

IL-2 MUTEINS AND USES THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 62/721,644, filed August 23, 2018, U.S. provisional Application No. 62/675,972 filed May 24, 2018, U.S. provisional Application No. 62/595,357 filed December 6, 2017, U.S. Non-Provisional application No. 16/109,875, filed August 23, 2018 and U.S. Non-Provisional application No. 16/109,897, filed August 23, 2018, each of which are hereby incorporated by reference in their entirety.

FIELD

[0002] Embodiments provided herein relate to proteins referred to as IL-2 muteins, compositions comprising the same, and methods of using the same.

BACKGROUND

[0003] IL-2 binds three transmembrane receptor subunits: IL-2R β and IL-2R γ , which together activate intracellular signaling events upon IL-2 binding, and CD25 (IL-2R α) which serves to present IL-2 to the other 2 receptor subunits. The signals delivered by IL-2R $\beta\gamma$ include those of the PI3-kinase, Ras-MAP-kinase, and STAT5 pathways.

[0004] T cells require expression of CD25 to respond to the low concentrations of IL-2 that typically exist in tissues. T cells that express CD25 include both CD4⁺ FOXP3⁺ regulatory T cells (T-reg cells)--which are essential for suppressing autoimmune inflammation--and FOXP3⁻ T cells that have been activated to express CD25. FOXP3⁻ CD4⁺ T effector cells (T-eff) may be either CD4⁺ or CD8⁺ cells, both of which can be pro-inflammatory and may contribute to autoimmunity and other diseases where the subject's immune system attacks an organ or other tissues. IL-2-stimulated STAT5 signaling is crucial for normal T-reg cell growth and survival and for high FOXP3 expression.

[0005] Because of the low affinity IL-2 possesses for each of the three IL-2R chains, a further reduction in affinity for IL-2R β and IL-2R γ could be offset by an increased affinity for CD25. Mutational variants of IL-2 have been generated. These IL-2 mutants can be referred to as IL-2 muteins and have been found useful in the treatment of various diseases. However, there is still a need for additional IL-2 muteins that can be used in various applications and compositions. The present embodiments satisfies these needs as well as others.

SUMMARY

[0006] In some embodiments, peptides comprising an amino acid sequence of SEQ ID NO: 1, wherein the peptide comprises a mutation at position 73, 76, 100, or 138 are provided.

[0007] In some embodiments peptides comprising an amino acid sequence of SEQ ID NO: 2, wherein the peptide comprises a mutation at position 53, 56, 80, or 118 are provided.

[0008] In some embodiments peptides comprising an amino acid sequence of SEQ ID NO: 43, wherein at least one of X₁, X₂, and X₃ and X₄ are I and the remainder are L or I.

[0009] Also provided are pharmaceutical compositions comprising the same and nucleic acid molecules encoding the proteins described herein. Also provided herein are vectors comprising the nucleic acid molecule encoding the proteins described herein. In some embodiments, plasmids comprising the nucleic acid encoding the proteins described herein are provided. In some embodiments, cells comprising the nucleic acid molecules, vectors, or plasmids, encoding the proteins described herein are provided.

[0010] In some embodiments, methods of activating T regulatory cells are provided. In some embodiments, the methods comprise contacting a T regulatory cell with a peptide described herein or a pharmaceutical composition described herein.

[0011] In some embodiments, methods of treating an inflammatory disorder in a subject are provided. In some embodiments, the methods comprise administering to a subject, including but not limited to a subject in need thereof, a peptide (*e.g.* a therapeutically effective amount of the peptide).

[0012] In some embodiments, methods of promoting or stimulating STAT5 phosphorylation in T regulatory cells are provided. In some embodiments, the methods comprise administering to a subject a peptide (*e.g.* a therapeutically effective amount of the peptide).

BRIEF DESCRIPTION OF FIGURES:

FIG. 1 illustrates a non-limiting embodiment of a IL-2 mutein provided for herein.

DETAILED DESCRIPTION

[0013] Described herein are therapeutics that can modulate (*e.g.* increase) T-reg cell proliferation, survival, activation and/or function. In some embodiments, the modulation is selective or specific for the T-reg cells.

[0014] As used herein, the term “selective” refers to the therapeutic or protein modulating the activity in T-reg cells but has limited or lacks the ability to promote the activity in non-regulatory T cells.

[0015] In some embodiments, the therapeutic is a mutant of IL-2. A mutant of IL-2 can be referred to as an IL-2 mutein. IL-2 can exist in two different forms, an immature form and a mature form. The mature form is where the leader sequence has been removed. This is done during a post-translational process. The wild-type sequence of the immature IL-2 is as follows:

MYRMQLLSIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGINNY
KNPKLTRMLTFKFYMPKKATELKHLQCLEEELKPLEEVLNLAQSKNFHLR
PRDLISNINVIVLELKGSETTFMCEYADETATIVEFLNRWITFCQSIISTLT
(SEQ ID NO: 1).

The wild-type sequence of the mature IL-2 is as follows:

APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKA
TELKHLQCLEEELKPLEEVLNLAQSKNFHLRPRDLISNINVIVLELKGSETT
FMCEYADETATIVEFLNRWITFCQSIISTLT (mature IL-2 sequence) (SEQ ID
NO: 2).

[0016] An IL-2 mutein molecule can be prepared by mutating one or more of the residues of IL-2. Non-limiting examples of IL-2-muteins can be found in WO2016/164937, US9580486, US7105653, US9616105, US 9428567, US2017/0051029, US2014/0286898A1, WO2014153111A2, WO2010/085495, WO2016014428A2, WO2016025385A1, and US20060269515, each of which are incorporated by reference in its entirety.

[0017] In some embodiments, the alanine at position 1 of the sequence above (SEQ ID NO: 2) is deleted. In some embodiments, the IL-2 mutein molecule comprises a serine substituted for cysteine at position 125 of the mature IL-2 sequence. Other combinations of mutations and substitutions that are IL-2 mutein molecules are described in US20060269515, which is incorporated by reference in its entirety. In some embodiments, the cysteine at position 125 is also substituted with a valine or alanine. In some embodiments, the IL-2 mutein molecule comprises a V91K substitution. In some embodiments, the IL-2 mutein molecule comprises a N88D substitution. In some embodiments, the IL-2 mutein molecule comprises a N88R

substitution. In some embodiments, the IL-2 mutein molecule comprises a substitution of H16E, D84K, V91N, N88D, V91K, or V91R, any combinations thereof. In some embodiments, these IL-2 mutein molecules also comprise a substitution at position 125 as described herein. In some embodiments, the IL-2 mutein molecule comprises one or more substitutions selected from the group consisting of: T3N, T3A, L12G, L12K, L12Q, L12S, Q13G, E15A, E15G, E15S, H16A, H16D, H16G, H16K, H16M, H16N, H16R, H16S, H16T, H16V, H16Y, L19A, L19D, L19E, L19G, L19N, L19R, L19S, L19T, L19V, D20A, D20E, D20H, D20I, D20Y, D20F, D20G, D20T, D20W, M23R, R81A, R81G, R81S, R81T, D84A, D84E, D84G, D84I, D84M, D84Q, D84R, D84S, D84T, S87R, N88A, N88D, N88E, N88I, N88F, N88G, N88M, N88R, N88S, N88V, N88W, V91D, V91E, V91G, V91S, I92K, I92R, E95G, and Q126. In some embodiments, the amino acid sequence of the IL-2 mutein molecule differs from the amino acid sequence set forth in mature IL-2 sequence with a C125A or C125S substitution and with one substitution selected from T3N, T3A, L12G, L12K, L12Q, L12S, Q13G, E15A, E15G, E15S, H16A, H16D, H16G, H16K, H16M, H16N, H16R, H16S, H16T, H16V, H16Y, L19A, L19D, L19E, L19G, L19N, L19R, L19S, L19T, L19V, D20A, D20E, D20F, D20G, D20T, D20W, M23R, R81A, R81G, R81S, R81T, D84A, D84E, D84G, D84I, D84M, D84Q, D84R, D84S, D84T, S87R, N88A, N88D, N88E, N88F, N88I, N88G, N88M, N88R, N88S, N88V, N88W, V91D, V91E, V91G, V91S, I92K, I92R, E95G, Q126I, Q126L, and Q126F. In some embodiments, the IL-2 mutein molecule differs from the amino acid sequence set forth in mature IL-2 sequence with a C125A or C125S substitution and with one substitution selected from D20H, D20I, D20Y, D20E, D20G, D20W, D84A, D84S, H16D, H16G, H16K, H16R, H16T, H16V, I92K, I92R, L12K, L19D, L19N, L19T, N88D, N88R, N88S, V91D, V91G, V91K, and V91S. In some embodiments, the IL-2 mutein comprises N88R and/or D20H mutations.

[0018] In some embodiments, the IL-2 mutein molecule comprises a mutation in the polypeptide sequence at a position selected from the group consisting of amino acid 30, amino acid 31, amino acid 35, amino acid 69, and amino acid 74. In some embodiments, the mutation at position 30 is N30S. In some embodiments, the mutation at position 31 is Y31H. In some embodiments, the mutation at position 35 is K35R. In some embodiments, the mutation at position 69 is V69A. In some embodiments, the mutation at position 74 is Q74P. In some embodiments, the mutein does not comprise a mutation at position 30, 31, and/or 35.

[0019] In some embodiments, the IL-2 mutein molecule comprises a substitution selected from the group consisting of: N88R, N88I, N88G, D20H, D109C, Q126L, Q126F, D84G, or D84I relative to mature human IL-2 sequence provided above. In some embodiments, the IL-2 mutein molecule comprises a substitution of D109C and one or both of a N88R substitution and a C125S substitution. In some embodiments, the cysteine that is in the IL-2 mutein molecule at position 109 is linked to a polyethylene glycol moiety, wherein the polyethylene glycol moiety has a molecular weight of from about 5 to about 40 kDa. In some embodiments, the mutein does not comprise a mutation at position 109, 126, or 84.

[0020] In some embodiments, any of the substitutions described herein are combined with a substitution at position 125. The substitution can be a C125S, C125A, or C125V substitution. In some embodiments, the mutein does not comprise a mutation at position 125.

[0021] The numbering referred to herein, unless indicated otherwise for the IL-2 muteins refers to the mature sequence. If a sequence or position refers to SEQ ID NO: 1 it is the immature sequence. However, to transpose the positions from the immature sequence (SEQ ID NO: 1) to the mature sequence (SEQ ID NO: 2) all that need be done is to subtract 20 from the position referred to in SEQ ID NO: 1 to get the corresponding position in SEQ ID NO: 2.

[0022] In addition to the substitutions or mutations described herein, in some embodiments, the IL-2 mutein has a substitution/mutation at one or more of positions 73, 76, 100, or 138 that correspond to SEQ ID NO: 1 or positions at one or more of positions 53, 56, 80, or 118 that correspond to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a mutation at positions 73 and 76; 73 and 100; 73 and 138; 76 and 100; 76 and 138; 100 and 138; 73, 76, and 100; 73, 76, and 138; 73, 100, and 138; 76, 100 and 138; or at each of 73, 76, 100, and 138 that correspond to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a mutation at positions 53 and 56; 53 and 80; 53 and 118; 56 and 80; 56 and 118; 80 and 118; 53, 56, and 80; 53, 56, and 118; 53, 80, and 118; 56, 80 and 118; or at each of 53, 56, 80, and 118 that correspond to SEQ ID NO: 2. As the IL-2 can be fused or tethered to other proteins, as used herein, the term corresponds to as reference to a SEQ ID NOs: 6 or 15 refer to how the sequences would align with default settings for alignment software, such as can be used with the NCBI website. In some embodiments, the mutation is leucine to isoleucine. Thus, the IL-2 mutein can comprise one more isoleucines at positions 73, 76, 100, or 138 that correspond to SEQ ID NO: 1

or positions at one or more of positions 53, 56, 80, or 118 that correspond to SEQ ID NO: 2. In some embodiments, the mutein comprises a mutation at L53 that correspond to SEQ ID NO: 2. In some embodiments, the mutein comprises a mutation at L56 that correspond to SEQ ID NO: 2. In some embodiments, the mutein comprises a mutation at L80 that correspond to SEQ ID NO: 2. In some embodiments, the mutein comprises a mutation at L118 that correspond to SEQ ID NO: 2. In some embodiments, the mutation is leucine to isoleucine. In some embodiments, the mutein also comprises a mutation as position 69, 74, 88, 125, or any combination thereof in these muteins that correspond to SEQ ID NO: 2. In some embodiments, the mutation is a V69A mutation. In some embodiments, the mutation is a Q74P mutation. In some embodiments, the mutation is a N88D or N88R mutation. In some embodiments, the mutation is a C125A or C125S mutation.

