

CHIMERIC POLYPEPTIDES AND METHODS OF ALTERING THEIR LOCALISATION IN THE CELL MEMBRANE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of Singapore application no. 11201908618S, the entire content of which is incorporated herein by reference.

This application claims priority to U.S. Provisional Patent Application Serial No. 62/477,733, filed March 28, 2017, and U.S. Provisional Patent Application Serial No. 62/587,262, filed November 16, 2017; the entire contents of which are herein incorporated by reference.

TECHNICAL FIELD

The present disclosure relates to the field of biotechnology, and more specifically, to the regulation of the cellular localization of a chimeric polypeptide.

BACKGROUND

Chimeric antigen receptors (CARs) are a subclass of single-chain and multi-chain polypeptides. Chimeric antigen receptors typically include, e.g., an antigen-binding domain, a transmembrane domain, a co-stimulatory domain, and a CD3 ζ or other signaling domain. CARs have been investigated for use in the clinical treatment of different cancers, e.g., hematological cancers, in mammals with considerable success. A limiting factor, however, has been uncontrollable toxicity associated with CAR anticancer activity.

Nuclear hormone receptors are class of polypeptides that include several domains, including a DNA-binding motif and a ligand-binding domain. In the absence of ligand, naturally-occurring nuclear hormone receptors associate with various chaperones and other interacting proteins which sequester the nuclear hormone receptor outside of the nucleus. Ligand binding induces changes in nuclear hormone receptor conformation and interaction partners and allows the nuclear translocation and transcriptional activation or repression of nuclear hormone target genes. While the classical view of steroid signaling holds that these hormones bind intracellular receptors that act as ligand-activated

transcription factors, it has been reported that steroids may also act by a non-genomic mechanism at the cell surface.

SUMMARY

The present disclosure is based, at least in part, on the discovery that the reversible extracellular membrane localization of chimeric polypeptides that include a transmembrane domain can be utilized for medical applications where it is desired to have reversibly expressed on the extracellular membrane a protein or peptide of interest. An exemplary feature of the present disclosure is that the toxicity associated with CAR T cells can be regulated by reversibly expressing on their surface an antigen binding domain of a CAR.

The present disclosure is further based, at least in part, on the discovery that the plasma membrane localization or extracellular membrane localization of chimeric polypeptides that include a transmembrane domain and a hormone receptor ligand binding domain, where the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to about 700 amino acids (e.g., 1 to about 500 amino acids), and the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal (e.g., a single-chain chimeric antigen receptor), in a mammalian cell can be regulated by contacting the mammalian cell with a hormone or a hormone analogue. In view of this discovery, provided herein are: single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and multi-chain chimeric antigen receptors; nucleic acids encoding the same; vectors including any of these nucleic acids; mammalian cells including any of these vectors; and methods of reversibly inducing the extracellular membrane localization and methods of altering the membrane localization of these single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and multi-chain chimeric polypeptides.

In some embodiments, reversibly inducing the plasma membrane localization or extracellular membrane localization of polypeptides (e.g., single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and/or multi-chain chimeric antigen receptors) using one or more of the compositions or methods disclosed herein is

useful in the area of cell-based adoptive immunotherapy, in which immune cells isolated from a subject can be modified to express synthetic proteins that enable the cells to perform new therapeutic functions after they are subsequently transferred back into the subject. Non-limiting examples of such synthetic proteins are chimeric antigen receptors (CARs) and engineered T cell Receptors (TCRs).

In some embodiments, reversibly inducing the plasma membrane localization or extracellular membrane localization of polypeptides (e.g., single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and/or multi-chain chimeric antigen receptors) using one or more of the compositions or methods disclosed herein is useful in controlling the toxic effects of chimeric antigen T cells (CAR-T cells) involved in eliminating cancer cells by regulating the presence or absence of an antigen binding moiety on the plasma membrane or extracellular membrane of the cell.

Provided herein are single-chain chimeric polypeptides that include: a transmembrane domain; and a hormone receptor ligand binding domain, where: the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to 500 amino acids; and the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal. In some embodiments of any of the single-chain chimeric polypeptides described herein, the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154. In some embodiments of any of the single-chain chimeric polypeptides described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor. In some embodiments of any of the single-chain chimeric polypeptides described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

In some embodiments of any of the single-chain chimeric polypeptides described herein, the transmembrane domain and the hormone receptor ligand binding domain directly abut each other. In some embodiments of any of the single-chain chimeric polypeptides described herein, the transmembrane domain and the hormone receptor

ligand binding domain are separated by 1 to 500 amino acids (e.g., 1 to 250 amino acids, or about 1 to 50 amino acids).

