates, comprising the wild-type or quadruple mutant IL-2, were determined by surface plasmon resonance (SPR) for the human IL-2R α -subunit using recombinant monomeric IL-2R α -subunit under the following conditions: human IL-2R α -subunit was immobilized on a CM5 chip (190 RU). MHLG1-KV9 Fab-IL-2 wt-Fab and Fab-IL-2 qm-Fab were used as analyte at 25°C in HBS-P buffer. Analyte concentration was 33.3 nM down to 0.4 nM (1:3 dil.) for IL-2R α at a flow of 30 μ l/min (association time 180 s, dissociation time 300 s). Regeneration was done for 10 s with 50 mM NaOH for IL-2R α . Data were fitted using a 1:1 binding, RI=0, Rmax=global for IL-2R α .

Results of the kinetic analysis with the IL-2R $\beta\gamma$ heterodimer are given in Table 10.

TABLE 10.

K_D in nM	Hu IL 2R $\beta\gamma$	Hu IL 2R α	Hu IL 2R α
T = 25°C	(kinetic)	(kinetic)	(steady state)
MHLG1-KV9 Fab-IL-2 wt-Fab	8.6	8.8	6.8

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	9.8	10.1	10.9
MHLG1-KV9 Fab-IL 2 qm-Fab	7.3 10.7	No binding	No binding

The data confirm that the MCSP-targeted MHLG1-KV9 Fab-IL-2 qm-Fab immunoconjugate has retained affinity for the IL-2R $\beta\gamma$ receptor, whereas binding affinity to CD25 is abolished compared to the immunoconjugate comprising wild-type IL-2.

- 5 Subsequently, the affinity of the 4G8- and 28H1-based IgG-IL-2 qm immunoconjugates to the IL-2R $\beta\gamma$ heterodimer and the IL-2R α -subunit were determined by surface plasmon resonance (SPR) in direct comparison to the Fab-IL-2 qm-Fab immunoconjugate format. Briefly, the ligands – either the human IL-2R α -subunit or the human IL-2R $\beta\gamma$ heterodimer – were immobilized on a CM5 chip. Subsequently, the 4G8- and 28H1-based IgG-IL-2 qm
- 10 immunoconjugates or the 4G8- and 28H1-based Fab-IL-2 qm-Fab immunoconjugates were applied to the chip as analytes at 25°C in HBS-EP buffer in concentrations ranging from 300 nM down to 1.2 nM (1:3 dil.). Flow rate was 30 μ l/min and the following conditions were applied for association: 180s, dissociation: 300 s, and regeneration: 2 x 30 s with 3 M MgCl_2 for IL-2R $\beta\gamma$ heterodimer, 10 s with 50 mM NaOH for IL-2R α -subunit. 1:1 binding was applied for fitting
- 15 (1:1 binding $\text{RI} \neq 0$, $\text{Rmax} = \text{local}$ for IL-2R $\beta\gamma$, apparent K_D , 1:1 binding $\text{RI} = 0$, $\text{Rmax} = \text{local}$ for IL-2R α). The respective K_D values are given in Table 11.

TABLE 11.

Apparent K_D [nM]	Hu IL-2R $\beta\gamma$	Hu IL-2R α
4G8 IgG-IL-2 qm	5.9	No binding
4G8 Fab-IL-2 qm-Fab	10.4	No binding
28H1 IgG-IL-2 qm	6.2	No binding
28H1 Fab-IL-2 qm-Fab	11.4	No binding

- The data show that the 4G8- and 28H1-based IgG-IL-2 qm immunoconjugates bind with at least
- 20 as good affinity as the Fab-IL-2 qm-Fab immunoconjugates to the IL-2R $\beta\gamma$ heterodimer, whereas they do not bind to the IL-2R α -subunit due to the introduction of the mutations interfering with CD25 binding. Compared to the corresponding Fab-IL-2 qm-Fab immunoconjugates the affinity of the IgG-IL-2 qm fusion proteins appears to be slightly enhanced within the error of the method.

Example 7

In a first set of experiments we confirmed that the FAP-targeted Fab-IL-2-Fab immunoconjugates comprising either wild-type or mutant IL-2 were able to bind to human FAP-expressing HEK 293-FAP cells by FACS (Figure 17) and that the IL-2 quadruple mutation did not impact binding to FAP-expressing cells (Figure 18).

TABLE 12. Binding of Fab-IL-2-Fab immunoconjugates to FAP-expressing HEK cells.

EC₅₀ values	nM
28H1 Fab-IL-2-Fab	0.64
28H1 Fab-IL-2 qm-Fab	0.70
29B11 Fab-IL-2-Fab	0.66
29B11 Fab-IL-2 qm-Fab	0.85
4G8 Fab-IL-2-Fab	0.65

In particular, these binding experiments showed that the affinity matured FAP binders 28H1, 29B11, 14B3 and 4B9 as Fab-IL-2 qm-Fab showed superior absolute binding to the HEK 293-FAP target cells compared to the Fab-IL-2-Fab immunoconjugates based on the parental FAP binders 3F2 (29B11, 14B3, 4B9) and 4G8 (28H1) (Figure 17), while retaining high specificity and no binding to HEK 293 cells transfected with DPPIV, a close homologue of FAP, or HEK 293 mock-transfected cells. For comparison the mouse anti-human CD26-PE DPPIV antibody clone M-A261 (BD Biosciences, #555437) was used as a positive control (Figure 19). Analysis of the internalization properties showed that the binding of Fab-IL-2-Fab immunoconjugates do not result in the induction of FAP internalization (Figure 20).

In a further experiment, binding of FAP-targeted 4G8-based IgG-IL-2 qm and Fab-IL-2 qm-Fab immunoconjugates to human FAP expressed on stably transfected HEK293 cells was measured by FACS. The results are shown in Figure 48. The data show that the IgG-IL-2 qm immunoconjugate binds to FAP-expressing cells with an EC₅₀ value of 0.9 nM, comparable to that of the corresponding 4G8-based Fab-IL-2 qm-Fab construct (0.7 nM).

The affinity matured anti-FAP Fab-IL-2-Fab immunoconjugates comprising wildtype IL-2 or the quadruple mutant were subsequently tested in cellular assays in comparison to Proleukin as described in the examples above.

IL-2 induced IFN- γ release was measured in the supernatant by ELISA following incubation of the NK cell line NK92 with these immunoconjugates (Figure 21) for 24 h. NK92 cells express CD25 on their surface. The results show that the Fab-IL-2-Fab immunoconjugate comprising wild-type IL-2 was less potent in inducing IFN- γ release than Proleukin as could be expected from the ca. 10-fold lower affinity of the Fab-IL-2 wt-Fab immunoconjugate for the IL-2R $\beta\gamma$ heterodimer. The Fab-IL-2 qm-Fab immunoconjugates were quite comparable to the respective wild-type construct for a selected clone in terms of potency and absolute induction of IFN- γ release despite the fact that NK92 cells express some CD25. It could, however, be observed that the 29B11 Fab-IL-2 qm-Fab induced less cytokine release compared to the 29B11 Fab-IL-2 wt-Fab as well as the 28H1 and 4G8 constructs, for which there was only a small shift in potency observed for Fab-IL-2 qm-Fab over Fab-IL-2 wt-Fab.

In addition, the MCSP-targeted MHLG1-KV9-based Fab-IL-2 qm-Fab immunoconjugate was compared to the 28H1 and 29B11 based Fab-IL-2 qm-Fab immunoconjugates in the IFN- γ release assay on NK92 cells. Figure 22 shows that the MCSP-targeted MHLG1-KV9-based Fab-IL-2 qm-Fab is quite comparable in inducing IFN- γ release to the FAP-targeted Fab-IL-2 qm-Fab immunoconjugates.

Subsequently, induction of proliferation of NK92 cells by IL-2 over a period of 3 days was assessed in a proliferation assay by ATP measurement using CellTiter Glo (Promega) (Figure 23). Given that NK92 cells express low amounts of CD25, a difference between Fab-IL-2-Fab immunoconjugates comprising wild-type IL-2 and immunoconjugates comprising quadruple mutant IL-2 could be detected in the proliferation assay, however, under saturating conditions both achieved similar absolute induction of proliferation.