[0023] In some embodiments, the IL-2 mutein comprises a mutation at one more of positions 49, 51, 55, 57, 68, 89, 91, 94, 108, and 145 that correspond to SEQ ID NO: 1 or one or more positions 29, 31, 35, 37, 48, 69, 71, 74, 88, and 125 that correspond to SEQ ID NO: 2. The substitutions can be used alone or in combination with one another. In some embodiments, the IL-2 mutein comprises substitutions at 2, 3, 4, 5, 6, 7, 8, 9, or each of positions 49, 51, 55, 57, 68, 89, 91, 94, 108, and 145. Non-limiting examples such combinations include, but are not limited to, a mutation at positions 49, 51, 55, 57, 68, 89, 91, 94, 108, and 145; 49, 51, 55, 57, 68, 89, 91, 94, and 108; 49, 51, 55, 57, 68, 89, 91, and 94; 49, 51, 55, 57, 68, 89, and 91; 49, 51, 55, 57, 68, and 89; 49, 51, 55, 57, and 68; 49, 51, 55, and 57; 49, 51, and 55; 49 and 51; 51, 55, 57, 68, 89, 91, 94, 108, and 145; 51, 55, 57, 68, 89, 91, 94, and 108; 51, 55, 57, 68, 89, 91, and 94; 51, 55, 57, 68, 89, and 91; 51, 55, 57, 68, and 89; 55, 57, and 68; 55 and 57; 55, 57, 68, 89, 91, 94, 108, and 145; 55, 57, 68, 89, 91, 94, and 108; 55, 57, 68, 89, 91, and 94; 55, 57, 68, 89, 91, and 94; 55, 57, 68, 89, and 91; 55, 57, 68, and 89; 55, 57, and 68; 55 and 57; 57, 68, 89, 91, 94, 108, and 145; 57, 68, 89, 91, 94, and 108; 57, 68, 89, 91, and 94; 57, 68, 89, and 91; 57, 68, and 89; 57 and 68; 68, 89, 91, 94, 108, and 145; 68, 89, 91, 94, and 108; 68, 89, 91, and 94; 68, 89, and 91; 68 and 89; 89, 91, 94, 108, and 145; 89, 91, 94, and 108; 89, 91, and 94; 89 and 91; 91, 94, 108, and 145; 91, 94, and 108; 91, and 94; or 94 and 108. Each mutation can be combined with one another. The same substitutions can be made in SEQ ID NO: 2, but the numbering would adjusted appropriately as is clear from the present disclosure (20 less than the numbering for SEQ ID NO: 1 corresponds to the positions in SEQ ID NO: 2).

[0024] In some embodiments, the IL-2 mutein comprises a mutation at one or more positions of 35, 36, 42, 104, 115, or 146 that correspond to SEQ ID NO: 1 or the equivalent positions at SEQ ID NO: 2 (e.g. positions 15, 16, 22, 84, 95, and 126). . These mutations can be combined with the other leucine to isoleucine mutations described herein or the mutation at positions 73, 76, 100, or 138 that correspond to SEQ ID NO: 1 or at one or more of positions 53, 56, 80, or 118 that correspond to SEQ ID NO: 2. In some embodiments, the mutation is a E35Q, H36N, Q42E, D104N, E115Q, or Q146E, or any combination thereof. In some embodiments, one or more of these substitutions is wildtype. In some embodiments, the mutein comprises a wild-type residue at one or more of positions 35, 36, 42, 104, 115, or 146 that correspond to SEQ ID NO: 1 or the equivalent positions at SEQ ID NO: 2 (e.g. positions 15, 16, 22, 84, 95, or 126).

[0025] The mutations at these positions can be combined with any of the other mutations described herein, including, but not limited to substitutions at positions 73, 76, 100, or 138 that correspond to SEQ ID NO: 1 or positions at one or more of positions 53, 56, 80, or 118 that correspond to SEQ ID NO: 2 described herein and above. In some embodiments, the IL-2 mutein comprises a N49S mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a Y51S or a Y51H mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a K55R mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a T57A mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a K68E mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a V89A mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a N91R mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a Q94P mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a N108D or a N108R mutation that corresponds to SEQ ID NO: 1. In some embodiments, the IL-2 mutein comprises a C145A or C145S mutation that corresponds to SEQ ID NO: 1.

[0026] These substitutions can be used alone or in combination with one another. In some embodiments, the mutein comprises each of these substitutions. In some embodiments, the mutein comprises 1, 2, 3, 4, 5, 6, 7, or 8 of these mutations. In some embodiments, the mutein comprises a wild-type residue at one or more of positions 35, 36, 42, 104, 115, or 146 that

correspond to SEQ ID NO: 1 or the equivalent positions at SEQ ID NO: 2 (e.g. positions 15, 16, 22, 84, 95, 126, and 126).

[0027] In some embodiments, the IL-2 mutein comprises a N29S mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a Y31S or a Y31H mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a K35R mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a T37A mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a K48E mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a V69A mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a N71R mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a Q74P mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a N88D or a N88R mutation that corresponds to SEQ ID NO: 2. In some embodiments, the IL-2 mutein comprises a C125A or C125S mutation that corresponds to SEQ ID NO: 2. These substitutions can be used alone or in combination with one another. In some embodiments, the mutein comprises 1, 2, 3, 4, 5, 6, 7, or 8 of these mutations. In some embodiments, the mutein comprises each of these substitutions. In some embodiments, the mutein comprises a wild-type residue at one or more of positions 35, 36, 42, 104, 115, or 146 that correspond to SEQ ID NO: 1 or the equivalent positions at SEQ ID NO: 2 (e.g. positions 15, 16, 22, 84, 95, and 126).

[0028] For any of the IL-2 muteins described herein, in some embodiments, one or more of positions 35, 36, 42, 104, 115, or 146 that correspond to SEQ ID NO: 1 or the equivalent positions at SEQ ID NO: 2 (e.g. positions 15, 16, 22, 84, 95, and 126) are wild-type (e.g. are as shown in SEQ ID NOs: 1 or 2). In some embodiments, 2, 3, 4, 5, 6, or each of positions 35, 36, 42, 104, 115, or 146 that correspond to SEQ ID NO: 1 or the equivalent positions at SEQ ID NO: 2 (e.g. positions 15, 16, 22, 84, 95, and 126) are wild-type.

[0029] In some embodiments, the IL-2 mutein comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATEIKHLQCLEEELKPLEEALRLAPSKNFHLR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFLNRWITFSQSIISTLT
(SEQ ID NO: 3)

[0030] In some embodiments, the IL-2 mutein comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATELKHIQCLEEELKPLEEALRLAPSKNFHLR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFLNRWITFSQSIISTLT
(SEQ ID NO: 4)

[0031] In some embodiments, the IL-2 mutein comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATELKHLQCLEEELKPLEEALRLAPSKNFHIR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFLNRWITFSQSIISTLT
(SEQ ID NO: 5)

[0032] In some embodiments, the IL-2 mutein comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATELKHLQCLEEELKPLEEALRLAPSKNFHLR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFINRWITFSQSIISTLT
(SEQ ID NO: 6)

[0033] In some embodiments, the IL-2 mutein sequences described herein do not comprise the IL-2 leader sequence. The IL-2 leader sequence can be represented by the sequence of MYRMQLLSICIALSLALVTNS (SEQ ID NO: 7). Therefore, in some embodiments, the sequences illustrated above can also encompass peptides without the leader sequence. Although SEQ ID NOs; 3-6 are illustrated with only mutation at one of positions 73, 76, 100, or 138 that correspond to SEQ ID NO: 1 or positions at one or more of positions 53, 56, 80, or 118 that correspond to SEQ ID NO: 2, the peptides can comprise 1, 2, 3, or 4 of the mutations at these positions. In some embodiments, the substitution at each position is isoleucine or other type of conservative amino acid substitution. In some embodiments, the leucine at the recited positions are substituted with, independently, isoleucine, valine, methionine, or glycine, alanine, glutamine or glutamic acid.

[0034] In some embodiments, the IL-2 protein of SEQ ID NO: 2 comprises the following mutations: V69A, Q74P, N88D, and C125S or C125A and one mutation selected from the group consisting of L53I, L56I, L80I, and L118I. In some embodiments, the IL-2 protein comprises

two mutations selected from the group consisting of L53I, L56I, L80I, and L118I. In some embodiments, the IL-2 protein comprises three or each of the mutations selected from the group consisting of L53I, L56I, L80I, and L118I. In some embodiments, the IL-2 protein comprises L53I and L56I, L53I and L80I, L53I and L118I, L56I and L80I, L56I and L118I, L80I and L118I, L53I, L56I, and L80I, L53I, L56I, and L118I, L56I, L80I, and L118I or L53I, L56I, L80I, and L118I. In some embodiments, the IL-2 mutein does not comprise L53I, L56I, L80I, or L118I mutations. In some embodiments, the IL-2 mutein comprises a T3A mutation.

[0035] In some embodiments, the IL-2 protein of SEQ ID NO: 2 comprises the following mutations: V69A, Q74P, N88D, and C125S or C125A and one or more mutations, such as but not limited to conservative substitutions, in regions of 45-55, 50-60, 52-57, 75-85, 100-130, 115-125 of SEQ ID NO: 2.

[0036] In some embodiments, the IL-2 mutein molecule is fused to a Fc Region or other linker region as described herein. Examples of such fusion proteins can be found in US9580486, US7105653, US9616105, US 9428567, US2017/0051029, WO2016/164937, US2014/0286898A1, WO2014153111A2, WO2010/085495, WO2016014428A2, WO2016025385A1, US2017/0037102, and US2006/0269515, each of which are incorporated by reference in its entirety.

[0037] In some embodiments, the Fc Region comprises what is known at the LALA mutations. In some embodiments, the Fc region comprises L234A and L235A mutations (EU numbering). In some embodiments, the Fc Region comprises a G237A (EU numbering). In some embodiments, the Fc Region does not comprise a mutation at position G237 (EU numbering). Using the Kabat numbering this would correspond to L247A, L248A, and/or G250A. In some embodiments, using the EU numbering system the Fc region comprises a L234A mutation, a L235A mutation, and/or a G237A mutation. Regardless of the numbering system used, in some embodiments, the Fc portion can comprise mutations that corresponds to one or more of these residues. In some embodiments, the Fc Region comprises N297G or N297A (kabat numbering) mutations. The Kabat numbering is based upon a full-length sequence, but would be used in a fragment based upon a traditional alignment used by one of skill in the art for the Fc region (see, for example, Kabat et al. ("Sequence of proteins of immunological interest," US Public Health Services, NIH Bethesda, MD, Publication No. 91, which is hereby incorporated by reference),

which is hereby incorporated by reference. In some embodiments, the Fc Region comprises a sequence of:

DKTHTCPPCPAPEAAGAPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDP
EVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKE
YKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCL
VKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQ
QGNVFSCSVMHEALHNHYTQKSLSLSPG. (SEQ ID NO: 8)

In some embodiments, the Fc Region comprises a sequence of:

DKTHTCPPCPAPPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDP
EVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKE
YKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCL
VKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQ
QGNVFSCSVMHEALHNHYTQKSLSLSPG (SEQ ID NO: 15)

[0038] In some embodiments, the IL-2 mutein is linked to the Fc Region. Non-limiting examples of linkers are glycine/serine linkers. For example, a glycine/serine linker can be, or comprise, a sequence of GGGGSGGGGSGGGGSGGGGS (SEQ ID NO: 9) or be, or comprise a sequence of GGGGSGGGGSGGGGS (SEQ ID NO: 16). This is simply a non-limiting example and the linker can have varying number of GGGGS (SEQ ID NO: 10) repeats. In some embodiments, the linker comprises 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 of the GGGGS (SEQ ID NO: 10) repeats.

[0039] In some embodiments, the IL-2 mutein is linked to the Fc Region using a flexible, rigid or cleavable linker. The linker can be as described herein or as illustrated in the following table:

Type	Sequence
flexible	GGGGS
flexible	(GGGGS) ₃
flexible	(GGGGS) _n (n=1, 2, 3, 4)
flexible	(Gly) ₈

flexible	(Gly) ₆
rigid	(EAAAK) ₃
rigid	(EAAK) _n (n=1-3)
rigid	A(EAAAK) ₄ ALEA(EAAAK) ₄ A
rigid	AEAAAKEAAKA
rigid	PAPAP
rigid	(Ala-Pro) _n (10-34 aa)
cleavable	disulfide
cleavable	VSQTSKLTRAETVFPDV
cleavable	PLGLWA
cleavable	RVLAEA
cleavable	EDVVCCMSY
cleavable	GGIEGRGS
cleavable	TRHRQPRGWE
cleavable	AGNRVRRSVG
cleavable	RRRRRRRRR
cleavable	GFLG
Dipeptide	LE

[0040] Thus, the IL-2/Fc Fusion can be represented by the formula of $Z_{IL-2M}-L_{gs}-Z_{Fc}$, wherein Z_{IL-2M} is an IL-2 mutein as described herein, L_{gs} is a linker sequence as described herein (e.g. glycine/serine linker) and Z_{Fc} is a Fc region described herein or known to one of skill in the art. In some embodiments, the formula can be in the reverse orientation $Z_{Fc}-L_{gs}-Z_{IL-2M}$.