Also provided herein are nucleic acids that include a nucleotide sequence encoding any of the single-chain chimeric polypeptides described herein. Also provided
5 herein are vectors that include any of the nucleic acids that include a nucleotide sequence encoding any of the single-chain chimeric polypeptides described herein. Also provided herein are mammalian cells that include any of the vectors described herein.

Also provided herein are methods of inducing the membrane localization of a single-chain chimeric polypeptide in a mammalian cell that include: contacting a
10 mammalian cell expressing any of the single-chain chimeric polypeptides described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell.

Also provided are methods of reversibly altering the membrane localization of a
15 single-chain chimeric polypeptide in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the single-chain chimeric polypeptides described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell; and (b) contacting the mammalian cell with a reduced
20 amount of the hormone or the hormone analogue that results in a decreased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the mammalian cell. Some embodiments of any of the methods described herein further include: (c) contacting the mammalian cell with an increased amount of the hormone or the hormone analogue that results in an increased level of the single-chain chimeric
25 polypeptide on the extracellular side of the plasma membrane of the cell as compared to the level of in step (b).

Some embodiments of any of the methods described herein further include: introducing a nucleic acid encoding the single-chain chimeric polypeptide into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric
30 polypeptide. In some embodiments of any of the methods described herein, the

mammalian cell is a T cell (e.g., a T-cell selected from the group of a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell).

In some embodiments of any of the methods described herein, the mammalian cell is a mammalian cell previously obtained from a subject. In some embodiments of any of the methods described herein, the subject has been identified or diagnosed as having a cancer. Some embodiments of any of the methods described herein further include: obtaining the mammalian cell from the subject. In some embodiments of any of the methods described herein, the contacting step is performed *in vitro*. In some embodiments of any of the methods described herein, the contacting step is performed in a mammal.

Also provided herein are single-chain chimeric antigen receptors that include: an extracellular antigen-binding domain; a transmembrane domain; a hormone receptor ligand binding domain; a costimulatory domain; and a immunoreceptor tyrosine-based activation motif (ITAM); where: the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to 500 amino acids; and the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is selected from the group of: a scFv, a (scFv)₂, a V_HH domain, and a V_{NAR} domain. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is a scFv.

In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to a single antigen. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the single antigen is a tumor antigen. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the tumor antigen is CD19. In some embodiments of

any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to two different antigens.

In some embodiments of any of the single chain chimeric antigen receptors described herein, the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

In some embodiments of any of the single-chain chimeric antigen receptors described herein, the costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, and B7-H3. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the costimulatory domain is 4-1BB or CD28. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the ITAM includes a cytoplasmic signaling sequence from CD3 ζ .

In some embodiments of any of the single-chain chimeric antigen receptors described herein, the transmembrane domain and the hormone receptor ligand binding domain directly abut each other. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 500 amino acids (e.g., 1 to 250 amino acids, or 1 to 50 amino acids).

Also provided herein are nucleic acids that include a nucleotide sequence encoding any of the single-chain chimeric antigen receptors described herein. Also provided herein are vectors that include a nucleic acid that includes a nucleotide sequence encoding any of the single-chain chimeric antigen receptors described herein. Also provided are mammalian cells that include any of the vectors described herein.

Also provided are methods of inducing the membrane localization of a single-chain chimeric antigen receptor in a mammalian cell that include: contacting a mammalian cell expressing any of the single-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce
5 localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

Also provided herein are methods of altering the membrane localization of a single-chain chimeric antigen receptor in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the single-chain chimeric antigen receptors described
10 herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and (b) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in a reduced level of the single-chain chimeric antigen receptor on the extracellular side of the plasma membrane
15 of the cell. Some embodiments of these methods further include: (c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increased level of single-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell as compared to the level in (b).

Some embodiments of any of the methods described herein further include:
20 introducing a nucleic acid encoding the single-chain chimeric antigen receptor into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric antigen receptor. In some embodiments of any of the methods described herein, the mammalian cell is a T cell. In some embodiments of any of the methods described herein, the T cell is selected from the group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory
25 T cell, a Treg cell, and a natural killer T cell.