In a further experiment we studied the effects of the 28H1 affinity matured FAP-directed Fab-IL-2 qm-Fab immunoconjugate on induction of STAT5 phosphorylation compared to 28H1 Fab-IL-2 wt-Fab and Proleukin on human NK cells, CD4⁺ T cells, CD8⁺ T cells and T_{reg} cells from human PBMCs (Figure 24). For NK cells and CD8⁺ T cells, that show no or very low CD25 expression (meaning that IL-2R signaling is mediated via the IL-2R $\beta\gamma$ heterodimer), the results showed that the Fab-IL-2-Fab immunoconjugate comprising wild-type IL-2 was ca. >10-fold less potent in inducing IFN- γ release than Proleukin, and that the Fab-IL-2 qm-Fab immunoconjugate was only very slightly less potent than the Fab-IL-2 wt-Fab construct. On CD4⁺ T cells that show a rapid up-regulation of CD25 upon stimulation, the Fab-IL-2 qm-Fab was significantly less potent than the Fab-IL-2 wt-Fab immunoconjugate, but still showed

comparable induction of IL-2R signaling at saturating concentrations. This is in contrast to T_{reg} cells, where the potency of the Fab-IL-2 qm-Fab was significantly reduced compared to the Fab-IL-2 wt-Fab construct due to the high CD25 expression on T_{reg} cells and the subsequent high binding affinity of the Fab-IL-2 wt-Fab construct to CD25 on T_{reg} cells. As a consequence of the abolishment of CD25 binding in the Fab-IL-2 qm-Fab immunoconjugate, IL-2 signaling in T_{reg} cells is only activated via the IL-2R $\beta\gamma$ heterodimer at concentrations where IL-2R signaling is activated on CD25 negative effector cells through the IL-2R $\beta\gamma$ heterodimer. The respective pM EC₅₀ values are given in Table 13.

TABLE 13. Induction of IFN- γ release from NK cells by 28H1 FAP-targeted Fab-IL-2-Fab immunoconjugates comprising mutant IL-2 polypeptides.

EC ₅₀ [pM]	NK cells	CD8 ⁺ T cells	CD4 ⁺ T cells	T _{reg} cells
Proleukin	222	1071	92	1
28H1 Fab-IL-2 wt-Fab	3319	14458	3626	15
28H1 Fab-IL-2 qm-Fab	3474	20583	70712	19719

In another set of experiments, the biological activity of FAP-targeted 4G8-based IgG-IL-2 qm and Fab-IL-2 qm-Fab immunoconjugates was investigated in several cellular assays.

FAP-targeted 4G8-based IgG-IL-2 qm and 28H1-based Fab-IL-2 qm-Fab immunoconjugates were studied for the induction of IFN- γ release by NK92 cells as induced by activation of IL-2R $\beta\gamma$ signaling. Figure 49 shows that the FAP-targeted 4G8-based IgG-IL-2 qm immunoconjugate was equally efficacious in inducing IFN- γ release as the affinity matured 28H1-based Fab-IL-2 qm-Fab immunoconjugate.

We also studied the effects of the FAP-targeted 4G8-based IgG-IL-2 qm immunoconjugate on the induction of STAT5 phosphorylation compared to the 28H1 based Fab-IL-2 wt-Fab and Fab-IL-2 qm-Fab immunoconjugates as well as Proleukin on human NK cells, CD4⁺ T cells, CD8⁺ T cells and T_{reg} cells from human PBMCs. The results of these experiments are shown in Figure 50. For NK cells and CD8⁺ T cells the 4G8-based IgG-IL-2 qm immunoconjugate was <10-fold less potent in inducing STAT5 phosphorylation than Proleukin, but slightly more potent than 28H1-based Fab-IL-2 wt-Fab and Fab-IL-2 qm-Fab immunoconjugates. On CD4⁺ T cells the 4G8-based IgG-IL-2 qm immunoconjugate was less potent than the 28H1 Fab-IL-2 wt-Fab immunoconjugate, but slightly more potent than the 28H1 Fab-IL-2 qm-Fab immunoconjugate,

and still showed induction of IL-2R signaling at saturating concentrations comparable to Proleukin and 28H1 Fab-IL-2 wt-Fab. This is in contrast to T_{reg} cells where the potency of the 4G8-based IgG-IL-2 qm and 28H1 Fab-IL-2 qm-Fab immunoconjugates was significantly reduced compared to the Fab-IL-2 wt-Fab immunoconjugate.

- 5 Taken together the IL-2 quadruple mutant described here is able to activate IL-2R signaling through the IL-2R $\beta\gamma$ heterodimer similar to wild-type IL-2, but does not result in a preferential stimulation of T_{reg} cells over other effector cells.

Example 8

- 10 The anti-tumoral effects of FAP-targeted Fab-IL-2 qm-Fab immunoconjugates were evaluated in vivo in comparison to FAP-targeted Fab-IL-2 wt-Fab immunoconjugates in ACHN xenograft and LLC1 syngeneic models. All FAP-targeted Fab-IL-2-Fab immunoconjugates (comprising wild-type or quadruple mutant IL-2) recognize murine FAP as well as the murine IL-2R. While the ACHN xenograft model in SCID-human Fc γ RIII transgenic mice is strongly positive for
15 FAP in IHC, it is an immunocompromised model and can only reflect immune effector mechanisms mediated by NK cells and/or macrophages/monocytes, but lacks T cell mediated immunity and thus cannot reflect AICD or effects mediated through T_{reg} cells. The syngeneic LLC1 model in contrast in fully immunocompetent mice can reflect adaptive T cell mediated immune effector mechanisms as well, but shows fairly low expression of FAP in the murine
20 stroma. Each of these models thus partially reflects the situation as encountered in human tumors.

ACHN Renal Cell Carcinoma Xenograft Model

- The FAP-targeted 4G8 Fab-IL-2 wt-Fab and 4G8 Fab-IL-2 qm-Fab immunoconjugates were tested using the human renal cell adenocarcinoma cell line ACHN, intra-renally injected into
25 SCID-human Fc γ RIII transgenic mice. ACHN cells were originally obtained from ATCC (American Type Culture Collection) and after expansion deposited in the Glycart internal cell bank. ACHN cells were cultured in DMEM containing 10% FCS, at 37°C in a water-saturated atmosphere at 5% CO₂. *In vitro* passage 18 was used for intrarenal injection, at a viability of 98.4%. A small incision (2 cm) was made at the right flank and peritoneal wall of anesthetized
30 SCID mice. Fifty μ l cell suspension (1x10⁶ ACHN cells in AimV medium) was injected 2 mm

subcapsularly in the kidney. Skin wounds and peritoneal wall were closed using clamps. Female SCID-FcγRIII mice (GLYCART-RCC), aged 8-9 weeks at the beginning of the experiment (bred at RCC, Switzerland) were maintained under specific-pathogen-free conditions with daily cycles of 12 h light / 12 h darkness according to committed guidelines (GV-Solas; Felasa; TierschG).

- 5 The experimental study protocol was reviewed and approved by local government (P 2008016). After arrival, animals were maintained for one week to get accustomed to new environment and for observation. Continuous health monitoring was carried out on a regular basis. Mice were injected intrarenally on study day 0 with 1×10^6 ACHN cells, randomized and weighed. One week after the tumor cell injection, mice were injected i.v. with 4G8 Fab-IL-2 wt-Fab and 4G8
10 Fab-IL-2 qm-Fab three times a week for three weeks. All mice were injected i.v. with 200 µl of the appropriate solution. The mice in the vehicle group were injected with PBS and the treatment groups with 4G8 Fab-IL-2 wt-Fab or 4G8 Fab-IL-2 qm-Fab immunoconjugate. To obtain the proper amount of immunoconjugate per 200 µl, the stock solutions were diluted with PBS when
15 immunoconjugates mediated superior efficacy in terms of enhanced median survival compared to vehicle group with an advantage for the 4G8 Fab-IL-2 wt-Fab over the 4G8 Fab-IL-2 qm-Fab immunoconjugate in terms of efficacy.

TABLE 14-A.