[0041] In some embodiments, the IL-2/Fc fusion comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATEIKHLQCLEEELKPLEEALRLAPSKNFHLR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFLNRWITFSQSIISTLTG
GGGSGGGGSGGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLFPPKPKDTL
MISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY
RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVY
TLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLD
SDGSFFLYSKLTVDKSRWQQGNVFSVMSMHEALHNHYTQKSLSLSPG
(SEQ ID NO: 11)

[0042] In some embodiments, the IL-2/Fc fusion comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATELKHILQCLEEELKPLEEALRLAPSKNFHLR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFLNRWITFSQSIISTLTG
GGGSGGGGSGGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLFPPKPKDTL
MISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY
RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVY
TLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLD
SDGSFFLYSKLTVDKSRWQQGNVFSVMSMHEALHNHYTQKSLSLSPG
(SEQ ID NO: 12)

[0043] In some embodiments, the IL-2/Fc fusion comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
KNPRLARMLTFKFYMPEKATELKHILQEEELKPLEEALRLAPSKNFHIR
PRDLISDINVIVLELKGSETTFMCEYADETATIVEFLNRWITFSQSIISTLTG
GGGSGGGGSGGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLFPPKPKDTL
MISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY
RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVY
TLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLD
SDGSFFLYSKLTVDKSRWQQGNVFSVMSMHEALHNHYTQKSLSLSPG
(SEQ ID NO: 13)

[0044] In some embodiments, the IL-2/Fc fusion comprises a sequence of:

MYRMQLLSICIALSLALVTNSAPTSSSTKKTQLQLEHLLLDLQMILNGISNH
 KNPRLARMLTFKFYMPEKATELKHLQCLEEEELKPLEEALRLAPSKNFHLR
 PRDLISDINVIVLELKGSETTFMCEYADETATIVEFINRWITFSQSIISTLTGG
 GSGGGGSGGGGSGGGGSDKTHTCPPEAAGAPSVFLFPPKPKDTL
 MISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY
 RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVY
 TLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLD
 SDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPG
 (SEQ ID NO: 14).

[0045] In some embodiments, the Fc region of SEQ ID NO: 8 is replaced with SEQ ID NO: 15.

[0046] The proteins described herein can also be fused to another protein, such as an antibody or other type of therapeutic molecule.

[0047] In some embodiments, the sequence of IL-2 mutein or IL-2/Fc fusion are as shown in the following table:

SEQ NO:	ID	Brief Description	Amino Acid Sequence
17		Human IL-2 with C125S mutation	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
18		Human IL-2 with C125S and T3A mutations	APASSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
19		Human IL-2 with N88R and C125S	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISRINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
20		Human IL-2 with V69A, Q74P and C125S mutations	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
21		Human IL-2 with V69A, Q74P, N88D	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAQSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT

	and C125S mutations	
22	Human IL-2 with V69A, Q74P, N88R and C125S mutations	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISRINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
23	Human IL-2 with N88D and C125S	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
24	Human IL-2 with L53I, V69A, Q74P, N88D and C125S mutations	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATEIKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
25	Human IL-2 with L56I, V69A, Q74P, N88D and C125S mutations	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHIQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
26	Human IL-2 with V69A, Q74P, L80I, N88D and C125S mutations	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHIRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLT
27	Human IL-2 with V69A, Q74P, N88D, L118I, and C125S mutations	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFINRWITFSQSIISTLT
28	Human IgG1 Fc (N-terminal fusions) with	DKTHTCPPCPAPEAAGAPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNW YVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEK TISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNY

	L234A, L235A, and G237A mutations	KTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
29	Human IgG1 Fc (truncated) with N297G mutation	DKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNW YVDGVEVHNAKTKPREEQYGSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEK TISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNY KTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
30	IL-2 C125S- G4Sx3-Fc	APTSSSTKKTQLQLEHLLLDLQMLNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
31	IL-2 T3A, C125S-G4Sx3- Fc	APASSSTKKTQLQLEHLLLDLQMLNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
32	IL-2 N88R, C125S-G4Sx3- Fc	APTSSSTKKTQLQLEHLLLDLQMLNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
33	IL-2 V69A, Q74P, C125S, - G4Sx3-Fc	APTSSSTKKTQLQLEHLLLDLQMLNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAQSKNFHLRPRDLISNINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGGSDKTHTCPPCPAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMEALHNHYTQKSLSLSPG

34	IL-2 N88D V69A, Q74P, C125S-G4Sx3-Fc	APTSSSTKKTQLQLEHLLLDLQMI LNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGSDKTHTCP PCAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMHEALHNHYTQKSLSLSPG
35	IL-2 N88R V69A, Q74P, C125S-G4Sx3-Fc	APTSSSTKKTQLQLEHLLLDLQMI LNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISRINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGSDKTHTCP PCAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMHEALHNHYTQKSLSLSPG
36	IL-2 N88D, C125S-G4Sx3-Fc	APTSSSTKKTQLQLEHLLLDLQMI LNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEVLNLAQSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGSDKTHTCP PCAPEAAGAPSVFLF PPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTY RVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREE MTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMHEALHNHYTQKSLSLSPG
37	IL-2 L53I, N88D, V69A, Q74P, C125S-G4Sx4-Fc	APTSSSTKKTQLQLEHLLLDLQMI LNGINNYKNPKLTRMLTFKFYMPKKATEIKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGGSGGSDKTHTCP PCAPEAAGAP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPP PSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSK LTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPG
38	IL-2 L56I N88D, V69A, Q74P, C125S-G4Sx4-Fc	APTSSSTKKTQLQLEHLLLDLQMI LNGINNYKNPKLTRMLTFKFYMPKKATELKHIQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGGSGGSDKTHTCP PCAPEAAGAP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPP PSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSK

		LTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
39	IL-2 L80I N88D V69A, Q74P, C125S- G4Sx4-Fc	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHIRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGGSGGGSDKHTCPCPAPEAAGAP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLTP PSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPVLDSDGSFFLYSK LTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
40	IL-2 L118I N88D V69A, Q74P, C125S- G4Sx4-Fc	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFINRWITFSQSIISTLTGGGGSGGGSGGGSGGGSGGGSDKHTCPCPAPEAAGAP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLTP PSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPVLDSDGSFFLYSK LTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
41	IL-2 N88D V69A, Q74P, C125S-G4Sx4- Fc	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELKHLQ CLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADETATI VEFLNRWITFSQSIISTLTGGGGSGGGSGGGSGGGSGGGSDKHTCPCPAPEAAGAP SVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLTP PSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPVLDSDGSFFLYSK LTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPG
42	Fc-G4S-IL-2 N88D V69A, Q74P	DKHTCPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNW YVDGVEVHNAKTKPREEQYGSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEK TISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNY KTTPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMEALHNHYTQKSLSLSPGGG GGSAPTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATELK HLQCLEEELKPLEEALNLAPSKNFHLRPRDLISDINVIVLELKGSETTFMCEYADET ATIVEFLNRWITFAQSIISTLT
43	IL-2 N88D V69A, Q74P, C125S-G4Sx4- Fc, wherein at least one	APTSSSTKKTQLQLEHLLLDLQMILNGINNYKNPKLTRMLTFKFYMPKKATEX ₁ KHX ₂ QCLEEELKPLEEALNLAPSKNFHX ₃ RPRDLISDINVIVLELKGSETTFMCEYADETA TIVEFX ₄ NRWITFSQSIISTLTGGGGSGGGSGGGSGGGSGGGSDKHTCPCPAPEAA GAPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPR EEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVY

	of X ₁ , X ₂ , X ₃ , and X ₄ is I and the remainder are L or I.	TLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFL YSKLTVDKSRWQQGNVFSVSMHEALHNHYTQKSLSLSPG
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[0048] Each of the proteins may also be considered to have the C125S and the LALA and/or G237A mutations as provided for herein. The C125 substitution can also be C125A as described throughout the present application.

[0049] In some embodiments, the sequences shown in the table or throughout the present application comprise or don't comprise one or more mutations that correspond to positions L53, L56, L80, and L118. In some embodiments, the sequences shown in the table or throughout the present application comprise or don't comprise one or more mutations that correspond to positions L59I, L63I, I24L, L94I, L96I or L132I or other substitutions at the same positions. In some embodiments, the mutation is leucine to isoleucine. In some embodiments, the mutein does not comprise another mutation other than as shown or described herein. In some embodiments, the peptide comprises a sequence of SEQ ID NO: 17, SEQ ID NO: 18, SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, SEQ ID NO: 23, SEQ ID NO: 24, SEQ ID NO: 25, SEQ ID NO: 26, SEQ ID NO: 27, SEQ ID NO: 28, SEQ ID NO: 29, SEQ ID NO: 30, SEQ ID NO: 31, SEQ ID NO: 32, SEQ ID NO: 33, SEQ ID NO: 34, SEQ ID NO: 35, SEQ ID NO: 36, SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40, SEQ ID NO: 41, SEQ ID NO: 42, or SEQ ID NO: 43.

[0050] In some embodiments, the Fc portion of the fusion is not included. In some embodiments, the peptide consists essentially of an IL-2 mutein provided for herein. In some embodiments, the protein is free of a Fc portion.

[0051] In some embodiments, a polypeptide is provided comprising SEQ ID NO: 43, wherein at least one of X₁, X₂, X₃, and X₄ is I and the remainder are L or I. In some embodiments, X₁, X₂, and X₃ are L and X₄ is I. In some embodiments, X₁, X₂, and X₄ are L and X₃ is I. In some embodiments, X₂, X₃, and X₄ are L and X₁ is I. In some embodiments, X₁, X₃, and X₄ are L and X₂ is I. In some embodiments, X₁ and X₂ are L and X₃ and X₄ are I. In some embodiments, X₁ and X₃ are L and X₂ and X₄ are I. In some embodiments, X₁ and X₄ are L and X₂ and X₃ are I. In some embodiments, X₂ and X₃ are L and X₁ and X₄ are I. In some embodiments, X₂ and X₄

are L and X₁ and X₃ are I. In some embodiments, X₃ and X₄ are L and X₁ and X₂ are I. In some embodiments, X₁, X₂, and X₃ are L and X₄ is I. In some embodiments, X₂, X₃, and X₄ are L and X₁ is I. In some embodiments, X₁, X₃, and X₄ are L and X₂ is I. In some embodiments, X₁, X₂, and X₄ are L and X₃ is I.

[0052] In some embodiments, the IL-2 mutein can be in the format as illustrated in FIG. 1. But as described herein, the IL-2 mutein can, in some embodiments, be used without a Fc domain or the Fc-domain is linked to the N-terminus of the IL-2 mutein as opposed to the Fc domain being linked to the C-terminus of the IL-2 mutein. The polypeptides described herein also encompass variants of the peptides described. In some embodiments, the IL-2 variants comprise a sequence of amino acids at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 91%, at least 92%, at least 93% at least 94%, at least 95%, at least 96%, at least 97%, at least 98%, at least 99% substantially similar to the sequences provided for herein. The variants include those that are described herein with the various substitutions described herein and above. In some embodiments, the variant has 1, 2, 3, 4, or 5 additional substitutions. In some embodiments, the substitution is G to A, L to I, G to S K to R, or other types of conservative substitutions. In some embodiments, the conservative substitution is selected based upon the following tables:

Basic (positively charged R-groups):	arginine lysine histidine
Acidic (negatively charged R-groups):	glutamic acid aspartic acid
Polar (Uncharged R-groups):	glutamine asparagine serine threonine cysteine proline
Non-Polar (aliphatic R-groups):	glycine alanine valine

	methionine leucine isoleucine
Non-Polar (aromatic R-groups):	phenylalanine tryptophan tyrosine

Original Residue	Substitutions
Ala	Gly; Ser; Thr
Arg	Lys; Gln
Asn	Gln; His; Ser
Asp	Glu; Asn
Cys	Ser; Sec
Gln	Asn; Ser; Asp; Glu
Glu	Asp; Gln; Lys
Gly	Ala; Pro; Asn
His	Asn; Gln; Tyr; Phe
Ile	Leu; Val; Met; Phe
Leu	Ile; Val; Met; Phe
Lys	Arg; Gln;
Met	Leu; Tyr; Ile; norleucine; Val; Phe
Pro	Beta homo proline; Ser; Thr; Ala; Gly; alpha homoproline
Phe	Met; Leu; Tyr; Trp
Ser	Thr; Gly; Asn; Asp
Thr	Ser; Asn
Trp	Tyr; Phe,;
Tyr	Trp; Phe;

Val	Ile; Leu; Met;Phe
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[0053] The percent identity of two amino acid or two nucleic acid sequences can be determined by visual inspection and mathematical calculation, or for example, the comparison is done by comparing sequence information using a computer program. An exemplary computer program is the Genetics Computer Group (GCG; Madison, Wis.) Wisconsin package version 10.0 program, GAP (Devereux et al. (1984), Nucleic Acids Res. 12: 387-95). The preferred default parameters for the GAP program includes: (1) The GCG implementation of a unary comparison matrix (containing a value of 1 for identities and 0 for non-identities) for nucleotides, and the weighted amino acid comparison matrix of Gribskov and Burgess, ((1986) Nucleic Acids Res. 14: 6745) as described in Atlas of Polypeptide Sequence and Structure, Schwartz and Dayhoff, eds., National Biomedical Research Foundation, pp. 353-358 (1979) or other comparable comparison matrices; (2) a penalty of 8 for each gap and an additional penalty of 2 for each symbol in each gap for amino acid sequences, or a penalty of 50 for each gap and an additional penalty of 3 for each symbol in each gap for nucleotide sequences; (3) no penalty for end gaps; and (4) no maximum penalty for long gaps. Other programs used by those skilled in the art of sequence comparison can also be used.