In some embodiments of any of the methods described herein, the mammalian cell is a mammalian cell previously obtained from a subject. In some embodiments of any of the methods described herein, the subject has been identified or diagnosed as having a cancer. Some embodiments of any of the methods described herein further
30 include: obtaining the mammalian cell from the subject. In some embodiments of any of the methods described herein, the contacting step is performed in vitro. In some

embodiments of any of the methods described herein, the contacting step is performed in a mammal. In some embodiments of any of the methods described herein, the mammal has a cancer. In some embodiments of any of the methods described herein, the contacting step results in the treatment of the cancer in the mammal.

Also provided herein are multi-chain chimeric antigen receptors that include at least one first polypeptide including: an extracellular antigen-binding domain; a transmembrane domain; and a hormone receptor ligand binding domain; where: the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to 500 amino acids; and the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_{HH} domain, and a V_{NAR} domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is a scFv.

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to a single antigen. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the single antigen is a tumor antigen. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the tumor antigen is CD19. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to two different antigens.

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the hormone receptor ligand binding

domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

5 In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the transmembrane domain and the hormone receptor ligand binding domain directly abut each other. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 500 amino acids (e.g., 1 to 250
10 amino acids, or 1 to 50 amino acids).

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the at least one polypeptide further includes a costimulatory domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-
15 1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the costimulatory domain is 4-1BB or CD28.

Also provided herein are methods of inducing membrane localization of a multi-
20 chain chimeric antigen receptor in a mammalian cell that include: contacting a mammalian cell expressing any of the multi-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

25 Also provided herein are methods of altering the membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the multi-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side
30 of the plasma membrane of the cell; and (b) contacting the mammalian cell with an amount of the hormone or the hormone analogue with an amount of the hormone or the

hormone analogue that results in a decreased level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell. Some embodiments of any of the methods described herein further include: (c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increase in the level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell. Some embodiments of any of the methods described herein further include: introducing a nucleic acid encoding the single-chain chimeric antigen receptor into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric antigen receptor. In some embodiments of any of the methods described herein, the mammalian cell is a T cell. In some embodiments of any of the methods described herein, the T cell is selected from the group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell.

In some embodiments of any of the methods described herein, the mammalian cell is a mammalian cell previously obtained from a subject. In some embodiments of any of the methods described herein, the subject has been identified or diagnosed as having a cancer. Some embodiments of any of the methods described herein further include: obtaining the mammalian cell from the subject. In some embodiments of any of the methods described herein, the contacting step is performed in vitro. In some embodiments of any of the methods described herein, the contacting step is performed in a mammal. In some embodiments of any of the methods described herein, the mammal has a cancer. In some embodiments of any of the methods described herein, the contacting step results in the treatment of the cancer in the mammal.

Also provided herein are methods of treating a cancer in a subject (e.g., a human) that include: (a) administering to the subject a mammalian cell expressing any of the single chain chimeric antigen receptors described herein or any of the multi-chain chimeric antigen receptors described herein, where the antigen binding domain binds specifically to an antigen expressed by the cancer in the subject; (b) administering to the subject an amount of a hormone or hormone sufficient to induce localization of the single-chain or multi-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell; (c) determining the presence or severity of one or more symptoms associated with toxicity, the level of one or more cytokines associated with a

cytokine storm, or both, in the subject following (b); (d) comparing the determined presence or severity of one or more symptoms associated with toxicity, the determined level of one or more cytokines associated with the cytokine storm, or both, to a control(s); and (e) administering to the subject an amount of the hormone or hormone analogue sufficient to reduce the level of the single-chain or multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell, such that the presence or severity of one or more symptoms associated with toxicity, the level of one or more cytokines associated with a cytokine storm, or both, is reduced in the subject after (e).

In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 25% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b). In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 50% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b). In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 75% as compared to the level of the hormone or hormone analogue administered to the subject in step (b). In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by 100% as compared to the level of the hormone or hormone analogue administered to the subject in step (b).