Compound	Dose	Formulation buffer	Concentration (mg/mL)
4G8 Fab-IL-2-Fab wild type= FAP 4G8 wt	20 µg	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	1.45
4G8 Fab-IL-2-Fab quadruple mutant= FAP 4G8 qm	20 µg	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	4.25

20 LLC1 Lewis Lung Carcinoma Syngeneic Model

- The FAP-targeted 4G8 Fab-IL-2 qm-Fab and 28H1 Fab-IL-2 qm-Fab immunoconjugates were tested using the mouse Lewis lung carcinoma cell line LLC1, i.v. injected into Black 6 mice. The LLC1 Lewis lung carcinoma cells were originally obtained from ATCC and after expansion deposited in the Glycart internal cell bank. The tumor cell line was routinely cultured in DMEM
25 containing 10 % FCS (Gibco) at 37°C in a water-saturated atmosphere at 5% CO₂. Passage 10 was used for transplantation, at a viability of 97.9%. 2×10^5 cells per animal were injected i.v.

into the tail vein in 200 μ l of Aim V cell culture medium (Gibco). Black 6 mice (Charles River, Germany), aged 8-9 weeks at the start of the experiment, were maintained under specific-pathogen-free conditions with daily cycles of 12 h light / 12 h darkness according to committed guidelines (GV-Solas; Felasa; TierschG). The experimental study protocol was reviewed and approved by local government (P 2008016). After arrival, animals were maintained for one week to get accustomed to the new environment and for observation. Continuous health monitoring was carried out on a regular basis. Mice were injected i.v. on study day 0 with 2×10^5 of LLC1 cells, randomized and weighed. One week after the tumor cell injection, mice were injected i.v. with 4G8 Fab-IL-2 qm-Fab or 28H1 Fab-IL-2 qm-Fab, three times a week for three weeks. All mice were injected i.v. with 200 μ l of the appropriate solution. The mice in the vehicle group were injected with PBS and the treatment group with the 4G8 Fab-IL-2 qm-Fab or 28H1 Fab-IL-2 qm-Fab constructs. To obtain the proper amount of immunoconjugate per 200 μ l, the stock solutions were diluted with PBS when necessary. Figure 26 shows that the 4G8 Fab-IL-2 qm-Fab or the affinity matured 28H1 Fab-IL-2 qm-Fab constructs mediated superior efficacy in terms of enhanced median survival compared to the vehicle group.

TABLE 14-B.

Compound	Dose	Formulation buffer	Concentration (mg/mL)
28H1 Fab-IL-2-Fab quadruple mutant= FAP 28H1 qm	30 μ g	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	2.74
4G8 Fab-IL-2-Fab quadruple mutant= FAP 4G8 qm	30 μ g	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	4.25

In another experiment, the FAP-targeted 28H1 Fab-IL-2 wt-Fab and 28H1 Fab-IL-2 qm-Fab immunoconjugates were tested in the same mouse Lewis lung carcinoma cell line LLC1, i.v. injected into Black 6 mice. Passage 9 was used for transplantation, at a viability of 94.5%. 2×10^5 cells per animal were injected i.v. into the tail vein in 200 μ l of Aim V cell culture medium (Gibco). Mice were injected i.v. on study day 0 with 2×10^5 of LLC1 cells, randomized and weighed. One week after the tumor cell injection, mice were injected i.v. with 28H1 Fab-IL-2 wt-Fab or 28H1 Fab-IL-2 qm-Fab, three times a week for three weeks. All mice were injected i.v. with 200 μ l of the appropriate solution. The mice in the vehicle group were injected with

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PBS and the treatment group with the 28H1 Fab-IL-2 wt-Fab or 28H1 Fab-IL-2 qm-Fab constructs. To obtain the proper amount of immunoconjugate per 200 μ l, the stock solutions were diluted with PBS when necessary. Figure 27 shows that the 28H1 Fab-IL-2 wt-Fab and 28H1 Fab-IL-2 qm-Fab immunoconjugates mediated superior efficacy in terms of enhanced median survival compared to the vehicle group with a slight advantage for the 28H1 Fab-IL-2 wt-Fab over the 28H1 Fab-IL-2 qm-Fab immunoconjugate in terms of efficacy.

TABLE 14-C.

Compound	Dose	Formulation buffer	Concentration (mg/mL)
28H1 Fab-IL-2-Fab quadruple mutant= FAP 28H1 qm	45 μ g	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	2.74
28H1 Fab-IL-2-Fab wild-type= FAP 28H1 wt	45 μ g	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	1.66

Example 9

- 10 The 4G8 based FAP-targeted Fab-IL-2 qm-Fab was subsequently compared to the 4G8 based FAP-targeted Fab-IL-2 wt-Fab immunoconjugate in a seven-day intravenous toxicity and toxicokinetic study in Black 6 mice. Table 15 shows the study design of the toxicity and toxicokinetic studies.

TABLE 15. Study design.

Group	Type	Dose [μ g/g]	Purpose
1	DPBS	0	Control
2	4G8 Fab-IL-2 wt-Fab	4.5	Toxicity titration
3		9.0	
4		4.5	
5	4G8 Fab-IL-2 qm-Fab	9.0	
6	4G8 Fab-IL-2 wt-Fab	4.5	Toxicokinetic study
7		9.0	
8	4G8 Fab-IL-2 qm-Fab	4.5	
9		9.0	

15

The purpose of this study was to characterize and compare the toxicity and toxicokinetic profiles of FAP-targeted 4G8 Fab-IL2-Fab wild type (wt) interleukin-2 (IL-2) and FAP-targeted G48

Fab-IL-2-Fab quadruple mutant IL-2 (qm) after once daily intravenous administration to non-tumor-bearing male mice for 7 days. For this study, 5 groups of 5 male mice/group were administered intravenously 0 (vehicle control), 4.5 or 9 $\mu\text{g/g/day}$ wt IL-2, or 4.5 or 9 $\mu\text{g/g/day}$ qm IL-2. An additional 4 groups of 6 male mice/group were administered 4.5 or 9 $\mu\text{g/g/day}$ wt IL-2, or 4.5 or 9 $\mu\text{g/g/day}$ qm IL-2 in order to assess toxicokinetics. The study duration was changed from 7 days to 5 days due to clinical signs observed in animals given 4.5 and 9 $\mu\text{g/g/day}$ wt IL-2. Assessment of toxicity was based upon mortality, in-life observations, body weight, and clinical and anatomic pathology. Blood was collected at various time points from animals in the toxicokinetic groups for toxicokinetic analysis. The toxicokinetic data showed that the mice treated with wt IL-2 or qm IL-2 had measurable plasma levels up to the last bleeding time, indicating that the mice were exposed to the respective compounds throughout the duration of treatment. Day 1 AUC_{0-inf} values suggest comparable exposure of wt IL-2 and qm IL-2 at both dose levels. Sparse samples were taken on Day 5 and showed equivalent plasma concentrations to Day 1, suggesting no accumulation occurred after 5 days of dosing either compound. In more details the following findings were observed.

Toxicokinetics

Table 16 summarizes the mean plasma toxicokinetic parameters for the FAP-targeted 4G8 Fab-IL-2 qm-Fab and the FAP-targeted 4G8 Fab-IL-2 wt-Fab as determined by WinNonLin Version 5.2.1 and a commercial kappa-specific ELISA (Human Kappa ELISA Quantitation Set, Bethyl Laboratories).

TABLE 16.