[0054] In some embodiments, the IL-2 muteins provided herein include proteins that have altered signaling through certain pathways activated by wild-type IL-2 via the IL-2R and result in preferential proliferation/survival/activation of T-regs.

[0055] The IL-2 muteins provided for herein can be produced using any suitable method known in the art, including those described in U.S. Pat. No. 6,955,807 for producing IL-2 variants, which is hereby incorporated by reference. Such methods include constructing a DNA sequence encoding the IL-2 variant and expressing those sequences in a suitably transformed host, such as a host cell. Utilizing these methods will produce recombinant proteins as provided herein. Proteins can also be produced synthetically or a combination of synthetic and recombinantly producing fragments in a cell and then combining the fragments to make the entire protein of interest.

[0056] In some embodiments, a nucleic acid molecule (*e.g.* DNA or RNA) is prepared by isolating or synthesizing a nucleic acid molecule encoding the protein of interest. Alternatively,

the wild-type sequence of IL-2 can be isolated and the mutated using routine techniques, such as site-specific mutagenesis.

[0057] Another method of constructing a DNA sequence encoding the IL-2 variant would be chemical synthesis. This for example includes direct synthesis of a peptide by chemical means of the protein sequence encoding for an IL-2 variant exhibiting the properties described herein. This method may incorporate both natural and unnatural amino acids at various positions. Alternatively, a nucleic acid molecule which encodes a desired protein may be synthesized by chemical means using an oligonucleotide synthesizer. The oligonucleotides are designed based on the amino acid sequence of the desired protein, which can also be selected by using codons that are favored in the cell in which the recombinant variant will be produced. It is well recognized that the genetic code is degenerate--that an amino acid may be coded for by more than one codon. Accordingly, it will be appreciated that for a given DNA sequence encoding a particular IL-2 protein, there will be many DNA degenerate sequences that will code for that IL-2 variant. According, in some embodiments, a nucleic acid molecule is provided that encodes the proteins described herein. The nucleic acid molecule can be DNA or RNA.

[0058] In some embodiments, the nucleic acid molecule will encode a signal sequence. A signal sequence can be chosen based upon the cell that will be expressed in. In some embodiments, if the host cell is prokaryotic, the nucleic acid molecule does not comprise a signal sequence. In some embodiments, if the host cell is a eukaryotic cell, the signal sequence can be used. In some embodiments, the signal sequence is the IL-2 signal sequence.

[0059] A nucleic acid molecule "encodes" a protein, as meant herein, if the nucleic acid molecule or its complement comprises the codons encoding the protein.

[0060] "Recombinant" as it applies to polypeptides or proteins, means that the production of the protein is dependent on at least one step in which nucleic acids, which may or may not encode the protein, are introduced into a cell in which they are not naturally found.

[0061] Various host (animals or cell systems) can be used to produce the proteins described herein. Examples of suitable host cells include, but are not limited to, bacteria, fungi (including yeasts), plant, insect, mammal, or other appropriate animal cells or cell lines, as well as transgenic animals or plants. In some embodiments, these hosts may include well known eukaryotic and prokaryotic hosts, such as strains of *E. coli*, *Pseudomonas*, *Bacillus*,

Streptomyces, fungi, yeast, insect cells such as *Spodoptera frugiperda* (Sf9), animal cells such as Chinese hamster ovary (CHO) and mouse cells such as NS/O, African green monkey cells such as COS 1, COS 7, BSC 1, BSC 40, and BNT 10, and human cells, as well as plant cells in tissue culture. For animal cell expression, CHO cells and COS 7 cells in cultures and particularly the CHO cell line CHO (DHFR-) or the HKB line may be used.

[0062] It should of course be understood that not all vectors and expression control sequences will function equally well to express the DNA sequences described herein. Neither will all hosts function equally well with the same expression system. However, one of skill in the art may make a selection among these vectors, expression control sequences and hosts without undue experimentation. For example, in selecting a vector, the host must be considered because the vector must replicate in it. The vectors copy number, the ability to control that copy number, and the expression of any other proteins encoded by the vector, such as antibiotic markers, should also be considered. For example, preferred vectors for use in this invention include those that allow the DNA encoding the IL-2 variants to be amplified in copy number. Such amplifiable vectors are well known in the art.

Vectors and Host Cells

[0063] Accordingly, in some embodiments, vectors encoding the proteins described herein are provided, as well as host cells transformed with such vectors. Any nucleic acids encoding the proteins described herein may be contained in a vector, which can, for example, comprise a selectable marker and an origin of replication, for propagation in a host. In some embodiments, the vectors further include suitable transcriptional or translational regulatory sequences, such as those derived from a mammalian, microbial, viral, or insect genes, operably linked to the nucleic acid molecule encoding the protein. Examples of such regulatory sequences include transcriptional promoters, operators, or enhancers, mRNA ribosomal binding sites, and appropriate sequences that control transcription and translation. Nucleotide sequences are operably linked when the regulatory sequence functionally relates to the DNA encoding the target protein. Thus, a promoter nucleotide sequence is operably linked to a nucleic acid molecule if the promoter nucleotide sequence directs the transcription of the nucleic acid molecule.

[0064] The host cells that can be used here described herein.

PHARMACEUTICAL COMPOSITIONS

[0065] In another aspect, the present embodiments provide compositions, e.g., pharmaceutically acceptable compositions, which include a therapeutic compound (IL-2 mutein) described herein, formulated together with a pharmaceutically acceptable carrier. As used herein, “pharmaceutically acceptable carrier” includes any and all solvents, dispersion media, isotonic and absorption delaying agents, and the like that are physiologically compatible. The carrier can be suitable for intravenous, intramuscular, subcutaneous, parenteral, rectal, local, topical, spinal or epidermal administration (e.g. by injection or infusion).

[0066] The compositions of this invention may be in a variety of forms. These include, for example, liquid, semi-solid and solid dosage forms, such as liquid solutions (e.g., injectable and infusible solutions), dispersions or suspensions, liposomes and suppositories. The preferred form depends on the intended mode of administration and therapeutic application. Typical compositions are in the form of injectable or infusible solutions. In an embodiment the mode of administration is parenteral (e.g., intravenous, subcutaneous, intraperitoneal, intramuscular). In an embodiment, the therapeutic molecule is administered by intravenous infusion or injection. In another embodiment, the therapeutic molecule is administered by intramuscular or subcutaneous injection. In another embodiment, the therapeutic molecule is administered locally, e.g., by injection, or topical application, to a target site.

[0067] The phrases “parenteral administration” and “administered parenterally” as used herein means modes of administration other than enteral and topical administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, epidural and intrasternal injection and infusion.

[0068] Therapeutic compositions typically should be sterile and stable under the conditions of manufacture and storage. The composition can be formulated as a solution, microemulsion, dispersion, liposome, or other ordered structure suitable to high therapeutic molecule concentration. Sterile injectable solutions can be prepared by incorporating the active compound (i.e., therapeutic molecule) in the required amount in an appropriate solvent with one or a combination of ingredients enumerated above, as required, followed by filtered sterilization.

Generally, dispersions are prepared by incorporating the active compound into a sterile vehicle that contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum drying and freeze-drying that yields a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof. The proper fluidity of a solution can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. Prolonged absorption of injectable compositions can be brought about by including in the composition an agent that delays absorption, for example, monostearate salts and gelatin.

[0069] As will be appreciated by the skilled artisan, the route and/or mode of administration will vary depending upon the desired results. In certain embodiments, the active compound may be prepared with a carrier that will protect the compound against rapid release, such as a controlled release formulation, including implants, transdermal patches, and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Many methods for the preparation of such formulations are patented or generally known to those skilled in the art. See, e.g., *Sustained and Controlled Release Drug Delivery Systems*, J. R. Robinson, ed., Marcel Dekker, Inc., New York, 1978.

[0070] In certain embodiments, a therapeutic compound can be orally administered, for example, with an inert diluent or an assimilable edible carrier. The compound (and other ingredients, if desired) may also be enclosed in a hard or soft shell gelatin capsule, compressed into tablets, or incorporated directly into the subject's diet. For oral therapeutic administration, the compounds may be incorporated with excipients and used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. To administer a compound of the invention by other than parenteral administration, it may be necessary to coat the compound with, or co-administer the compound with, a material to prevent its inactivation. Therapeutic compositions can also be administered with medical devices known in the art.

[0071] Dosage regimens are adjusted to provide the optimum desired response (e.g., a therapeutic response). For example, a single bolus may be administered, several divided doses

may be administered over time or the dose may be proportionally reduced or increased as indicated by the exigencies of the therapeutic situation. It is especially advantageous to formulate parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers to physically discrete units suited as unitary dosages for the subjects to be treated; each unit contains a predetermined quantity of active compound calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier. The specification for the dosage unit forms of the invention are dictated by and directly dependent on (a) the unique characteristics of the active compound and the particular therapeutic effect to be achieved, and (b) the limitations inherent in the art of compounding such an active compound for the treatment of sensitivity in individuals.

[0072] An exemplary, non-limiting range for a therapeutically or prophylactically effective amount of a therapeutic compound is 0.1-30 mg/kg, more preferably 1-25 mg/kg. Dosages and therapeutic regimens of the therapeutic compound can be determined by a skilled artisan. In certain embodiments, the therapeutic compound is administered by injection (e.g., subcutaneously or intravenously) at a dose of about 1 to 40 mg/kg, e.g., 1 to 30 mg/kg, e.g., about 5 to 25 mg/kg, about 10 to 20 mg/kg, about 1 to 5 mg/kg, 1 to 10 mg/kg, 5 to 15 mg/kg, 10 to 20 mg/kg, 15 to 25 mg/kg, or about 3 mg/kg. The dosing schedule can vary from e.g., once a week to once every 2, 3, or 4 weeks, or, in some embodiments, the dosing schedule can be, once every month, every 2 months, every 3 months, or every 6 months. In one embodiment, the therapeutic compound is administered at a dose from about 10 to 20 mg/kg every other week. The therapeutic compound can be administered by intravenous infusion at a rate of more than 20 mg/min, e.g., 20-40 mg/min, and typically greater than or equal to 40 mg/min to reach a dose of about 35 to 440 mg/m², typically about 70 to 310 mg/m², and more typically, about 110 to 130 mg/m². In embodiments, the infusion rate of about 110 to 130 mg/m² achieves a level of about 3 mg/kg. In other embodiments, the therapeutic compound can be administered by intravenous infusion at a rate of less than 10 mg/min, e.g., less than or equal to 5 mg/min to reach a dose of about 1 to 100 mg/m², e.g., about 5 to 50 mg/m², about 7 to 25 mg/m², or, about 10 mg/m². In some embodiments, the therapeutic compound is infused over a period of about 30 min. It is to be noted that dosage values may vary with the type and severity of the condition to be alleviated. It is to be further understood that for any particular subject, specific dosage regimens should be adjusted over time according to the individual need and the professional judgment of the person

administering or supervising the administration of the compositions, and that dosage ranges set forth herein are exemplary only and are not intended to limit the scope or practice of the claimed composition.

[0073] The pharmaceutical compositions of the invention may include a “therapeutically effective amount” or a “prophylactically effective amount” of a therapeutic molecule of the invention. A “therapeutically effective amount” refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic result. A therapeutically effective amount of a therapeutic molecule may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the therapeutic compound to elicit a desired response in the individual. A therapeutically effective amount is also one in which any toxic or detrimental effects of a therapeutic molecule is outweighed by the therapeutically beneficial effects. A “therapeutically effective dosage” preferably inhibits a measurable parameter, e.g., immune attack at least about 20%, more preferably by at least about 40%, even more preferably by at least about 60%, and still more preferably by at least about 80% relative to untreated subjects. The ability of a compound to inhibit a measurable parameter, e.g., immune attack, can be evaluated in an animal model system predictive of efficacy in transplant rejection or autoimmune disorders. Alternatively, this property of a composition can be evaluated by examining the ability of the compound to inhibit, such inhibition in vitro by assays known to the skilled practitioner.

[0074] A “prophylactically effective amount” refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired prophylactic result. Typically, since a prophylactic dose is used in subjects prior to or at an earlier stage of disease, the prophylactically effective amount will be less than the therapeutically effective amount.