In some embodiments of any of the methods described herein, the one or more symptoms associated with toxicity are selected from the group consisting of: high fever, swelling, chills, hypotension, tachycardia, asthenia, headache, rash, scratchy throat, dyspnea, redness, extreme fatigue, nausea, and cerebral edema. In some embodiments of these methods, the one or more cytokines associated with a cytokine storm are selected from the group consisting of: include tumor necrosis factor-alpha, IFN γ , IL-10, IL-1 β , IL-2, IL-6, IL-8, and IL-10, granulocyte macrophage-colony-stimulating factor (GM-CSF), and IL-5.

Also provided herein are single-chain chimeric polypeptides that include: an extracellular hormone receptor ligand binding domain; and a transmembrane domain, where: the hormone receptor ligand binding domain and the extracellular transmembrane domain directly abut each other or are separated by 1 to 700 amino acids; and the transmembrane domain and the extracellular hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal. In some embodiments of any of the single-chain chimeric polypeptides described herein, the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154. In some embodiments of any of the single chain chimeric polypeptides described herein, the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor. In some embodiments of any of the single-chain chimeric polypeptides described herein, the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor. In some embodiments of any of the single-chain chimeric polypeptides described herein, the extracellular hormone receptor ligand binding domain is a ligand binding domain from a human estrogen receptor. In some embodiments of any of the single-chain chimeric polypeptides described herein, the ligand binding domain of the human estrogen receptor has a wildtype sequence, except that it comprises one or both of a substitution at amino acid position 521 and a substitution at amino acid position 537, each numbered relative to the full-length wildtype sequence of human hormone receptor.

In some embodiments of any of the single-chain chimeric polypeptide described herein, the extracellular hormone receptor ligand binding domain and the transmembrane domain directly abut each other. In some embodiments of any of the single-chain chimeric polypeptides described herein, the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 700 amino acids (e.g., 1 to 500 amino acids, 1 to 250 amino acids, 1 to 100 amino acids, 1 to 50 amino acids, or 1 to 25 amino acids).

In some embodiments of any of the single-chain chimeric polypeptides described herein, when going in the N-terminal to C-terminal direction, the single-chain chimeric polypeptide includes the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain. In some embodiments of any of the single-chain chimeric polypeptides described herein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide includes the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain. In some embodiments of any of the single-chain chimeric polypeptides described herein, when going in the N-terminal to the C-terminal direction, the single-chain chimeric polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain. In some embodiments of any of the single-chain chimeric polypeptides described herein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

Also provided herein are nucleic acids that include a nucleotide sequence encoding any of the single-chain chimeric polypeptides described herein. Also provided herein are vectors that include a nucleic acid that includes a nucleotide sequence encoding any of the single-chain chimeric polypeptides described herein. Also provided herein are mammalian cells that include any of the vectors described herein. In some embodiments of any of the mammalian cells described herein, the mammalian cell is a T cell. In some embodiments of any of the mammalian cells described herein, the T cell is selected from the group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

Also provided herein are methods of inducing the plasma membrane localization of a single-chain chimeric polypeptide in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the single-chain chimeric polypeptides described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell.

Also provided herein are methods of reversibly altering the plasma membrane localization of a single-chain chimeric polypeptide in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the single-chain chimeric polypeptides described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell; and (b) contacting the mammalian cell with a reduced amount of the hormone or the hormone analogue that results in a decreased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the mammalian cell. Some embodiments of any of the methods described herein further include: (c) contacting the mammalian cell with an increased amount of the hormone or the hormone analogue that results in an increased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the cell as compared to the level of in step (b). Some embodiments of any of the methods described herein further include, before step (a), introducing a nucleic acid encoding the single-chain chimeric polypeptide into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric polypeptide.

In some embodiments of any of the methods described herein, the mammalian cell is a T cell. In some embodiments of any of the methods described herein, the T cell is selected from the group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell. In some embodiments of any of the methods described herein, the mammalian cell is a mammalian cell previously obtained from a subject. In some embodiments of any of the methods described herein, the subject has been identified or diagnosed as having a cancer. Some embodiments of any of the methods described herein further include: obtaining the mammalian cell from the subject.

In some embodiments of any of the methods described herein, the contacting step(s) is performed *in vitro*. In some embodiments of any of the methods described herein, the contacting step(s) is performed in a mammal.