Parameter	Units	Group 6 4G8-FAP-Wild Type IL-2	Group 7 4G8-FAP-Wild Type IL-2	Group 8 4G8-FAP- Mutant IL-2	Group 9 4G8-FAP- Mutant IL-2
C _{max}	ng/ml	47198	97986	60639	146416
C _{max} /Dose	(ng/ml)/($\mu\text{g/g}$)	0.011	0.011	0.0135	0.016
AUC	ng*h/ml	331747	747449	355030	926683
AUC/Dose	(ng*h/ml)/($\mu\text{g/g}$)	0.074	0.083	0.079	0.103
T _{1/2z}	h	3.6	3.11	4.3	3.12
Original Dose	$\mu\text{g/g}$	4.5	9	4.5	9
Route		IV	IV	IV	IV

*TK Parameters were calculated in WinNonlin Version 5.2.1 using noncompartmental analysis

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The individual serum concentrations are given in the following:

Group (dose)	Bleed Day	Time (h)	Animal	Serum conc. (ng/ml)	Mean conc (ng/ml)
Group 6 (4.5 µg/g) 4G8 Fab-IL2-Fab WT	1	1	26	64241	47198
			27	30155	
	1	5.5	28	14693	15784
			29	16875	
	1	24	30	318	419
			31	520	
	5	5.5	29	13061	13335
			30	13620	
			31	13325	
Group 7 (9 µg/g) 4G8 Fab-IL2-Fab WT	1	1	32	101208	97986
			33	94764	
	1	5.5	34	35766	34062
			35	32359	
	1	24	36	573	580
			37	588	
	5	5.5	32	31779	37473
			33	51143	
			35	53409	
Group 8 (4.5 µg/g) 4G8 Fab-IL2-Fab Mutant	1	1	38	73326	60639
			39	47953	
	1	5.5	40	12168	13269
			41	14371	
	1	24	42	494	490
			43	487	
	5	5.5	40	6561	10957
			41	15352	
	5	24	38	608	721
			39	543	
			42	1298	
			43	437	
Group 9 (9 µg/g) 4G8 Fab-IL2-Fab Mutant	1	1	44	162970	146416
			45	129862	
	1	5.5	46	20475	24800
			47	29125	
	1	24	48	478	493
			49	509	
	5	5.5	46	20504	48031
			47	75557	
	5	24	44	634	703
			45	796	
			48	661	
			49	719	

These data show that both, the 4G8 Fab-IL-2 qm-Fab and the 4G8 Fab-IL-2 wt-Fab show comparable pharmacokinetic properties with slightly higher exposure for the 4G8 Fab-IL-2 qm-Fab.

Mortality

In the 9 µg/g FAP-targeted 4G8 Fab-IL-2 wt-Fab group, treatment-related mortality occurred in one animal prior to necropsy on Day 5. Hypoactivity, cold skin, and hunched posture were noted prior to death. This animal likely died due to a combination of cellular infiltration in the lung that was accompanied with edema and hemorrhage and marked bone marrow necrosis. Mortality is summarized in Table 17.

TABLE 17. Mortality day 5.

Group	Type	Dose [µg/g]	Found dead	Severe toxicity Sacrifice**	Total
1	DPBS	0	0/5	0/5	0/5
2	4G8 Fab-IL-2 wt-	4.5	0/5	5/5	5/5
3	Fab	9	1/5*	4/5	4/5
4	4G8 Fab-IL-2 qm-	4.5	0/5	0/5	0/5
5	Fab	9	0/5	0/5	0/5
6	4G8 Fab-IL-2 wt-Fab	4.5	1/6	5/6	6/6
7		9	2/6	4/6	6/6
8	4G8 Fab-IL-2 qm-Fab	4.5	0/6	0/6	0/6
9		9	0/6	0/6	0/6

* in route to necropsy

** study was planned for seven days but all mice treated with the wild-type IL-2 immunoconjugate were markedly affected by Day 5 and were sacrificed as they were not expected to survive.

Clinical Observations

Observations of hypoactivity, cold skin, and hunched posture were noted in animals given 4.5 and 9 µg/g/day wt IL-2. Clinical observations are summarized in Table 18.

TABLE 18. Clinical observations day 5.

Group	Type	Dose [µg/g]	Hunched posture	Hypoactive	Cool to touch
1	DPBS	0	0/5	0/5	0/5
2	4G8 Fab-IL-2 wt-	4.5	4/5	4/5	5/5
3	Fab	9	5/5	5/5	5/5
4	4G8 Fab-IL-2 qm-	4.5	0/5	0/5	0/5
5	Fab	9	0/5	0/5	0/5
6	4G8 Fab-IL-2 wt-Fab	4.5	6/6	2/6	2/6
7		9	6/6	5/6	6/6

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8	4G8 Fab-IL-2 qm-Fab	4.5	0/6	0/6	0/6
9		9	0/6	0/6	0/6

Body Weight

A moderate decrease in body weight was observed after 5 days of treatment in animals given 4.5 and 9 (9% and 11%, respectively) $\mu\text{g/g/day}$ wt IL-2. A slight decrease in body weight was observed after 5 days of treatment in animals given 4.5 or 9 (2% and 1%, respectively) $\mu\text{g/g/day}$ qm IL-2. A moderate (9%) decrease in body weight was also observed in vehicle controls after 5 days of treatment. However, the percent decrease would have been 5% if a potential outlier (Animal #3) was excluded. The body weight loss in the vehicle group may have been attributed to stress.

10 Hematology

A reduced platelet count was observed in animals given 4.5 (~4.5 fold) and 9 $\mu\text{g/g/day}$ (~11 fold) 4G8 Fab-IL-2 wt-Fab, which correlated with reduced megakaryocytes in the bone marrow as well as systemic consumptive effects (fibrin) in spleen and lung of these animals (see Histopathology section below) These findings indicated that reduced platelets were likely due to combined effects of consumption and decrease in production/bone marrow crowding due to increase in lymphocyte / myeloid cell production as a direct or indirect effect of IL-2.

Hematologic findings of uncertain relationship to compound administration consisted of absolute lymphocyte count decreases with 4G8 Fab-IL-2 wt-Fab at 4.5 (~5-fold) and 9 $\mu\text{g/g}$ (~3-fold) compared to the mean value of the vehicle control group. These findings lacked clear dose-dependency, but could be considered secondary to effects associated with stress noted in in-life observations or exaggerated pharmacology of the compound (lymphocytes migrating into tissues). There were no treatment-related hematological changes attributed to the administration of 4G8 Fab-IL-2 qm-Fab. A few isolated hematologic findings were statistically different from their respective controls. However, these findings were of insufficient magnitude to suggest pathological relevance.

Gross Pathology and Histopathology

Treatment-related gross findings included enlarged spleen found in 5/5 and 4/5 mice of 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab groups, respectively, and in 1/5 in both 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 qm-Fab treatment groups.

Treatment-related histopathology findings were present in groups given 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab and 4.5 and 9 µg/g 4G8 Fab-IL-2 qm-Fab in lung, bone marrow, liver, spleen, and thymus, with differences in incidence, severity grading or nature of the changes, as reported below.

- 5 Treatment-related histopathology findings in the lung consisted of mononuclear infiltration found mild to marked in 5/5 mice of the 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups and marginally in 5/5 mice of the 4.5 and 9 µg/g 4G8 Fab-IL-2 qm-Fab groups. Mononuclear infiltration consisted of lymphocytes (some of which were noted as having cytoplasmic granules) as well as reactive macrophages. These cells were most often noted to have vasocentric patterns, often with margination noted within the vessels in the lung. These cells were also noted surrounding the vessels, but in more severe cases, the pattern was more diffuse. Hemorrhage was seen marginal to mild in 5/5 mice of the 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups and marginally in 2/5 mice in the 9 µg/g 4G8 Fab-IL-2 qm-Fab group. Though the hemorrhage was most often noted perivascularly, in more severe cases, it was noted in alveolar spaces. Edema was noted mild to moderate in 5/5 mice in the 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups and marginally in 5/5 mice in the 9 µg/g 4G8 Fab-IL-2 qm-Fab group. Though the edema was frequently seen perivascularly, in more severe cases, it was noted in alveolar spaces as well. Marginal cellular degeneration and karyorrhexis was noted in 2/5 and 5/5 mice in the 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups, respectively and consisted of degeneration of infiltrative or reactive leukocytes. Selected animals with MSB stains were positive for fibrin found within the lungs of animals in both 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups which correlates in part with the reduced platelets noted in these animals.