[0075] Also within the scope of the invention is a kit comprising a therapeutic compound described herein. The kit can include one or more other elements including: instructions for use; other reagents, e.g., a label, a therapeutic agent, or an agent useful for chelating, or otherwise coupling, a therapeutic molecule to a label or other therapeutic agent, or a radioprotective composition; devices or other materials for preparing the therapeutic molecule for administration; pharmaceutically acceptable carriers; and devices or other materials for administration to a subject.

[0076] Combinations

[0077] The proteins described herein can also be administered in conjunction with other agents useful for treating the condition with which the patient is suffering from. Examples of such agents include both proteinaceous and non-proteinaceous drugs. When multiple therapeutics are co-administered, dosages may be adjusted accordingly, as is recognized in the pertinent art. “Co-administration” and combination therapy are not limited to simultaneous administration, but also include treatment regimens in which a T-reg-selective IL-2 protein is administered at least once during a course of treatment that involves administering at least one other therapeutic agent to the patient.

[0078] In some embodiments, a T-reg-selective IL-2 protein is administered in combination with an inhibitor of the PI3-K/AKT/mTOR pathway, e.g., rapamycin (rapamune, sirolimus). Inhibitors of this pathway in combination with IL-2 favor T-reg enrichment. In some embodiments, the IL-2 protein is administered without another therapeutic that is not directly fused or attached to the IL-2 protein.

[0079] Therapeutic Methods

[0080] “Treatment” of any disease mentioned herein encompasses an alleviation of at least one symptom of the disease, a reduction in the severity of the disease, or the delay or prevention of disease progression to more serious symptoms that may, in some cases, accompany the disease or to at least one other disease. Treatment need not mean that the disease is totally cured. A useful therapeutic agent needs only to reduce the severity of a disease, reduce the severity of symptom(s) associated with the disease or its treatment, or delay the onset of more serious symptoms or a more serious disease that can occur with some frequency following the treated condition. For example, if the disease is an inflammatory bowel disease, a therapeutic agent may reduce the number of distinct sites of inflammation in the gut, the total extent of the gut affected, reduce pain and/or swelling, reduce symptoms such as diarrhea, constipation, or vomiting, and/or prevent perforation of the gut. A patient's condition can be assessed by standard techniques such as an x-ray performed following a barium enema or enteroclysis, endoscopy, colonoscopy, and/or a biopsy. Suitable procedures vary according to the patient's condition and symptoms.

In some embodiments, the proteins are used to treat inflammatory disorders. In some embodiments, the inflammatory disorder is inflammation, autoimmune disease, atopic diseases,

paraneoplastic autoimmune diseases, cartilage inflammation, arthritis, rheumatoid arthritis (*e.g.* active), juvenile arthritis, juvenile rheumatoid arthritis, pauciarticular juvenile rheumatoid arthritis, polyarticular juvenile rheumatoid arthritis, systemic onset juvenile rheumatoid arthritis, juvenile ankylosing spondylitis, juvenile enteropathic arthritis, juvenile reactive arthritis, juvenile Reiter's Syndrome, SEA Syndrome (Seronegativity, Enthesopathy, Arthropathy Syndrome), juvenile dermatomyositis, juvenile psoriatic arthritis, juvenile scleroderma, juvenile systemic lupus erythematosus, juvenile vasculitis, pauciarticular rheumatoid arthritis, polyarticular rheumatoid arthritis, systemic onset rheumatoid arthritis, ankylosing spondylitis, enteropathic arthritis, reactive arthritis, Reiter's Syndrome, SEA Syndrome (Seronegativity, Enthesopathy, Arthropathy Syndrome), dermatomyositis, psoriatic arthritis, scleroderma, vasculitis, myolitis, polymyolitis, dermatomyolitis, polyarteritis nodosa, Wegener's granulomatosis, arteritis, ploymyalgia rheumatica, sarcoidosis, sclerosis, primary biliary sclerosis, sclerosing cholangitis, Sjogren's syndrome, psoriasis, plaque psoriasis, guttate psoriasis, inverse psoriasis, pustular psoriasis, erythrodermic psoriasis, dermatitis, atopic dermatitis, dermatitis herpetiformis, Behcet's disease, including but not limited to the effects on the skin, alopecia, alopecia areata, alopecia totalis, atherosclerosis, lupus, Still's disease, Systemic Lupus Erythematosus (SLE) (*e.g.* active), myasthenia gravis, inflammatory bowel disease (IBD), Crohn's disease, ulcerative colitis, celiac disease, multiple sclerosis (MS), asthma, COPD, rhinosinusitis, rhinosinusitis with polyps, eosinophilic esophagitis, eosinophilic bronchitis, Guillain-Barre disease, Type I diabetes mellitus, thyroiditis(*e.g.*, Graves' disease), Addison's disease, Raynaud's phenomenon, autoimmune hepatitis, graft versus host disease, steroid refractory chronic graft versus host disease, transplantation rejection(*e.g.* kidney, lung, heart, skin, and the like), kidney damage, hepatitis C-induced vasculitis, spontaneous loss of pregnancy, alopecia, vitiligo, focal segmental glomerulosclerosis (FSGS), Minimal Change Disease, Membranous Nephropathy, ANCA Associated Glomerulonephropathy, Membranoproliferative Glomerulonephritis, IgA Nephropathy, lupus nephritis, and the like. In some embodiments, the proteins are used to treat steroid refractory chronic graft versus host disease. In some embodiments, the proteins are used to treat active systemic lupus erythematosus. In some embodiments, the proteins are used to treat active rheumatoid arthritis.

[0081] In some embodiments, the methods comprise administering a pharmaceutical composition comprising the proteins described herein to the subject. In some embodiments, the

subject is a subject in need thereof. Any of the above-described therapeutic proteins can be administered in the form of a compositions (*e.g.* pharmaceutical compositions) that are described herein. For example, a composition may comprise an IL-2 protein as described herein plus a buffer, an antioxidant such as ascorbic acid, a low molecular weight polypeptide (such as those having less than 10 amino acids), a protein, amino acids, carbohydrates such as glucose, sucrose, or dextrans, chelating agent such as EDTA, glutathione, and/or other stabilizers, excipients, and/or preservatives. The composition may be formulated as a liquid or a lyophilizate. Further examples of components that may be employed in pharmaceutical formulations are presented in Remington's Pharmaceutical Sciences, 16^{sup}.th Ed., Mack Publishing Company, Easton, Pa., (1980) and others as described herein.

[0082] To treat the disease of interest, the compositions comprising therapeutic molecules described herein can be administered by any appropriate method including, but not limited to, parenteral, topical, oral, nasal, vaginal, rectal, or pulmonary (by inhalation) administration. If injected, the composition(s) can be administered intra-articularly, intravenously, intraarterially, intramuscularly, intraperitoneally, or subcutaneously by bolus injection or continuous infusion. Localized administration, that is, at the site of disease, is contemplated, as are transdermal delivery and sustained release from implants, skin patches, or suppositories. Delivery by inhalation includes, for example, nasal or oral inhalation, use of a nebulizer, inhalation in aerosol form, and the like. Administration via a suppository inserted into a body cavity can be accomplished, for example, by inserting a solid form of the composition in a chosen body cavity and allowing it to dissolve. Other alternatives include eyedrops, oral preparations such as pills, lozenges, syrups, and chewing gum, and topical preparations such as lotions, gels, sprays, and ointments. In most cases, therapeutic molecules that are polypeptides can be administered topically or by injection or inhalation.

[0083] In the performance of the methods of treatment, the therapeutic molecules described above can be administered as described herein and above. For example, the composition can be administered at any dosage, frequency, and duration that can be effective to treat the condition being treated. The dosage depends on the molecular nature of the therapeutic molecule and the nature of the disorder being treated. Treatment may be continued as long as necessary to achieve the desired results. Therapeutic molecules of the invention can be administered as a single dosage or as a series of dosages given periodically, including multiple times per day, daily, every

other day, twice a week, three times per week, weekly, every other week, and monthly dosages, among other possible dosage regimens. The periodicity of treatment may or may not be constant throughout the duration of the treatment. For example, treatment may initially occur at weekly intervals and later occur every other week. Treatments having durations of days, weeks, months, or years are encompassed by the invention. Treatment may be discontinued and then restarted. Maintenance doses may or may not be administered after an initial treatment.

[0084] Dosage may be measured as milligrams per kilogram of body weight (mg/kg) or as milligrams per square meter of skin surface (mg/m²) or as a fixed dose, irrespective of height or weight. All of these are standard dosage units in the art. A person's skin surface area is calculated from her height and weight using a standard formula.

[0085] Also provided herein are methods of promoting stimulating STAT5 phosphorylation in T regulatory cells. In some embodiments, the methods comprise administering to a subject in need thereof a therapeutically effective amount of a peptide described herein or a pharmaceutical composition comprising the same.

[0086] As used herein, the phrase “in need thereof” means that the subject (animal or mammal) has been identified as having a need for the particular method or treatment. In some embodiments, the identification can be by any means of diagnosis. In any of the methods and treatments described herein, the animal or mammal can be in need thereof. In some embodiments, the animal or mammal is in an environment or will be traveling to an environment in which a particular disease, disorder, or condition is prevalent.

[0087] Unless defined otherwise, all technical and scientific terms have the same meaning as is commonly understood by one of ordinary skill in the art to which the embodiments disclosed belongs.

[0088] As used herein, the terms “a” or “an” means that “at least one” or “one or more” unless the context clearly indicates otherwise.

[0089] As used herein, the term “about” means that the numerical value is approximate and small variations would not significantly affect the practice of the disclosed embodiments. Where a numerical limitation is used, unless indicated otherwise by the context, “about” means

the numerical value can vary by $\pm 10\%$ and remain within the scope of the disclosed embodiments.

[0090] As used herein, the term “individual” or “subject,” or “patient” used interchangeably, means any animal, including mammals, such as mice, rats, other rodents, rabbits, dogs, cats, swine, cattle, sheep, horses, or primates, such as humans.

[0091] As used herein, the terms “comprising” (and any form of comprising, such as “comprise”, “comprises”, and “comprised”), “having” (and any form of having, such as “have” and “has”), “including” (and any form of including, such as “includes” and “include”), or “containing” (and any form of containing, such as “contains” and “contain”), are inclusive or open-ended and do not exclude additional, unrecited elements or method steps. Any step or composition that uses the transitional phrase of “comprise” or “comprising” can also be said to describe the same with the transitional phrase of “consisting of” or “consists.”

[0092] As used herein, the term “contacting” means bringing together of two elements in an in vitro system or an in vivo system. For example, “contacting” a peptide or composition described herein with a T-reg cell or with an individual or patient or cell includes the administration of the compound to an individual or patient, such as a human, as well as, for example, introducing a compound into a sample containing a cellular or purified preparation containing the T-reg cell.

[0093] As used herein, the term “fused” or “linked” when used in reference to a protein having different domains or heterologous sequences means that the protein domains are part of the same peptide chain that are connected to one another with either peptide bonds or other covalent bonding. The domains or section can be linked or fused directly to one another or another domain or peptide sequence can be between the two domains or sequences and such sequences would still be considered to be fused or linked to one another. In some embodiments, the various domains or proteins provided for herein are linked or fused directly to one another or a linker sequences, such as the glycine/serine sequences described herein link the two domains together.

[0094] In some embodiments, embodiments provided herein also include, but are not limited to:

1. A peptide comprising an amino acid sequence of SEQ ID NO: 1, wherein the peptide comprises a mutation at position 73, 76, 100, or 138.
2. The peptide of embodiment 1, wherein the mutation is a L to I mutation at position 73,

76, 100, or 138.

3. The peptide of embodiment 1, wherein the peptide further comprises a mutation at one or more of positions 49, 51, 55, 57, 68, 89, 91, 94, 108, and 145.
4. The peptide of embodiment 1, further comprising a mutation at one or more of positions E35, H36, Q42, D104, E115, or Q146 or 1, 2, 3, 4, 5, or each of E35, H36, Q42, D104, E115, or Q146 is wild-type.
5. The peptide of embodiment 4, wherein the mutation is one or more of E35Q, H36N, Q42E, D104N, E115Q, or Q146E.
6. The peptide of any one of embodiments 1-5, wherein the peptide comprises a N49S mutation.
7. The peptide of any one of embodiments 1-6, wherein the peptide comprises a Y51S or a Y51H mutation.
8. The peptide of any one of embodiments 1-7, wherein the peptide comprises a K55R mutation.
9. The peptide of any one of embodiments 1-8, wherein the peptide comprises a T57A mutation.
10. The peptide of any one of embodiments 1-9, wherein the peptide comprises a K68E mutation.
11. The peptide of any one of embodiments 1-10, wherein the peptide comprises a V89A mutation.
12. The peptide of any one of embodiments 1-11, wherein the peptide comprises a N91R mutation.
13. The peptide of any one of embodiments 1-12, wherein the peptide comprises a Q94P mutation.
14. The peptide of any one of embodiments 1-13, wherein the peptide comprises a N108D or a N108R mutation.
15. The peptide of any one of embodiments 1-14, wherein the peptide comprises a C145A or C145S mutation.
- 15.1. The peptide of any one of the embodiments 1-15, wherein the peptide comprises V89A, Q94P, N108R or N108D, and one or more of L73I, L76I, L100I, L118I mutations, and optionally C145A or C145S mutation.