Also provided herein are single-chain chimeric antigen receptors that include: an extracellular antigen-binding domain; an extracellular hormone receptor ligand binding domain; a transmembrane domain; an intracellular costimulatory domain; and an intracellular immunoreceptor tyrosine-based activation motif (ITAM); where: the

transmembrane domain and the extracellular hormone receptor ligand binding domain directly abut each other or are separated by 1 to 700 amino acids; and the transmembrane domain and the extracellular hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal. In some

5 embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_{HH} domain, and a V_{NAR} domain. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is a scFv.

10 In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to a single antigen. In some embodiments of any of the single-chain chimeric antigen receptors, the single antigen is a tumor antigen. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the tumor antigen is selected from the group

15 of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the tumor antigen is CD19. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to two different antigens. In some embodiments of any of the

20 single-chain chimeric antigen receptors described herein, at least one of the two different antigens is a tumor antigen. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16. In some embodiments of any of the single-chain chimeric antigen receptors

25 described herein, the tumor antigen is CD19.

In some embodiments of any of the single-chain chimeric antigen receptors described herein, the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16,

30 CD22, CD86, CD134, CD137, or CD154. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular hormone receptor

ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain is a ligand binding domain from a human estrogen receptor. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the ligand binding domain of the human estrogen receptor has a wildtype sequence, except that it comprises one or both of a substitution at amino acid position 521 and a substitution at amino acid position 537, each numbered relative to the full-length wildtype sequence of human hormone receptor.

In some embodiments of any of the single-chain chimeric antigen receptors described herein, the intracellular costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the intracellular costimulatory domain is the cytoplasmic costimulatory domain from 4-1BB or CD28. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the intracellular ITAM comprises a cytoplasmic signaling sequence from CD3ζ.

In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain and the transmembrane domain directly abut each other. In some embodiments of any of the single-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 700 amino acids (e.g., 1 to 500 amino acids, 1 to 250 amino acids, 1 to 100 amino acids, 1 to 50 amino acids, or 1 to 25 amino acids).

In some embodiments of any of the single-chain chimeric antigen receptors described herein, when going in the N-terminal to C-terminal direction, the single-chain chimeric antigen receptor includes the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, the transmembrane domain, the

intracellular costimulatory domain, and the ITAM. In some embodiments of any of the single-chain chimeric antigen receptors described herein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric antigen receptor includes the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM. In some embodiments of any of the single-chain chimeric antigen receptors described herein, when going in the N-terminal to the C-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM. In some embodiments of any of the single-chain chimeric antigen receptors described herein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM.

Also provided herein are nucleic acids that include a nucleotide sequence encoding any of the single-chain chimeric antigen receptors described herein. Also provided herein are vectors that include a nucleic acid that includes a nucleotide sequence encoding any of the single-chain chimeric antigen receptors described herein. Also provided are mammalian cells that include any of the vectors described herein. In some embodiments of any of the mammalian cells described herein, the mammalian cell is a T cell. In some embodiments of any of the mammalian cells described herein, the T cell is selected from the group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

Also provided are methods of inducing the plasma membrane localization of a single-chain chimeric antigen receptor in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the single-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

Also provided herein are methods of altering the plasma membrane localization of a single-chain chimeric antigen receptor in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the single-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce

5 localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and (b) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in a reduced level of the single-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell. Some embodiments of any of the methods described herein further include:

10 (c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increased level of single-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell as compared to the level in (b).

Some embodiments of any of the methods described herein further include before step (a): introducing a nucleic acid encoding the single-chain chimeric antigen receptor into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric antigen receptor.

In some embodiments of any of the methods described herein, the mammalian cell is a T cell. In some embodiments of any of the methods described herein, the T cell is selected from the group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell. In some embodiments of any of the methods described herein, the mammalian cell is a mammalian cell previously obtained from a subject. In some embodiments of any of the methods described herein, the subject has been identified or diagnosed as having a cancer. Some embodiments of any of the methods described herein further include: obtaining the mammalian cell from the subject. In some 25 embodiments of any of the methods described herein, the contacting step(s) is performed in vitro. In some embodiments of any of the methods described herein, the contacting step(s) is performed in a mammal. In some embodiments of any of the methods described herein, the mammal has a cancer. In some embodiments of any of the methods described herein, the contacting step results in the treatment of the cancer in the mammal.