- Treatment-related changes in the bone marrow included marginal to mild increased overall marrow cellularity in 5/5 mice and 2/5 mice of both 4.5 and 5/5 mice and 2/5 mice of both 9 µg/g 4G8 Fab-IL-2 wt-Fab and 4G8 Fab-IL-2 qm-Fab groups, respectively. This was characterized by increased marginal to moderate lymphocyte-myelocyte hyperplasia in these groups that was supported, in part, by increased numbers of CD3 positive T cells within the marrow and sinuses (specifically T-lymphocytes, confirmed by immunohistochemistry with the pan-T-cell marker CD3 done on selected animals). CD3 positive T cell increase was moderate in both 4G8 Fab-IL-2 wt-Fab groups and marginal to mild in both 4G8 Fab-IL-2 qm-Fab groups. Marginal to mild decreases in megakaryocytes were observed in 2/5 mice in the 4.5 and 5/5 mice in the 9 µg/g 4G8 Fab-IL-2 wt-Fab groups and marginal to moderate decreases in erythroid precursors were

noted in 3/5 mice in the 4.5 and 5/5 mice in the 9 µg/g 4G8 Fab-IL-2 wt-Fab groups. Bone marrow necrosis was noted in 1/5 mice in 4.5 (minimal) and 5/5 mice in 9 (mild to marked) µg/g 4G8 Fab-IL-2 wt-Fab groups. The reduced number of megakaryocytes in the bone marrow correlated with decreased platelets which could be due to direct crowding of the bone marrow by increased lymphocytes/myeloid precursors and/or the bone marrow necrosis, and/or consumption of platelets due to inflammation in various tissues (see spleen and lung). The decreased erythroid precursors noted in the bone marrow, did not correlate with the peripheral blood hematology findings likely due to temporal effects (seen in bone marrow before peripheral blood) and the longer half-life of peripheral erythrocytes (compared to platelets). The mechanism of bone marrow necrosis in the bone marrow may be secondary due to overt overcrowding of the marrow cavity (due to production and growth of lymphocytes / myeloid cells), systemic or local release of cytokines from the proliferating cell types, possibly related to local affects of hypoxia or other pharmacologic effects of the compound.

Treatment-related findings in the liver consisted of mild to moderate primarily vasocentric mononuclear cell infiltrate and marginal to mild single cell necrosis in 5/5 mice of the 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups. Marginal single cell necrosis was seen in 2/5 and 4/5 mice in the 4.5 and 9 µg/g 4G8 Fab-IL-2 qm-Fab groups, respectively. The mononuclear infiltrate consisted primarily of lymphocytes (specifically T-lymphocytes, confirmed by immunohistochemistry with the pan-T cell marker CD3 done on selected animals) that were most often noted vasocentrically as well as marginating within the central and portal vessels. Selected animals for immunohistochemistry staining for F4/80 showed increased numbers and size (activated) of macrophages/Kupffer cells throughout the hepatic sinusoids in 9 µg/g 4G8 Fab-IL-2 wt-Fab and 4G8 Fab-IL-2 qm-Fab groups.

Treatment-related findings in the spleen consisted of moderate to marked lymphoid hyperplasia/infiltration and mild to moderate macrophage hyperplasia/infiltration in 5/5 mice in 4.5 and 9 µg/g 4G8 Fab-IL-2 wt-Fab groups and mild to moderate lymphoid hyperplasia/infiltration with marginal to mild macrophage hyperplasia/infiltration in 5/5 mice in 4.5 and 9 µg/g 4G8 Fab-IL-2 qm-Fab groups. Immunohistochemistry for 9 µg/g 4G8 Fab-IL-2 wt-Fab and 4G8 Fab-IL-2 qm-Fab showed different patterns using the pan-T cell marker CD3, as well as the macrophage marker F4/80. For 9 µg/g 4G8 Fab-IL-2 wt-Fab, the pattern of T-cell and macrophage immunoreactivity remained primarily within the red pulp areas, as the architecture of the primary follicles had been altered by lymphocytolysis and necrosis (described below). For

- 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 qm-Fab, special stains showed a pattern similar to that of the vehicle control, but with periarteriolar lymphoid sheath (PALS) white pulp expansion, by a T-cell population and a larger, expanded red pulp area. T-cell and macrophage positivity was also evident within the red pulp, with a similar pattern to the vehicle control group, but expanded.
- 5 These findings correlate with the gross findings of enlarged spleen. Necrosis was noted marginally in 3/5 mice and marginally to mildly in 5/5 mice in 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab groups, respectively. Necrosis was usually located around the area of the primary follicles and selected animals using MSB stain were positive for fibrin in both 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab groups which correlates in part with the reduced platelets noted in these animals.
- 10 Lymphocytolysis was seen in the 4.5 $\mu\text{g/g}$ (minimal to mild) and 9 $\mu\text{g/g}$ (moderate to marked) 4G8 Fab-IL-2 wt-Fab groups.

Treatment-related findings in the thymus included minimal to mild increases in lymphocytes in both 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab and in 4.5 $\mu\text{g/g}$ 4G8 Fab-IL-2 qm-Fab groups. The cortex and medulla were not individually evident, in 4G8 Fab-IL-2 wt-Fab groups, but

15 immunohistochemistry for the pan T cell marker (CD3) on selected animals in 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 qm-Fab groups showed strong positivity for the majority of the cells within the thymus. Increased lymphocytes in the thymus was considered to be a direct pharmacologic effect of both compounds where IL-2 induced proliferation of lymphocytes migrating to the thymus (T cells) from the bone marrow for further differentiation and clonal

20 expansion. This occurred in all groups except 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 qm-Fab, which is likely a temporal effect. Lymphocytolysis was mild in 4.5 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab group, and was moderate to marked in the 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab group. Moderate lymphoid depletion was noted in both 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab groups. While these findings appear more robust in the 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 wt-Fab groups, these animals were described as

25 moribund on Day 5, and the mild to marked lymphocytolysis as well as moderate lymphoid depletion may be related to this in-life observation (stress-related effects due to poor physical condition).

Histopathology findings of uncertain relationship to compound administration in the liver consisted of a marginal mixed cell (lymphocytes and macrophages) infiltrate/ activation noted as

30 small foci/microgranulomas scattered randomly throughout the liver in 5/5 mice in both 4.5 and 9 $\mu\text{g/g}$ 4G8 Fab-IL-2 qm-Fab groups. This marginal change was also seen in the vehicle control group but with fewer incidence and severity. Stomach glandular dilation and atrophy was seen

marginally to mildly in 5/5 mice and ileal villous atrophy was seen marginally in 3/5 mice in the 9 µg/g 4G8 Fab-IL-2 wt-Fab group. This finding is most likely attributed to poor physical condition seen in these mice such as reduced body weight, especially in the 9 µg/g 4G8 Fab-IL-2 wt-Fab group noted in the in-life observations.

- 5 Injection site findings included mixed cell infiltrate, perivascular edema, and myodegeneration that was noted equally in vehicle control, 9 µg/g 4G8 Fab-IL-2 wt-Fab and 9 µg/g 4G8 Fab-IL-2 qm-Fab groups. One animal had epidermal necrosis. These findings were not attributed to the treatment(s) itself, but to the daily i.v. injection and handling of the tail. Another animal had macrophage infiltration of the skeletal muscle (noted on the lung tissue histology section)
- 10 associated with myodegeneration and myoregeneration likely due to a chronic lesion and was not attributed to the treatment. Marginal lymphoid depletion was noted in 3/5 and 4/5 mice in the 4.5 and 9 µg/g 4G8 Fab-IL-2 qm-Fab groups, respectively and was most likely attributed to normal physiologic changes seen in the thymus as mice get older (also seen in similar incidence, 4/5 mice, and severity in vehicle control animals).
- 15 In conclusion, the daily intravenous administration of 4G8 Fab-IL-2 wt-Fab or 4G8 Fab-IL-2 qm-Fab at doses of 4.5 or 9 µg/g/day for up to 5 days in male mice resulted in similar treatment-related histologic findings with both compounds. However, the findings were generally more prevalent and more severe with FAP-targeted 4G8 Fab-IL-2 wt-Fab in the lung (Figure 28 and 29) (mononuclear infiltration consisting of lymphocytes and reactive macrophages, hemorrhage,
- 20 and edema), bone marrow (lympho-myelo hyperplasia and increased cellularity), liver (Figure 30) (single cell necrosis, Kupffer cell/macrophage increase in number and activation), spleen (grossly enlarged, macrophage and lymphocyte infiltration/hyperplasia) and thymus (increased lymphocytes).. In addition, mortality, lymphocytolysis, necrosis or cellular degeneration in the lung, spleen, bone marrow, and thymus, as well as reduced megakaryocytes and erythrocytes in
- 25 bone marrow and reduced platelets in peripheral blood were seen only in animals given wt IL-2. Based on the clinical and anatomic pathologic findings, as well as clinical observations, and the comparable systemic exposure of both compounds, the qm IL-2 under conditions of this study exhibited markedly less systemic toxicity following 5 doses than wt IL-2.