16. A peptide comprising an amino acid sequence of SEQ ID NO: 2, wherein the peptide comprises a mutation at position 53, 56, 80, or 118.
17. The peptide of embodiment 16, wherein the mutation is a L to I mutation at position 53, 56, 80, or 118.
18. The peptide of embodiments 16 or 17, wherein the peptide further comprises a mutation at one or more of positions 29, 31, 35, 37, 48, 69, 71, 74, 88, and 125.
19. The peptide of embodiment 16, further comprising a mutation at one or more of positions E15, H16, Q22, D84, E95, or Q126 or 1, 2, 3, 4, 5, or each of positions E15, H16, Q22, D84, E95, or Q126 is wild-type.
20. The peptide of embodiment 19, wherein the mutation is one or more of E15Q, H16N, Q22E, D84N, E95Q, or Q126E.
21. The peptide of any one of embodiments 16-20, wherein the peptide comprises a N29S mutation.
22. The peptide of any one of embodiments 16-21, wherein the peptide comprises a Y31S or a Y51H mutation.
23. The peptide of any one of embodiments 16-22, wherein the peptide comprises a K35R mutation.
24. The peptide of any one of embodiments 16-23, wherein the peptide comprises a T37A mutation.
25. The peptide of any one of embodiments 16-24, wherein the peptide comprises a K48E mutation.
26. The peptide of any one of embodiments 16-25, wherein the peptide comprises a V69A mutation.
27. The peptide of any one of embodiments 16-26, wherein the peptide comprises a N71R mutation.
28. The peptide of any one of embodiments 16-27, wherein the peptide comprises a Q74P mutation.
29. The peptide of any one of embodiments 16-28, wherein the peptide comprises a N88D or a N88R mutation.
30. The peptide of any one of embodiments 16-29, wherein the peptide comprises a C125A or C125S mutation.

31. The peptide of any one of the embodiments 16-30, wherein the peptide comprises V69A, Q74P, N88R or N88D, and one or more of L53I, L56I, L80I, L118I mutations, and optionally C125A or C125S mutation.
32. The peptide of any of the preceding embodiments, wherein the peptide does not comprise a mutation that corresponds to positions 30, 31, and/or 35.
33. The peptide of any of the preceding embodiments, further comprising a Fc peptide.
- 33A. The peptide of embodiment 33, wherein the Fc peptide comprises a mutation at position, using the Kabat numbering L247, L248, and G250, or using the EU numbering at positions L234, L235, and G237.
- 33B. The peptide of embodiment 33, wherein the Fc peptide comprises the following mutations: L247A, L248A, and G250A (Kabat Numbering) or L234A L235A, and G237A (EU Numbering).
34. The peptide of embodiment 33, wherein the Fc peptide comprises the sequence of SEQ ID NO: 8 or SEQ ID NO: 15.
35. The peptide of any of the preceding embodiments, further comprising a linker peptide that links the peptide of SEQ ID NO: 1 or SEQ ID NO: 2 and the Fc peptide.
36. The peptide of embodiment 35, wherein the linker comprises a sequence of GGGGSGGGGSGGGGSGGGGS or GGGGSGGGGSGGGGS.
37. A peptide of any of the preceding embodiments, wherein the peptide comprises a sequence of SEQ ID NO: 17-43.
38. A peptide comprising an amino acid sequence of SEQ. ID. NO: 27.
39. The peptide of embodiment 38, further comprising a N-terminal leader peptide having the sequence of SEQ. ID. No: 7.
40. The peptide of embodiment 1, further comprising a linker peptide at the C-terminus.
41. The peptide of embodiment 40, wherein the linker peptide comprises the sequence of (GGGS)_n, wherein n is 1, 2, 3, or 4.
42. The peptide of embodiment 41, wherein n is 1.
43. The peptide of embodiment 41, wherein n is 2.
44. The peptide of embodiment 41, wherein n is 3.

45. The peptide of embodiment 41, wherein n is 4.
46. The peptide of any one of embodiments 48-45, further comprising a Fc peptide.
47. The peptide of embodiment 46, wherein the Fc peptide comprises the sequence of SEQ ID NO: 8 or SEQ ID NO: 15.
48. The peptide of embodiment 47, further comprising a leader peptide having the sequence of SEQ. ID. No: 7 at the N-terminus.
49. The peptide of embodiment 46, wherein the Fc peptide is at the C-terminus of the peptide comprising SEQ ID NO: 27.
50. The peptide of embodiment 46, wherein the Fc peptide is at the N-terminus of the peptide comprising SEQ ID NO: 27.
51. The peptide of embodiment 1, further comprising a linker peptide that links the peptide of SEQ ID NO: 27 and a Fc peptide.
52. The peptide of embodiment 51, wherein the linker peptide is (GGGGS)_n, wherein n is 1, 2, 3, or 4.
53. The peptide of embodiment 52, wherein n is 4.
54. The peptide of embodiments 51-53, wherein the Fc peptide comprises the sequence of SEQ ID NO: 8 or SEQ ID NO: 15.
55. The peptide of embodiments 51-54, wherein the Fc peptide is at the C-terminus of the peptide comprising SEQ ID NO: 27.
56. The peptide of embodiments 51-54, wherein the Fc peptide is at the N-terminus of the peptide comprising SEQ ID NO: 27.
57. The peptide of embodiment 14, wherein the peptide comprises a peptide comprising the sequence of SEQ ID NOs: 37, 38, 39, or 40.
58. A pharmaceutical composition comprising a peptide of any one of the preceding embodiments.
59. A method of activating T regulatory cells, the method comprising contacting a T regulatory cell with a peptide of any one of embodiments 1-57 or the pharmaceutical

composition of embodiment 58.

60. A method of treating an inflammatory disorder in a subject, said method comprising administering to a subject in need thereof a therapeutically effective amount of a peptide of any one of embodiments 1-57 or the pharmaceutical composition of embodiment 58.

61. The method of embodiment 60, wherein the inflammatory disorder is inflammation, autoimmune disease, atopic diseases, paraneoplastic autoimmune diseases, cartilage inflammation, arthritis, rheumatoid arthritis, juvenile arthritis, juvenile rheumatoid arthritis, pauciarticular juvenile rheumatoid arthritis, polyarticular juvenile rheumatoid arthritis, systemic onset juvenile rheumatoid arthritis, juvenile ankylosing spondylitis, juvenile enteropathic arthritis, juvenile reactive arthritis, juvenile Reiter's Syndrome, SEA Syndrome (Seronegativity, Enthesopathy, Arthropathy Syndrome), juvenile dermatomyositis, juvenile psoriatic arthritis, juvenile scleroderma, juvenile systemic lupus erythematosus, juvenile vasculitis, pauciarticular rheumatoid arthritis, polyarticular rheumatoid arthritis, systemic onset rheumatoid arthritis, ankylosing spondylitis, enteropathic arthritis, reactive arthritis, Reiter's Syndrome, SEA Syndrome (Seronegativity, Enthesopathy, Arthropathy Syndrome), dermatomyositis, psoriatic arthritis, scleroderma, vasculitis, myolitis, polymyolitis, dermatomyolitis, polyarteritis nodosa, Wegener's granulomatosis, arteritis, polymyalgia rheumatica, sarcoidosis, sclerosis, primary biliary sclerosis, sclerosing cholangitis, Sjogren's syndrome, psoriasis, plaque psoriasis, guttate psoriasis, inverse psoriasis, pustular psoriasis, erythrodermic psoriasis, dermatitis, atopic dermatitis, atherosclerosis, lupus, Still's disease, Systemic Lupus Erythematosus (SLE), myasthenia gravis, inflammatory bowel disease (IBD), Crohn's disease, ulcerative colitis, celiac disease, multiple sclerosis (MS), asthma, COPD, rhinosinusitis, rhinosinusitis with polyps, eosinophilic esophagitis, eosinophilic bronchitis, Guillain-Barre disease, Type I diabetes mellitus, thyroiditis (e.g., Graves' disease), Addison's disease, Raynaud's phenomenon, autoimmune hepatitis, graft versus host disease (GVHD), steroid refractory chronic graft versus host disease, transplantation rejection (e.g. kidney, lung, heart, skin, and the like), kidney damage, hepatitis C-induced vasculitis, spontaneous loss of pregnancy, alopecia, vitiligo, focal segmental glomerulosclerosis (FSGS), Minimal Change Disease, Membranous Nephropathy, ANCA Associated Glomerulonephropathy, Membranoproliferative Glomerulonephritis, IgA Nephropathy, lupus nephritis, and the like.

62. A method of promoting or stimulating STAT5 phosphorylation in T regulatory cells, said

method administering to a subject in need thereof a therapeutically effective amount of a peptide of any one of embodiments 1-57 or the pharmaceutical composition of embodiment 58.

63. Use of a peptide of any one of embodiments 1-57 or the pharmaceutical composition of embodiment 58 in the preparation of a medicament for the treatment of an inflammatory disorder.

64. The use of embodiment 63, wherein the inflammatory disorder is inflammation, autoimmune disease, atopic diseases, paraneoplastic autoimmune diseases, cartilage inflammation, arthritis, rheumatoid arthritis, juvenile arthritis, juvenile rheumatoid arthritis, pauciarticular juvenile rheumatoid arthritis, polyarticular juvenile rheumatoid arthritis, systemic onset juvenile rheumatoid arthritis, juvenile ankylosing spondylitis, juvenile enteropathic arthritis, juvenile reactive arthritis, juvenile Reiter's Syndrome, SEA Syndrome (Seronegativity, Enthesopathy, Arthropathy Syndrome), juvenile dermatomyositis, juvenile psoriatic arthritis, juvenile scleroderma, juvenile systemic lupus erythematosus, juvenile vasculitis, pauciarticular rheumatoid arthritis, polyarticular rheumatoid arthritis, systemic onset rheumatoid arthritis, ankylosing spondylitis, enteropathic arthritis, reactive arthritis, Reiter's Syndrome, SEA Syndrome (Seronegativity, Enthesopathy, Arthropathy Syndrome), dermatomyositis, psoriatic arthritis, scleroderma, vasculitis, myolitis, polymyolitis, dermatomyolitis, polyarteritis nodosa, Wegener's granulomatosis, arteritis, polymyalgia rheumatica, sarcoidosis, sclerosis, primary biliary sclerosis, sclerosing cholangitis, Sjogren's syndrome, psoriasis, plaque psoriasis, guttate psoriasis, inverse psoriasis, pustular psoriasis, erythrodermic psoriasis, dermatitis, atopic dermatitis, atherosclerosis, lupus, Still's disease, Systemic Lupus Erythematosus (SLE), myasthenia gravis, inflammatory bowel disease (IBD), Crohn's disease, ulcerative colitis, celiac disease, multiple sclerosis (MS), asthma, COPD, rhinosinusitis, rhinosinusitis with polyps, eosinophilic esophagitis, eosinophilic bronchitis, Guillain-Barre disease, Type I diabetes mellitus, thyroiditis(e.g., Graves' disease), Addison's disease, Raynaud's phenomenon, autoimmune hepatitis, graft versus host disease (GVHD), steroid refractory chronic graft versus host disease, transplantation rejection(e.g. kidney, lung, heart, skin, and the like), kidney damage, hepatitis C-induced vasculitis, spontaneous loss of pregnancy, alopecia, vitiligo, focal segmental glomerulosclerosis (FSGS), Minimal Change Disease, Membranous Nephropathy, ANCA Associated Glomerulonephropathy, Membranoproliferative Glomerulonephritis, IgA Nephropathy, lupus nephritis, and the like.

- 65. A nucleic acid molecule encoding a peptide of any one of embodiments 1-57.
- 66. A vector comprising the nucleic acid molecule of embodiment 65.
- 67. A plasmid comprising the nucleic acid molecule of embodiment 65.
- 68. A cell comprising the nucleic acid molecule of embodiment 65.
- 69. A cell comprising the plasmid of embodiment 67.
- 70. A cell comprising the vector of embodiment 66.
- 71. A cell comprising or expressing a peptide of any one of embodiments 1-57 or a peptide as described herein.

[0095] The following examples are illustrative, but not limiting, of the compounds, compositions and methods described herein. Other suitable modifications and adaptations known to those skilled in the art are within the scope of the following embodiments.

EXAMPLES

[0096] Example 1:

[0097] A therapeutic composition comprising a protein of SEQ ID NOs: 11, 12, 13, or 14 is administered to a subject suffering from IBD. The subject's immune system is down-regulated and the symptoms of the IBD are alleviated.

[0098] Example 2:

[0099] A therapeutic composition comprising a protein of SEQ ID NOs: 3, 4, 5, or 6, with or without the leader sequence, is administered to a subject suffering from IBD. The subject's immune system is down-regulated and the symptoms of the IBD are alleviated.