30 Also provided herein are multi-chain chimeric antigen receptors that include at least one first polypeptide including: an extracellular antigen-binding domain; an

extracellular hormone receptor ligand binding domain; and a transmembrane domain; where: the transmembrane domain and the extracellular hormone receptor ligand binding domain directly abut each other or are separated by 1 to 700 amino acids; and the transmembrane domain and the extracellular hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_HH domain, and a V_{NAR} domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain is a scFv.

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to a single antigen. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the single antigen is a tumor antigen. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the tumor antigen is CD19. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular antigen-binding domain binds specifically to two different antigens. In some embodiments of any of the multi-chain chimeric antigen receptors described herein at least one of the two different antigens is a tumor antigen. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the tumor antigen is CD19.

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154. In some embodiments of any of the multi-

chain chimeric antigen receptors described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain is a ligand binding domain from a human estrogen receptor. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the ligand binding domain of the human estrogen receptor has a wildtype sequence, except that it includes one or both of a substitution at amino acid position 521 and a substitution at amino acid position 537, each numbered relative to the full-length wildtype sequence of human hormone receptor.

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain and the transmembrane domain directly abut each other. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 700 amino acids (e.g., 1 to 500 amino acids, 1 to 250 amino acids, 1 to 100 amino acids, 1 to 50 amino acids, or 1 to 25 amino acids).

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the at least one polypeptide further includes an intracellular costimulatory domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the intracellular costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, the intracellular costimulatory domain is the cytoplasmic costimulatory domain from 4-1BB or CD28.

In some embodiments of any of the multi-chain chimeric antigen receptors described herein, when going in the N-terminal to C-terminal direction, the at least one first polypeptide includes the extracellular antigen-binding domain, the extracellular

hormone receptor ligand binding domain, and the transmembrane domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, when going in the C-terminal to N-terminal direction, the at least one first polypeptide includes the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, when going in the N-terminal to C-terminal direction, the at least one first polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain. In some embodiments of any of the multi-chain chimeric antigen receptors described herein, when going in the C-terminal to N-terminal direction, the at least one first polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

Also provided herein are nucleic acids that encode any of the multi-chain chimeric antigen receptors described herein. Also provided herein are sets of nucleic acids that together encode any of the multi-chain chimeric antigen receptors described herein. Also provided herein are mammalian cells that include a nucleic acid that encodes any of the multi-chain chimeric antigen receptors described herein. Also provided herein are mammalian cells that include a set of nucleic acids that together encode any of the multi-chain chimeric antigen receptors described herein. In some embodiments of any of the mammalian cells described herein, the mammalian cell is a T cell. In some embodiments of any of the mammalian cells described herein, the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

Also provided herein are methods of inducing the plasma membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the multi-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

Also provided herein are methods of altering the plasma membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell that include: (a) contacting a mammalian cell expressing any of the multi-chain chimeric antigen receptors described herein with an amount of a hormone or a hormone analogue sufficient to induce

5 localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and (b) contacting the mammalian cell with an amount of the hormone or the hormone analogue with an amount of the hormone or the hormone analogue that results in a decreased level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell. Some

10 embodiments of any of the methods described herein further include: (c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increase in the level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell. Some embodiments of any of the methods described herein further include before step (a): introducing a nucleic acid

15 encoding the multi-chain chimeric antigen receptor or a set of nucleic acids that together encode the multi-chain chimeric receptor, into a mammalian cell to generate the mammalian cell expressing the multi-chain chimeric antigen receptor. In some embodiments of any of the methods described herein, the mammalian cell is a T cell. In some embodiments of any of the methods described herein, the T cell is selected from the

20 group of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell. In some embodiments of any of the methods described herein, the mammalian cell is a mammalian cell previously obtained from a subject. In some embodiments of any of the methods described herein, the subject has been identified or diagnosed as having a cancer. Some embodiments of any of the methods described herein further

25 include obtaining the mammalian cell from the subject. In some embodiments of any of the methods described herein, the contacting step is performed in vitro. In some embodiments of any of the methods described herein, the contacting step is performed in a mammal. In some embodiments of any of the methods described herein, the mammal has a cancer. In some embodiments of any of the methods described herein, the

30 contacting step results in the treatment of the cancer in the mammal.