Induction of NK cell IFN-γ secretion by wild type and quadruple mutant IL-2

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NK-92 cells were starved for 2 h before seeding 100000 cells/well into a 96 well-F-bottom plate. IL-2 constructs were titrated onto the seeded NK-92 cells. After 24 h or 48 h, plates were centrifuged before collecting the supernatants to determine the amount of human IFN- γ using a commercial IFN- γ ELISA (BD #550612).

- 5 Two different in-house preparations of wild type IL-2 (probably differing slightly in their O-glycosylation profiles, see Example 2), a commercially available wild-type IL-2 (Proleukin) and in-house prepared quadruple mutant IL-2 (first batch) were tested.

Figure 31 shows that the quadruple mutant IL-2 is equally potent as commercially obtained (Proleukin) or in-house produced wild-type IL-2 in inducing IFN- γ secretion by NK cells for 24
10 (A) or 48 hours (B).

Example 11

Induction of NK cell proliferation by wild type and quadruple mutant IL-2

- NK-92 cells were starved for 2 h before seeding 10000 cells/well into 96-well-black-F-clear
15 bottom plates. IL-2 constructs were titrated onto the seeded NK-92 cells. After 48 h the ATP content was measured to determine the number of viable cells using the “CellTiter-Glo Luminescent Cell Viability Assay” Kit from Promega according to the manufacturer’s instructions.

The same IL-2 preparations as in Example 10 were tested.

- 20 Figure 32 shows that all tested molecules were able to induce proliferation of NK cells. At low concentrations (< 0.01 nM) the quadruple mutant IL-2 was slightly less active than the in-house produced wild-type IL-2, and all in-house preparations were less active than the commercially obtained wild-type IL-2 (Proleukin).

- In a second experiment, the following IL-2 preparations were tested: wild-type IL-2 (pool 2),
25 quadruple mutant IL-2 (first and second batch).

Figure 33 shows that all tested molecules were about similarly active in inducing proliferation of NK cells, with the two mutant IL-2 preparations being only minimally less active than the wild-type IL-2 preparations at the lowest concentrations.

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Example 12

Induction of human PBMC proliferation by immunoconjugates comprising wild type or quadruple mutant IL-2

Peripheral blood mononuclear cells (PBMC) were prepared using Histopaque-1077 (Sigma Diagnostics Inc., St. Louis, MO, USA). In brief, venous blood from healthy volunteers was drawn into heparinized syringes. The blood was diluted 2:1 with calcium- and magnesium-free PBS, and layered on Histopaque-1077. The gradient was centrifuged at 450 x g for 30 min at room temperature (RT) without breaks. The interphase containing the PBMCs was collected and washed three times with PBS (350 x g followed by 300 x g for 10 min at RT).

Subsequently, PBMCs were labeled with 40 nM CFSE (carboxyfluorescein succinimidyl ester) for 15 min at 37°C. Cells were washed with 20 ml medium before recovering the labeled PBMCs for 30 min at 37°C. The cells were washed, counted, and 100000 cells were seeded into 96-well-U-bottom plates. Pre-diluted Proleukin (commercially available wild-type IL-2) or IL-2-immunoconjugates were titrated onto the seeded cells which were incubated for the indicated time points. After 4-6 days, cells were washed, stained for appropriate cell surface markers, and analyzed by FACS using a BD FACSCantoII. NK cells were defined as CD3⁻/CD56⁺, CD4 T cells as CD3⁺/CD8⁻, and CD8 T cells as CD3⁺/CD8⁺.

Figure 34 shows proliferation of NK cells after incubation with different FAP-targeted 28H1 IL-2 immunoconjugates for 4 (A), 5 (B) or 6 (C) days. All tested constructs induced NK cell proliferation in a concentration-dependent manner. Proleukin was more efficacious than the immunoconjugates at lower concentrations, this difference no longer existed at higher concentrations, however. At earlier time points (day 4), the IgG-IL2 constructs appeared slightly more potent than the Fab-IL2-Fab constructs. At later time points (day 6), all constructs had comparable efficacy, with the Fab-IL2 qm-Fab construct being least potent at the low concentrations.

Figure 35 shows proliferation of CD4 T-cells after incubation with different FAP-targeted 28H1 IL-2 immunoconjugates for 4 (A), 5 (B) or 6 (C) days. All tested constructs induced CD4 T cell proliferation in a concentration-dependent manner. Proleukin had a higher activity than the immunoconjugates, and the immunoconjugates comprising wild-type IL-2 were slightly more potent than the ones comprising quadruple mutant IL-2. As for the NK cells, the Fab-IL2 qm-Fab construct had the lowest activity. Most likely the proliferating CD4 T cells are partly regulatory T cells, at least for the wild-type IL-2 constructs.

Figure 36 shows proliferation of CD8 T-cells after incubation with different FAP-targeted 28H1 IL-2 immunoconjugates for 4 (A), 5 (B) or 6 (C) days. All tested constructs induced CD8 T cell proliferation in a concentration-dependent manner. Proleukin had a higher activity than the immunoconjugates, and the immunoconjugates comprising wild-type IL-2 were slightly more

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potent than the ones comprising quadruple mutant IL-2. As for the NK and CD4 T cells, the Fab-IL2 qm-Fab construct had the lowest activity.

Figure 37 depicts the results of another experiment, wherein FAP-targeted 28H1 IgG-IL-2, comprising either wild-type or quadruple mutant IL-2, and Proleukin were compared. Incubation time was 6 days. As shown in the figure, all three IL-2 constructs induce NK (A) and CD8 T-cell (C) proliferation in a dose-dependent manner with similar potency. For CD4 T-cells (B), the IgG-IL2 qm immunoconjugate has a lower activity, particularly at medium concentrations, which might be due to its lack of activity on CD25-positive (including regulatory) T cells which are a subset of CD4 T cells.

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Example 13

Effector cell activation by wild-type and quadruple mutant IL-2 (pSTAT5 assay)

PBMCs were prepared as described above. 500000 PBMCs/well were seeded into 96-well-U-bottom plates and rested 45 min at 37°C in RPMI medium containing 10% FCS and 1% Glutamax (Gibco). Afterwards, PBMCs were incubated with Proleukin, in-house produced wild-type IL-2 or quadruple mutant IL-2 at the indicated concentrations for 20 min at 37°C to induce phosphorylation of STAT5. Subsequently, cells were immediately fixed (BD Cytofix Buffer) for 10 min at 37°C and washed once, followed by a permeabilization step (BD Phosflow Perm Buffer III) for 30 min at 4°C. Afterwards, cells were washed with PBS / 0.1% BSA and stained with mixtures of FACS antibodies for detection of NK cells (CD3⁻/CD56⁺), CD8⁺ T cells (CD3⁺/CD8⁺), CD4⁺ T cells (CD3⁺/CD4⁺/CD25⁻/CD127⁺) or T_{reg} cells (CD4⁺/CD25⁺/CD127⁻/FoxP3⁺), as well as pSTAT5 for 30 min at RT in the dark. Cells were washed twice with PBS / 0.1% BSA and resuspended in 2% PFA before flow cytometric analysis (BD FACSCantoII).

Figure 38 shows STAT phosphorylation in NK cells (A), CD8 T-cells (B), CD4 T-cells (C) and regulatory T-cells (D) after 30 min incubation with Proleukin, in-house produced wild-type IL-2 (pool 2) and quadruple mutant IL-2 (batch 1). All three IL-2 preparations were equally potent in inducing STAT phosphorylation in NK as well as CD8 T-cells. In CD4 T-cells and even more so in regulatory T-cells, the quadruple mutant IL-2 had a lower activity than the wild-type IL-2 preparations.

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Example 14

Effector cell activation by wild-type and quadruple mutant IgG-IL-2 (pSTAT5 assay)

Experimental conditions were as described above (see Example 13).

Figure 39 shows STAT phosphorylation in NK cells (A), CD8 T-cells (B), CD4 T-cells (C) and regulatory T-cells (D) after 30 min incubation with Proleukin, IgG-IL-2 comprising wild-type IL-2 or IgG-IL-2 comprising quadruple mutant IL-2. On all cell types Proleukin was more potent in inducing STAT phosphorylation than the IgG-IL-2 immunoconjugates. The IgG-IL-2 wild-type and quadruple mutant constructs were equally potent in NK as well as CD8 T-cells. In CD4 T-cells and even more so in regulatory T-cells, the IgG-IL-2 quadruple mutant had a lower activity than the IgG-IL-2 wild-type immunoconjugate.