[00100] Example 3: Generation of IL-muteins

[00101] A pTT5 vector containing the single gene encoding the human IL-2M polypeptide fused N-terminally (SEQ ID NO: 40) or C-terminally (SEQ ID NO: 41) to human IgG1 Fc domain was transfected into HEK293 Expi cells. After 5-7 days, cell culture supernatants expressing IL-2Ms were harvested, and clarified by centrifugation and filtered through a 0.22um filtration device. IL-2Ms were captured on proA resin. The resin was washed with PBS pH 7.4 and the captured protein was eluted using 0.25% acetic acid pH 3.5, with neutralization using a tenth volume of 1M Tris pH 8.0. The protein was buffer exchanged into 30mM HEPES 150mM NaCl pH 7, and analyzed by size exclusion chromatography on a Superdex 200 3.2/300 column.

Analysis of 5ug of purified material by reducing and non-reducing SDS-PAGE on a Bis-Tris 4-12% gel was conducted. The IL-2Ms were expressed at over 10mg/L, and were over 95% monodispersed after purification as shown by size exclusion chromatography and reducing/non-reducing SDS-PAGE.

[00102] Example 4: IL-2M Molecules can bind CD25

[00103] An immunosorbent plate was coated with CD25 at a concentration of 0.5 µg/mL in PBS pH 7.4, 75 ul/well, and incubated overnight at 4°C. Wells were washed with PBS pH 7.4 containing 0.05% Tween-20 (wash buffer) three times, and then blocked with 200ul/well 1% BSA in PBS pH 7.4 (block buffer) for two hours at room temperature. After three washes with wash buffer IL-2M molecules were diluted to eleven –two fold serial dilution in PBS containing 1% BSA and 0.05% Tween-20 (assay buffer) with 2nM being the highest concentration. The diluted material was added to the CD25 coated plate at 75ul/well for 1 hour at room temperature. After three washes with wash buffer, a goat biotinylated anti-IL-2 polyclonal antibody, diluted to 0.05 µg/mL in assay buffer, was added to the plate at 75ul/well for 1 hr at room temperature. After three washes with wash buffer streptavidin HRP diluted in assay buffer at 1:5000 was added to the plate at 75ul / well for 15 minutes at room temperature. After three washes with wash buffer and 1 wash with wash buffer (with no tween-20), the assay was developed with TMB, and stopped with 1N HCL. OD 450nm was measured. The experiment included appropriate controls for non-specific binding of IL-2M molecules to the plate/block in the absence of CD25 and a negative control molecule that is unable to bind CD25.

[00104] The results indicate that at concentrations of 2nM-1.9pM, IL-2M molecules are able to bind CD25 with sub nanomolar EC50s. Additionally, there was no detection of any compound at any concentration tested, when CD25 was not present on the plate surface, indicating none of the test compounds were interacting non-specifically with the plate surface (data not shown).

[00105] Example 5: In Vitro P-STAT5 Assay To Determine Potency and Selectivity of IL-2M Molecules. Peripheral blood mononuclear cells (PBMCs) were prepared using FICOLL-PAQUE Premium and Sepmate tubes from freshly isolated heparinized human whole blood. PBMCs were cultured in 10% fetal bovine serum RPMI medium in the presence of wild-type IL-2 or IL-2M of Example 12 for 20 minutes and then fixed for 10 minutes with BD Cytofix.

[00106] Fixed cells were sequentially permeabilized with BD Perm III and then BioLegend FOXP3 permeabilization buffer. After blocking with human serum for 10 minutes, cells were stained for 30 minutes with antibodies for phospho-STAT5 FITC, CD25 PE, FOXP3 AF647 and CD4 PerCP Cy5.5 and then acquired on an Attune NXT with plate reader. The IL-2M of SEQ ID NO: 23 potently and selectively induces STAT5 phosphorylation in Tregs but not Teffs.

[00107] Example 6: Immunogenicity of IL-2 muteins

[00108] IL-2 Mutein Mutant sequences were analyzed using the NetMHCIIpan 3.2 software, which can be found at [www “dot” cbs “dot” dtu “dot” dk/services/NetMHCIIpan/](http://www.cbs.dtu.dk/services/NetMHCIIpan/). Artificial neural networks were used to determine peptide affinity to MHC class II alleles. In that analysis, 9-residue peptides with potentially direct interaction with the MHC class II molecules were recognized as binding cores. Residues adjacent to binding cores, with potential to influence the binding indirectly, were also examined as masking residues. Peptides comprising both the binding cores and masking residues were marked as strong binders when their predicted K_D to the MHC class II molecule was lower than 50 nM. Strong binders have a greater chance of introducing T cell immunogenicity.

[00109] A total of 9 MHCII alleles that are highly represented in North America and Europe were included in the *in silico* analysis. The panel of IL-2M (IL-2 muteins) molecules tested included the IL-2 Muteins with L53I, L56I, L80I, or L118I mutations. Only MHCII alleles DRB1_1101, DRB1_1501, DRB1_0701, and DRB1_0101 yielded hits with any of the molecules assessed. The peptide hits for DRB1_1501 were identical between all constructs tested including wild-type IL-2 with the C125S mutation. The addition of L80I removes 1 T cell epitope for DRB1-0101 [ALNLAPSKNFHLRPR] and modestly reduces the affinity of two other T cell epitopes [EEALNLAPSKNFHLR and EALNLAPSKNFHLRP]. For MHCII allele DRB1-0701, L80I removes 1 T cell epitope [EEALNLAPSKNFHLR]. Therefore, the data demonstrates that a IL-2 mutein comprising the L80I mutation should be less immunogenic, which is a surprising and unexpected result from the *in silico* analysis.

[00110] Example 7: Generation of Additional IL-2 Muteins

[00111] A pTT5 vector containing the single gene encoding the single IL-2M (IL-2 mutein) SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40 (and IL-2M

control; SEQ ID NO: 34) polypeptide with human IL-2M or IL-2M fused N-terminally of human IgG1 Fc domain was transfected into HEK293 Expi cells. After 5-7 days, cell culture supernatants expressing SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40 (and IL-2M control; SEQ ID NO: 34) were harvested, and clarified by centrifugation and filtration through a 0.22um filtration device. SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40 (and IL-2M control; SEQ ID NO: 34) were captured on proA resin. The resin was washed with PBS pH 7.4 and the captured protein was eluted using 0.25% acetic acid pH 3.5, with neutralization using a tenth volume of 1M Tris pH 8.0. The protein was buffer exchanged into 30mM HEPES 150mM NaCl pH 7, and analyzed by size exclusion chromatography on a Superdex 200 3.2/300 column. Analysis of 5ug of purified material by reducing and non-reducing SDS-PAGE on a Bis-Tris 4-12% gel was conducted.

[00112] IL-2Ms SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40 (and IL-2M control; SEQ ID NO: 34) expressed at over 45mg/L, and were over 95% monodispersed after purification as shown by size exclusion chromatography and reducing/non-reducing SDS-PAGE.

[00113] Example 8: IL-2Ms can bind CD25

[00114] An immunosorbent plate was coated with CD25 at a concentration of 0.5 µg/mL in PBS pH 7.4, 75 ul/well, and incubated overnight at 4°C. Wells were washed with PBS pH 7.4 containing 0.05% Tween-20 (wash buffer) three times, and then blocked with 200ul/well 1% BSA in PBS pH 7.4 (block buffer) for two hours at room temperature. After three washes with wash buffer IL-2Ms SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40 were diluted to eleven –two fold serial dilution in PBS containing 1% BSA and 0.05% Tween-20 (assay buffer) with 2nM being the highest concentration. The diluted material was added to the CD25 coated plate at 75ul/well for 1 hour at room temperature. After three washes with wash buffer, a goat biotinylated anti-IL-2 polyclonal antibody, diluted to 0.05 µg/mL in assay buffer, was added to the plate at 75ul/well for 1 hr at room temperature. After three washes with wash buffer high sensitivity streptavidin HRP diluted in assay buffer at 1:5000 was added to the plate at 75ul / well for 15 minutes at room temperature. After three washes with wash buffer and 1 wash with wash buffer (with no tween-20), the assay was developed with TMB, and stopped with 1N HCL. OD 450nm was measured. The experiment included appropriate controls for

non-specific binding of the molecules to the plate/block in the absence of CD25. The results indicate that at concentrations of 2nM-1.9pM, the muteins of Example 7 were able to bind CD25 with sub nanomolar EC50s. Additionally, there was no detection of any compound at any concentration tested, when CD25 was not present on the plate surface, indicating none of the test compounds were interacting non-specifically with the plate surface. Thus, the muteins of Example 7 can bind to CD25.

[00115] Example 9: IL-2 Muteins of Example 7 are Potent and Selective

[00116] Peripheral blood mononuclear cells (PBMCs) were prepared using FICOLL-PAQUE Premium and Sepmate tubes from freshly isolated heparinized human whole blood. PBMCs were cultured in 10% fetal bovine serum RPMI medium in the presence of wild-type IL-2 or the muteins of Example 7 for 20 minutes and then fixed for 10 minutes with BD Cytofix. Fixed cells were sequentially permeabilized with BD Perm III and then BioLegend FOXP3 permeabilization buffer. After blocking with human serum for 10 minutes, cells were stained for 30 minutes with antibodies for phospho-STAT5 FITC (CST), CD25 PE, FOXP3 AF647 and CD4 PerCP Cy5.5 (all BD) and then acquired on an Attune NXT with plate reader. The IL-2 muteins of Example 7 were found to be potent and have selectivity against Treg versus Teff. The mutein comprising the L118I mutation was found to have increased activity and selectivity as compared to the other muteins.

[00117] Example 10: IL-2 muteins Expand Tregs in Humanized Mice

[00118] NSG mice humanized with human CD34+ hematopoietic stem cells were purchased from Jackson Labs. On days 0 and 7, the mice were dosed subcutaneously with 1ug IL-2Mutein SEQ ID NO: 34 or other IL-2 muteins SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, or SEQ ID NO: 40. On Day 7, mice were euthanized and whole blood and spleens were collected. Whole blood was aliquoted into a 96 well deep well plate and fixed for 10 minutes using BD Fix Lyse. Splenocytes were isolated using 70um filters (BD) and red blood cells were lysed using RBC lysis buffer from BioLegend. After washing with 2% fetal bovine serum PBS, splenocytes were labeled with near infrared live dead stain (Invitrogen) for 20 minutes and then fixed for 20 minutes using BioLegend fixation buffer. Both whole blood cells and splenocytes were then permeabilized using BioLegend FOXP3 permeabilization buffer, blocked with human serum and stained for 30 minutes with antibodies against human CD8a FITC (BL), human CD25

PE (BD), human FOXP3 AF647 (BD) CD4 PerCP Cy5.5 (BD), human Siglec-8 PE Cy7 (BL), human CD3 BV421 (BL), human CD45 BV605 (BL), human CD56 BV785 (BL) and mouse CD45 (BV711) and acquired on an Attune NXT with plate loader.

[00119] Compared to vehicle control, IL-2Ms SEQ ID NO: 37 and SEQ ID NO: 38 and SEQ ID NO: 39 and SEQ ID NO: 40 selectively induced human Tregs in mouse spleens and whole blood in humanized mice. There were no significant changes in the frequencies of human CD56pos NK cells, CD3pos T cells, CD8pos cytotoxic T lymphocytes, CD4pos helper T cells or CD25lo/FOXP3neg T effectors. These results demonstrate that the IL-2 muteins increase the frequency of regulatory T cells.

[00120] Example 11: Durability of Signaling induced by IL-2 muteins

[00121] Peripheral blood mononuclear cells (PBMCs) were prepared using FICOLL-PAQUE Premium and Sepmate tubes from freshly isolated heparinized human whole blood. PBMCs were cultured in 10% fetal bovine serum RPMI medium in the presence of IL-2M for 60 minutes. Cells were then wash 3 times and incubated for an additional 3 hours. Cells were then fixed for 10 minutes with BD Cytotfix. Fixed cells were sequentially permeabilized with BD Perm III and then BioLegend FOXP3 permeabilization buffer. After blocking with human serum for 10 minutes, cells were stained for 30 minutes with antibodies for phospho-STAT5 FITC, CD25 PE, FOXP3 AF647 and CD4 PerCP Cy5.5 and then acquired on an Attune NXT with plate reader. All four IL-2 muteins of Example 19 induced durable signaling in Treg but not in Teff as compared to the control. SEQ ID NO: 40 is superior to SEQ ID NO: 39, SEQ ID NO: 38 or SEQ ID NO: 37. These results demonstrate that the IL-2 can induce durable and selective signaling in Treg which should lead to greater Treg expansion in vivo and permit less frequent dosing to achieve Treg expansion.

[00122] The examples provided for herein demonstrate the surprising and unexpected result that a IL-2 mutein can function to selectively and potently activate Tregs over Teffs, which demonstrates that the molecules can be used to treat or ameliorate the conditions described herein. The IL-2 muteins, as provided for herein, can also be generated and used with or without being fused to a Fc domain or a linker as provided for herein.