Also provided herein are methods of treating a cancer in a subject that include: (a) administering to the subject a mammalian cell expressing any of the single-chain chimeric antigen receptors described herein or any of the multi-chain chimeric antigen receptors described herein, where the antigen binding domain binds specifically to an antigen expressed by the cancer in the subject; (b) administering to the subject an amount of a hormone or hormone sufficient to induce localization of the single-chain or multi-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell; (c) determining the presence or severity of one or more symptoms associated with toxicity or the level of one or more cytokines associated with a cytokine storm, or both, in the subject following (b); (d) comparing the determined presence or severity of one or more symptoms associated with toxicity or the determined level of one or more cytokines associated with the cytokine storm, or both, to a control(s); and (e) administering to the subject an amount of the hormone or hormone analogue sufficient to reduce the level of the single-chain or multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell, such that the presence or severity of one or more symptoms associated with toxicity or the level of one or more cytokines associated with a cytokine storm, or both, is reduced in the subject after (e).

In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 25% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b). In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 50% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b). In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 75% as compared to the level of the hormone or hormone analogue administered to the subject in step (b). In some embodiments of any of the methods described herein, the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by 100% as compared to the level of the hormone or hormone analogue administered to the subject in step (b).

In some embodiments of any of the methods described herein, the one or more symptoms associated with toxicity are selected from the group of: high fever, swelling, chills, hypotension, tachycardia, asthenia, headache, rash, scratchy throat, dyspnea, redness, extreme fatigue, nausea, and cerebral edema. In some embodiments of any of the methods described herein, the one or more cytokines associated with a cytokine storm are selected from the group of: include tumor necrosis factor-alpha, IFN γ , IL-10, IL-1 β , IL-2, IL-6, IL-8, and IL-10, granulocyte macrophage-colony-stimulating factor (GM-CSF), and IL-5.

The use of the term “a” before a noun is meant “one or more” of the particular noun. For example, the phrase “a mammalian cell” means “one or more mammalian cell.”

The term “single-chain chimeric polypeptide” means a single-chain polypeptide that includes a first contiguous amino acid sequence (e.g., a first domain) and a second contiguous amino acid sequence (e.g., a second domain), where the first contiguous amino acid sequence and the second contiguous amino acid sequence are not present in the same endogenous single-chain polypeptide in a mammal. In some examples, the first contiguous amino acid sequence and the second contiguous amino acid sequence directly abut each other in the single-chain chimeric polypeptide. In some examples, the first contiguous amino acid sequence and the second contiguous amino acid sequence are separated by one or more intervening amino acids (e.g., one or more domains). The term “single-chain chimeric polypeptide” is not meant to limit in any way the relative positioning of the first contiguous amino acid sequence and the second contiguous sequence in the single-chain polypeptide. Non-limiting examples of single-chain chimeric polypeptides (e.g., single-chain chimeric antigen receptors) are described herein. Additional examples of single-chain chimeric polypeptides (e.g., single-chain chimeric antigen receptors) are known in the art.

The terms “chimeric antigen receptor” and “CAR” are used interchangeably herein, and refer to artificial multi-module molecules capable of triggering or inhibiting the activation of an immune cell which generally but not exclusively comprise an extracellular domain (e.g., a ligand/antigen binding domain), a transmembrane domain and one or more intracellular signaling domains. CAR molecules and derivatives thereof

(e.g., CAR variants) are described, e.g., in PCT Application No. US2014/016527; Fedorov et al. *Sci Transl Med* (2013) ;5(215):215ra172; Glienke et al. *Front Pharmacol* (2015) 6:21; Kakarla & Gottschalk 52 *Cancer J* (2014) 20(2):151-5; Riddell et al. *Cancer J* (2014) 20(2):141-4; Pegram et al. *Cancer J* (2014) 20(2):127-33; Cheadle et al. *Immunol Rev* (2014) 257(1):91-106; Barrett et al. *Annu Rev Med* (2014) 65:333-47; Sadelain et al. *Cancer Discov* (2013) 3(4):388-98; Cartellieri et al., *J Biomed Biotechnol* (2010) 956304; the disclosures of which are incorporated herein by reference in their entirety.

The term “multi-chain chimeric polypeptide” means a polypeptide including two or more single-chain polypeptides, where at least one of the two or more single-chain polypeptides is a single-chain chimeric polypeptide as defined and described herein. Non-limiting examples of multi-chain chimeric polypeptides (e.g., multi-chain chimeric antigen receptors) are described herein. Additional examples of multi-chain chimeric polypeptides (e.g., multi-chain chimeric antigen receptors) are known in the art.