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Example 15

Maximum tolerated dose (MTD) of FAP-targeted Fab-IL2 wt-Fab and Fab-IL2 qm-Fab immunoconjugates

Escalating doses of FAP-targeted Fab-IL2-Fab immunoconjugates, comprising either wild type (wt) or quadruple mutant (qm) IL-2, were tested in tumor free immunocompetent Black 6 mice.

15 Female Black 6 mice (Charles River, Germany), aged 8-9 weeks at the start of the experiment, were maintained under specific-pathogen-free conditions with daily cycles of 12 h light / 12 h darkness according to committed guidelines (GV-Solas; Felasa; TierschG). The experimental study protocol was reviewed and approved by local government (P 2008016). After arrival, animals were maintained for one week to get accustomed to the new environment and for
20 observation. Continuous health monitoring was carried out on a regular basis.

Mice were injected i.v. once a day for 7 days with 4G8 Fab-IL2 wt-Fab at doses of 60, 80 and 100 µg/mouse or 4G8 Fab-IL2 qm-Fab at doses of 100, 200, 400, 600 and 1000 µg/mouse. All mice were injected i.v. with 200 µl of the appropriate solution. To obtain the proper amount of immunoconjugate per 200 µl, the stock solutions were diluted with PBS as necessary.

25 Figure 40 shows that the MTD (maximum tolerated dose) for Fab-IL2 qm-Fab is 10-fold higher than for Fab-IL2 wt-Fab, namely 600 µg/mouse daily for 7 days for the Fab-IL2 qm-Fab vs. 60 µg/mouse daily for 7 days for the Fab-IL2 wt-Fab.

TABLE 19.

Compound	Dose	Formulation buffer	Concentration (mg/mL)
4G8 Fab-IL2 wt-Fab	60, 80, 100 µg	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	3.32 (= stock solution)
4G8 Fab-IL2 qm-Fab	100, 200, 400, 600, 1000 µg	25 mM potassium phosphate, 125 mM NaCl, 100 mM glycine, pH 6.7	4.25 (= stock solution)

Example 16

Pharmacokinetics of a single dose of FAP-targeted and untargeted IgG-IL2 wt and qm

5 A single dose pharmacokinetics (PK) study was performed in tumor-free immunocompetent 129 mice for FAP-targeted IgG-IL2 immunoconjugates comprising either wild type or quadruple mutant IL-2, and untargeted IgG-IL2 immunoconjugates comprising either wild type or quadruple mutant IL-2.

Female 129 mice (Harlan, United Kingdom), aged 8-9 weeks at the start of the experiment, were maintained under specific-pathogen-free conditions with daily cycles of 12 h light / 12 h darkness according to committed guidelines (GV-Solas; Felasa; TierschG). The experimental study protocol was reviewed and approved by local government (P 2008016). After arrival, animals were maintained for one week to get accustomed to the new environment and for observation. Continuous health monitoring was carried out on a regular basis.

15 Mice were injected i.v. once with FAP-targeted 28H1 IgG-IL2 wt (2.5 mg/kg) or 28H1 IgG-IL2 qm (5 mg/kg), or untargeted DP47GS IgG-IL2 wt (5 mg/kg) or DP47GS IgG-IL2 qm (5 mg/kg). All mice were injected i.v. with 200 µl of the appropriate solution. To obtain the proper amount of immunoconjugate per 200 µl, the stock solutions were diluted with PBS as necessary.

Mice were bled at 1, 8, 24, 48, 72, 96 h; and every 2 days thereafter for 3 weeks. Sera were extracted and stored at -20°C until ELISA analysis. Immunoconjugate concentrations in serum were determined using an ELISA for quantification of the IL2-immunoconjugate antibody (Roche-Penzberg). Absorption was measured using a measuring wavelength of 405 nm and a reference wavelength of 492 nm (VersaMax tunable microplate reader, Molecular Devices).

Figure 41 shows the pharmacokinetics of these IL-2 immunoconjugates. Both the FAP-targeted (A) and untargeted (B) IgG-IL2 qm constructs have a longer serum half-life (approx. 30 h) than the corresponding IgG-IL2 wt constructs (approx. 15 h).

TABLE 20.

Compound	Dose	Formulation buffer	Concentration (mg/mL)
28H1-IgG-IL2 wt	2.5 mg/kg	20 mM Histidine, 140 mM NaCl, pH 6.0	3.84 (= stock solution)
28H1-IgG-IL2 qm	5 mg/kg	20 mM Histidine, 140 mM NaCl, pH 6.0	2.42 (= stock solution)
DP47GS-IgG-IL2wt	5 mg/kg	20 mM Histidine, 140 mM NaCl, pH 6.0	3.74 (= stock solution)
DP47GS-IgG-IL2QM	5 mg/kg	20 mM Histidine, 140 mM NaCl, pH 6.0	5.87 (= stock solution)

Example 17**5 Pharmacokinetics of a single dose of untargeted Fab-IL2 wt-Fab and Fab-IL2 qm-Fab**

A single dose pharmacokinetics (PK) study was performed in tumor-free immunocompetent 129 mice for untargeted Fab-IL2-Fab immunoconjugates comprising either wild type or quadruple mutant IL-2.

Female 129 mice (Harlan, United Kingdom), aged 8-9 weeks at the start of the experiment, were maintained under specific-pathogen-free conditions with daily cycles of 12 h light / 12 h darkness according to committed guidelines (GV-Solas; Felasa; TierschG). The experimental study protocol was reviewed and approved by local government (P 2008016). After arrival, animals were maintained for one week to get accustomed to the new environment and for observation. Continuous health monitoring was carried out on a regular basis.

Mice were injected i.v. once with DP47GS Fab-IL2 wt-Fab at a dose of 65 nmol/kg or DP47GS Fab-IL2 qm-Fab at a dose of 65 nM/kg. All mice were injected i.v. with 200 µl of the appropriate solution. To obtain the proper amount of immunoconjugate per 200 µl, the stock solutions were diluted with PBS as necessary.

Mice were bled at 0.5, 1, 3, 8, 24, 48, 72, 96 hours and thereafter every 2 days for 3 weeks. Sera were extracted and stored at -20°C until ELISA analysis. Immunoconjugate concentrations in serum were determined using an ELISA for quantification of IL2-immunoconjugate antibody (Roche-Penzberg). Absorption was measured using a measuring wavelength of 405 nm and a reference wavelength of 492 nm (VersaMax tunable microplate reader, Molecular Devices).

Figure 42 shows the pharmacokinetics of these IL-2 immunoconjugates. Fab-IL2-Fab wt and qm constructs have an approx. serum half-life of 3-4 h. The difference in serum half-life between constructs comprising wild-type or quadruple mutant IL-2 is less pronounced for the Fab-IL2-Fab constructs than for IgG-like immunoconjugates, which per se have longer half-lives.

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TABLE 21.

Compound	Dose	Formulation buffer	Concentration (mg/mL)
DP47GS Fab-IL2 wt-Fab	65 nM/kg	100 mM glycine, 125 mM NaCl, 25 mM KH ₂ PO ₄ , pH 6.7	3.84 (= stock solution)
DP47GS Fab-IL2 qm-Fab	65 nM/kg	100 mM glycine, 125 mM NaCl, 25 mM KH ₂ PO ₄ , pH 6.7	2.42 (= stock solution)

Example 18**10 Activation induced cell death of IL-2 activated PBMCs**

Freshly isolated PBMCs from healthy donors were pre-activated overnight with PHA-M at 1 µg/ml in RPMI1640 with 10% FCS and 1% Glutamine. After pre-activation PBMCs were harvested, labeled with 40 nM CFSE in PBS, and seeded in 96-well plates at 100 000 cells/well. Pre-activated PBMCs were stimulated with different concentrations of IL-2 immunoconjugates (4B9 IgG-IL-2 wt, 4B9 IgG-IL-2 qm, 4B9 Fab-IL-2 wt-Fab, and 4B9 Fab-IL-2 qm-Fab). After six days of IL-2 treatment PBMCs were treated with 0.5 µg/ml activating anti-Fas antibody overnight. Proliferation of CD4 (CD3⁺CD8⁻) and CD8 (CD3⁺CD8⁺) T cells was analyzed after six days by CFSE dilution. The percentage of living T cells after anti-Fas treatment was determined by gating on CD3⁺ Annexin V negative living cells.