[00123] The embodiments has been described with reference to specific examples. These examples are not meant to limit the embodiments in any way. It is understood for purposes of

this disclosure, that various changes and modifications may be made that are well within the scope of the present disclosure. Numerous other changes may be made which will readily suggest themselves to those skilled in the art and which are encompassed in the spirit of the invention disclosed herein and as defined in the appended claims.

[00124] Example 12: Muteins exhibit overall POI and lower aggregation.

[00125] IL-2 muteins with the mutations of V69A, Q74P, N88D, and C125S and one of the following mutations L53I, L56I, L80I, or L118I linked to a Fc region comprising L234A, L235A, and G237A mutations as provided for herein were expressed in a pTT5 vector by transfecting the vector into HEK293 Expi cells. The IL-2 mutein was linked to the N-terminus of the Fc region with 4 GGGGS repeats. After 5-7 days, cell culture supernatants expressing the different IL-2 muteins were harvested, and clarified by centrifugation and filtration through a 0.22um filtration device. The IL-2 muteins were captured on proA resin. The resin was washed with PBS pH 7.4 and the captured protein was eluted using 0.25% acetic acid pH 3.5, with neutralization using a tenth volume of 1M Tris pH 8.0. The protein was buffer exchanged into 30mM HEPES 150mM NaCl pH 7, and analyzed by size exclusion chromatography on an AdvanceBio SEC column for percent peak of interest (POI). The results demonstrated that the different muteins were expressed at over 60mg/L. However, it was surprisingly found that muteins with the L80I or L118I mutation were greater than 90% monodispersed while muteins with the L53I or L56I mutations were not as shown by size exclusion chromatography. Thus, the muteins with the L80I or L118I substitution had less aggregation. The differences in aggregation amongst the four molecules (IL-2 muteins comprising L80I, L118I, L53I, and L56I) were surprising due to the type of mutation that was being made. Therefore, the muteins with the L80I or the L118I mutation have a surprising advantage over other muteins in that it does not aggregate as much as other muteins.

[00126] Example 13: IL-2 Muteins Have Unexpected Increase in Potency

[00127] The muteins described in Example 12 were analyzed for potency in an *in vitro* assay. Briefly, PBMCs were isolated from heparinized human whole blood and stimulated with the different muteins at a concentration for 30 min at 37 C. The stimulation was stopped by fixation. After permeabilization, PBMCs were stained for intracellular FoxP3 and phospho-STAT5 levels and surface CD4 and CD25 expression and analyzed by flow cytometry.

Regulatory T cells (Tregs) and effector T cells (Teffs) were gated as CD4+CD25hiFoxP3+ or CD4+CD25loFoxP3-, respectively. The percent of cells that stained positive for phospho-STAT5 is shown. This assay measures the ability of the muteins to specifically stimulate Tregs without stimulating Teffs. A best-fit dose-response curve for each test article was used to calculate an EC50 value.

[00128] Surprisingly, the muteins with the mutations of L118I, L80I, L56I, or L53I had increased potency (stimulating Tregs) as compared to an IL-2 mutein without any of these mutations. The IL-2 mutein without a mutation of L118I, L80I, L56I, or L53I, but having the V69A, Q74P, and N88D mutations was approximately 51 pM. Each of the EC₅₀s for the muteins comprising one of L118I, L80I, L56I, or L53I had EC₅₀s of approximately 30, 40, 41, and 45, respectively. The differences in EC50 for stimulating Tregs (with no changes in Teff stimulation) was surprising and would not have been predicted for the muteins having one of the mutations described in this example. The data can also be evaluated by comparing the ratio of the parent IL-2 muteins (comprising V69A, Q74P, N88D, and C125S) to the muteins that also comprise one of L118I, L80I, L56I, or L53I mutations. Using this ratio normalizes for different cell populations that are used for different experiments. Using this ratio the L118I had an average increase of approximately 25% more potency (standard error of mean 0.16) as compared to the parent control, whereas the other mutations had a decrease in activity as compared to the parent control using this ratio.

[00129] The *in vitro* data was confirmed *in vivo* for the muteins having one of L118I, L80I, L56I, or L53I mutations. L118I was found to be more potent than a mutein without the L118I mutation *in vivo*. Briefly, Nod-Scid-IL-2Rgamma-deficient (NSG) mice reconstituted with human CD34+ hematopoietic stem cells were injected subcutaneously with 1 microgram of the indicated test article or vehicle on days 0 and 7. On Day 11, mice were killed and blood was collected by cardiac puncture into tubes containing heparin. Peripheral blood leukocytes (PBLs) were isolated by lysis of red blood cells and stained with antibodies reactive to the human markers CD45, CD3, CD8, CD4, FoxP3, CD25 and CD56. The percent of human regulatory T cells (Tregs, CD45+CD3+CD4+CD25+FoxP3+), activated effector T cells (act Teff, CD45+CD3+CD4+CD25+FoxP3-) and NK cells (CD45+CD56+) was determined by flow cytometry. The frequency of total CD45+, total CD4+ and total CD8+ cells did not change. Similar results were observed in the spleens of mice. The *in vivo* potency as measured in this

assay of the IL-2 mutein with the L80I mutation was slightly increased as compared to a mutein without the L80I mutation and the *in vivo* potency as measured in this assay of the muteins with either the L56I or the L53I mutation was about the same as a mutein without the mutations. The muteins were N-terminal linked to a Fc region as described herein with a 20 amino acid (GGGGS)₄ linker. That is the linker connected the C-terminus of the IL-2 mutein to the N-terminus of the Fc region.

[00130] Example 14: N-terminal Fc Orientation with a 20 Amino Acid Linker is Most Effective at Stimulating Tregs. An IL-2 mutein with V69A, Q74P, and N88D was fused to a Fc region comprising the mutations of L234A, L235A and G237A mutation using different lengths of GGGGS repeats. IL2-Mutein molecules fused via the c-terminus of the mutein to the n-terminus of human IgG1 Fc with linkers comprising 3 and 4 GGGGS repeats were tested to determine if the length of the linker affected the potency of the IL-2 mutein. A mutein fused via its n-terminus to the c-terminus of human IgG1 Fc with a single GGGGS repeat was also tested. Briefly, Nod-Scid-IL-2Rgamma-deficient (NSG) mice reconstituted with human CD34+ hematopoietic stem cells were injected subcutaneously with 1 microgram of the different IL-2 muteins with different linker lengths or vehicle on day 0. On Day 7, mice were sacrificed and blood was collected by cardiac puncture into tubes containing heparin. Peripheral blood leukocytes (PBLs) were isolated by lysis of red blood cells and stained with antibodies reactive to the human markers CD45, CD3, CD8, CD4, FoxP3, CD25 and CD56. The percent of human regulatory T cells (Tregs, CD45+CD3+CD4+CD25+FoxP3+), activated effector T cells (act Teff, CD45+CD3+CD4+CD25+FoxP3-) and NK cells (CD45+CD56+) was determined by flow cytometry. The frequency of total CD45+, total CD4+ and total CD8+ cells did not change. Similar results were observed in the spleens of mice.

[00131] It was found that the mutein fused at the N-terminus of the human IgG1 Fc with a linker comprising 4 GGGGS repeats was the most potent as compared to a mutein with a linker that only had 3 GGGGS repeats or a mutein fused at the c-terminus of the human IgG1 Fc with a single GGGGS repeat. Additionally, although the protein with the 4 GGGGS repeats was more effective at expanding Tregs, the configuration did not trigger any differential expansion of CD56+ NK cells. It could not have been predicted that protein with N-terminally Fc fused mutein with the longer linker would be the most potent and also not trigger any differential expansion of CD56+ NK cells.

[00132] Example 15: Treating Patients with Active Rheumatoid Arthritis.

[00133] A pharmaceutical composition comprising a IL-2 mutein protein comprising a sequence of SEQ ID NO: 37, 38, 39, or 40 are administered to patients with active rheumatoid arthritis. The IL-2 muteins are found to be effective in treating active rheumatoid arthritis in the patients.

[00134] Example 16: Treating Patients with Subjects With Active Systemic Lupus Erythematosus.

[00135] A pharmaceutical composition comprising a IL-2 mutein protein comprising a sequence of SEQ ID NO: 37, 38, 39, or 40 are administered to patients with active systemic lupus erythematosus. The IL-2 muteins are found to be effective in treating active systemic lupus erythematosus.

[00136] Example 17: Treating Patients with Subjects With Steroid Refractory Chronic Graft Versus Host Disease.

[00137] A pharmaceutical composition comprising a IL-2 mutein protein comprising a sequence of SEQ ID NO: 37, 38, 39, or 40 are administered to patients with Steroid refractory chronic graft versus host disease. The IL-2 muteins are found to be effective in treating steroid refractory chronic graft versus host disease.

[00138] Example 18: IL-2 muteins induce pSTAT5 in Human Tregs. Purified PBMC from heparinized whole blood from six healthy donors were treated with serial dilutions of a IL-2 mutein protein comprising a sequence of SEQ ID NO: 39 or 40 at 37 C for 30 minutes. Cells were fixed, washed, permeabilized and washed. Cells were stained with antibodies that detect both surface markers and intracellular/nuclear markers (pSTAT5 and FOXP3). Data was collected on Attune NxT cytometer. Tregs were gated as mononuclear, singlet, CD3pos, CD4pos, CD25hi, FoxP3pos. The % of gated Tregs that express phosphorylated STAT5 was measured. Best-fit curves were fit to the dose-response of pSTAT5 and EC50 values were determined. Average EC50 values of all 6 donors were determined for IL-2 of SEQ ID NO 39 (37.26 ± 7.30 ; n=16) and for IL-2 of SEQ ID NO: 40 (23.11 ± 5.35 ; n=15). The data demonstrate that the IL-2 muteins can induce pSTAT5 in human Tregs. The IL-2 comprising a

sequence of SEQ ID NO: 40 is more potent than the IL-2 sequence comprising SEQ ID NO: 39, but both are active across multiple populations of cells.

[00139] Example 19: IL-2 muteins induce pSTAT5 in monkey PBMCs *in vitro*. Purified PBMC from heparinized whole blood from three healthy monkeys were treated with serial dilutions a IL-2 mutein protein comprising a sequence of SEQ ID NO: 39 or 40 at 37 C for 60 minutes. Fluorochrome conjugated Anti-CD25 and anti-CD4 were added for the final 30 min of of the IL-2 mutein treatment. Cells were fixed, washed, permeabilized and washed. Cells were stained with remaining antibodies that detect both surface markers and intracellular/nuclear markers (pSTAT5 and FOXP3). Data was collected on Attune NxT cytometer. Tregs were gated as mononuclear, singlet, CD4pos, CD25hi, FoxP3pos. The % of gated Tregs that express phosphorylated STAT5 was measured. The IL-2 muteins were found to induce pSTAT5 in monkeys.

[00140] Example 20: IL-2 muteins induce expand Treg cells and induce Treg proliferation *in vivo*. Venous whole blood was collected in K2EDTA tubes from monkeys (cynomolgus) before dosing with IL-2 muteins of SEQ ID NO: 39 or 40 (2 timepoints/cyno, 5 cynos) and after dosing with either SEQ ID NO: 39 (5 timepoints/cyno, 2 cynos) or SEQ ID NO: 40 (5 timepoints/cyno, 3 cynos). Samples were divided in two and stained for two FACS panels separately. One was a “Treg panel” and one was a general immunophenotyping panel. RBCs were lysed and cells were stained for surface and intracellular markers after fixation and permeabilization. For the FACS analysis the number of total cells/ul was determined by ADVIA. The number of cells of a given subpopulation/ul was then calculated with the total number/ul and the % of total. For each monkey, the average number of a given cell type/ul of the two pre-dose bleeds was averaged and used to normalize the post-dose bleeds, such that “fold-change from pre-dose” was determined. To analyze serum cytokines and chemokines, plasma from K2EDTA whole blood was frozen until the end of the study. Chemokine and cytokine amounts were quantified by a multiplex MSD assay using serial dilutions of a standard control. The average and range of MCP-1 and IP-10 were determined in pre-dose bleeds. Both muteins were found to expand Treg and induce Treg proliferation in the monkeys. These results demonstrate that the IL-2 muteins function in an *in vivo* animal model that is similar to humans. It was also found that neither molecule significantly expanded Tconv cells, CD4 cells (Tnaive) or CD8 cells (Cytotoxic T), NK cells in the monkeys (non-human primate). It was also found that neither

molecule significantly induced Serum chemokines. This data demonstrates that the IL-2 muteins can expand Treg cells and induce Treg cell proliferation without unwanted expansion or activation of other pathways. Thus, the IL-2 muteins are surprisingly potent, effective, and selective for Treg expansion and proliferation.

[00141] In summary, the embodiments and examples provided herein demonstrate that the IL-2 muteins can function as intended and be used to treat the diseases and conditions described herein.

[00142] This specification contains numerous citations to patents, patent applications, and publications. Each is hereby incorporated by reference for all purposes.