As shown in Figure 44, all constructs induced proliferation of pre-activated T cells. At low concentrations the constructs comprising wild-type IL-2 wt were more active than the IL-2 qm-comprising constructs. IgG-IL-2 wt, Fab-IL-2 wt-Fab and Proleukin had similar activity. Fab-IL-2 qm-Fab was slightly less active than IgG-IL-2 qm. The constructs comprising wild-type IL-2 were more active on CD4 T cells than on CD8 T cells, most probably because of the activation of regulatory T cells. The constructs comprising quadruple mutant IL-2 were similarly active on CD8 and CD4 T cells.

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As shown in Figure 45, T cells stimulated with high concentrations of wild-type IL-2 are more sensitive to anti-Fas induced apoptosis than T cells treated with quadruple mutant IL-2.

* * *

- 5 Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, the descriptions and examples should not be construed as limiting the scope of the invention. The disclosures of all patent and scientific literature cited herein are expressly incorporated in their entirety by reference.

Claims

1. A mutant interleukin-2 (IL-2) polypeptide comprising at a first amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2
5 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide, characterized in that said first amino acid mutation is at a position corresponding to residue 72 of human IL-2.
2. The mutant interleukin-2 polypeptide of claim 1, wherein said first amino acid mutation is an amino acid substitution, selected from the group of L72G, L72A, L72S, L72T,
10 L72Q, L72E, L72N, L72D, L72R, and L72K.
3. The mutant interleukin-2 polypeptide of claim 1 or 2, comprising a second amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide.
- 15 4. The mutant interleukin-2 polypeptide of claim 3, wherein said second amino acid mutation is at a position selected from the positions corresponding to residue 35, 38, 42, 43, and 45 of human IL-2.
5. The mutant interleukin-2 polypeptide of claims 3 or 4, wherein said second amino acid mutation is at a position corresponding to residue 42 of human IL-2.
- 20 6. The mutant interleukin-2 polypeptide of claim 5, wherein said second amino acid mutation is an amino acid substitution, selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, and F42K.
7. The mutant interleukin-2 polypeptide of any one of claims 3 to 6, comprising a third
25 amino acid mutation that abolishes or reduces affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserves affinity of the mutant IL-2 polypeptide to the intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide.
8. The mutant interleukin-2 polypeptide of any one of claims 1 to 7, comprising three amino acid mutations that abolish or reduce affinity of the mutant IL-2 polypeptide to the high-affinity IL-2 receptor and preserve affinity of the mutant IL-2 polypeptide to the

intermediate-affinity IL-2 receptor, each compared to a wild-type IL-2 polypeptide, wherein said three amino acid mutations are at positions corresponding to residue 42, 45, and 72 of human IL-2.

- 5 9. The mutant interleukin-2 polypeptide of claim 8, wherein said three amino acid mutations are amino acid substitutions selected from the group of F42A, F42G, F42S, F42T, F42Q, F42E, F42N, F42D, F42R, F42K, Y45A, Y45G, Y45S, Y45T, Y45Q, Y45E, Y45N, Y45D, Y45R, Y45K, L72G, L72A, L72S, L72T, L72Q, L72E, L72N, L72D, L72R, and L72K.
- 10 10. The mutant interleukin-2 polypeptide of any one of claims 1 to 9, further comprising an amino acid mutation which eliminates the O-glycosylation site of IL-2 at a position corresponding to residue 3 of human IL-2.
11. The mutant interleukin-2 polypeptide of any one of claims 1 to 10, wherein said mutant IL-2 polypeptide is linked to a non-IL-2 moiety.
12. The mutant interleukin-2 polypeptide of any one of claims 1 to 11, wherein said mutant
15 IL-2 polypeptide is linked to a first and a second non-IL-2 moiety.
13. The mutant interleukin-2 polypeptide of claim 12, wherein said mutant IL-2 polypeptide shares a carboxy-terminal peptide bond with said first non-IL-2 moiety and an amino-terminal peptide bond with said second non-IL-2 moiety.
14. The mutant interleukin-2 polypeptide of any one of claims 11 to 13, wherein said non-IL-
20 2 moiety is an antigen binding moiety.
15. An immunoconjugate comprising a mutant IL-2 polypeptide according to any one of claims 1 to 10 and an antigen binding moiety.
16. The immunoconjugate of claim 15, wherein said mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with said antigen binding moiety.
- 25 17. The immunoconjugate of claims 15 or 16, wherein said immunoconjugate comprises as first and a second antigen binding moiety.
18. The immunoconjugate of claim 17, wherein said mutant IL-2 polypeptide shares an amino- or carboxy-terminal peptide bond with said first antigen binding moiety and said

second antigen binding moiety shares an amino- or carboxy-terminal peptide bond with either i) said mutant IL-2 polypeptide or ii) said first antigen binding moiety.

19. The mutant interleukin-2 polypeptide of claim 14 or the immunoconjugate of any one of claims 15 to 18, wherein said antigen binding moiety is an antibody or an antibody
5 fragment.
20. The mutant interleukin-2 polypeptide of claim 14 or the immunoconjugate of any one of claims 15 to 18, wherein said antigen binding moiety is selected from a Fab molecule and a scFv molecule.
21. The mutant interleukin-2 polypeptide of claim 14 or the immunoconjugate of any one of
10 claims 15 to 18, wherein said antigen binding moiety is an immunoglobulin molecule, particularly an IgG molecule.
22. The mutant interleukin-2 polypeptide of claim 14 or the immunoconjugate of any one of claims 15 to 21, wherein said antigen binding moiety is directed to an antigen presented on a tumor cell or in a tumor cell environment.
- 15 23. The mutant interleukin-2 polypeptide or immunoconjugate of claim 22, wherein said antigen is selected from the group of Fibroblast Activation Protein (FAP), the A1 domain of Tenascin-C (TNC A1), the A2 domain of Tenascin-C (TNC A2), the Extra Domain B of Fibronectin (EDB), Carcinoembryonic Antigen (CEA) and the Melanoma-associated Chondroitin Sulfate Proteoglycan (MCSP).
- 20 24. An isolated polynucleotide encoding the mutant IL-2 polypeptide or immunoconjugate of any one of claims 1 to 23.
25. An expression vector comprising the polynucleotide of claim 24.
26. A host cell comprising the polynucleotide of claim 24 or the expression vector of claim 25.
- 25 27. A method of producing a mutant IL-2 polypeptide or an immunoconjugate thereof, comprising culturing the host cell of claim 26 under conditions suitable for the expression of the mutant IL-2 polypeptide or the immunoconjugate.
28. A mutant IL-2 polypeptide or immunoconjugate produced by the method of claim 27.

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29. A pharmaceutical composition comprising the mutant IL-2 polypeptide or immunoconjugate of any one of claims 1 to 23 or 28 and a pharmaceutically acceptable carrier.
30. The mutant IL-2 polypeptide or immunoconjugate of any one of claims 1 to 23 or 28 for use in the treatment of a disease in an individual in need thereof.
31. The mutant IL-2 polypeptide or immunoconjugate of claim 30, wherein said disease is cancer.
32. Use of the mutant IL-2 polypeptide or immunoconjugate of any one of claims 1 to 23 or 28 for manufacture of a medicament for treating a disease in an individual in need thereof.
33. A method of treating disease in an individual, comprising administering to said individual a therapeutically effective amount of a composition comprising the mutant IL-2 polypeptide or immunoconjugate of any one of claims 1 to 23 or 28 in a pharmaceutically acceptable form.
34. The method of claim 33, wherein said disease is cancer.
35. A method of stimulating the immune system of an individual, comprising administering to said individual a effective amount of a composition comprising the mutant IL-2 polypeptide or immunoconjugate of any one of claims 1 to 23 or 28 in a pharmaceutically acceptable form.
36. The invention as described hereinbefore.