The term “transmembrane domain” means a domain of a polypeptide that includes at least one contiguous amino acid sequence that traverses a lipid bilayer when present in the corresponding endogenous polypeptide when expressed in a mammalian cell. For example, a transmembrane domain can include one, two, three, four, five, six, seven, eight, nine, or ten contiguous amino acid sequences that each traverse a lipid bilayer when present in the corresponding endogenous polypeptide when expressed in a mammalian cell. As is known in the art, a transmembrane domain can, e.g., include at least one (e.g., two, three, four, five, six, seven, eight, nine, or ten) contiguous amino acid sequence (that traverses a lipid bilayer when present in the corresponding endogenous polypeptide when expressed in a mammalian cell) that has α -helical secondary structure in the lipid bilayer. In some embodiments, a transmembrane domain can include two or more contiguous amino acid sequences (that each traverse a lipid bilayer when present in the corresponding endogenous polypeptide when expressed in a mammalian cell) that form a β -barrel secondary structure in the lipid bilayer. Non-limiting examples of transmembrane domains are described herein. Additional examples of transmembrane domains are known in the art.

The phrase “extracellular side of the plasma membrane” when used to describe the location of a polypeptide means that the polypeptide includes at least one transmembrane domain that traverses the plasma membrane and at least one domain (e.g., at least one antigen-binding domain) that is located in the extracellular space.

5 The term “hormone receptor ligand binding domain” means a domain in a hormone receptor polypeptide that binds specifically to a hormone or a hormone analogue. Non-limiting examples of a hormone receptor ligand binding domains (LBD) are described herein. In some cases, a LBD of a nuclear hormone receptor is selected from an estrogen receptor, an ecdysone receptor, a PPAR γ receptor, a glucocorticoid
10 receptor, an androgen receptor, a thyroid hormone receptor, a mineralocorticoid receptor, a progesterone receptor, a vitamin D receptor, a PPAR receptor α , a PPAR β/δ receptor, a pregnane X receptor, a liver X receptor, a farnesoid X receptor, a retinoid X receptor, a RAR-related orphan receptor, and a retinoic acid receptor. In some cases, a polypeptide chain of a heterodimeric polypeptide of the present disclosure comprises a single LBD of
15 a nuclear hormone receptor. In some cases, a polypeptide chain of a heterodimeric polypeptide of the present disclosure comprises multiple (e.g., two or more) LBDs of a nuclear hormone receptor. In some cases, a polypeptide chain of a heterodimeric polypeptide of the present disclosure comprises two LBDs of a nuclear hormone receptor. In some cases, a polypeptide chain of a heterodimeric polypeptide of the present
20 disclosure comprises three LBDs of a nuclear hormone receptor. Where a polypeptide chain of a heterodimeric polypeptide of the present disclosure comprises multiple (e.g., two or more) LBDs of a nuclear hormone receptor, in some cases the multiple LBDs comprise identical amino acid sequences. In some cases, the two or more LBD are in tandem, either directly or separated by a linker (e.g., any of the linkers described herein).

25 The term “antigen-binding domain” means a domain that binds specifically to a target antigen. In some examples, an antigen-binding domain can be formed from the amino acids present within a single-chain polypeptide. In other examples, an antigen-binding domain can be formed from amino acids present within a first single-chain polypeptide and the amino acids present in one or more additional single-chain
30 polypeptides (e.g., a second single-chain polypeptide). Non-limiting examples of antigen-binding domains are described herein, including, without limitation, scFvs, or

LBDs of growth factors. Additional examples of antigen-binding domains are known in the art.

As used herein, the term “antigen” refers generally to a binding partner specifically recognized by an antigen-binding domain described herein. Exemplary
5 antigens include different classes of molecules, such as, but not limited to, polypeptides and peptide fragments thereof, small molecules, lipids, carbohydrates, and nucleic acids. Non-limiting examples of antigen or antigens that can be specifically bound by any of the antigen-binding domains are described herein. Additional examples of antigen or
10 antigens that can be specifically bound by any of the antigen-binding domains are known in the art.

The term “costimulatory domain” means a signaling domain from an endogenous co-stimulatory transmembrane polypeptide expressed in a T lymphocyte that promotes the downstream T-cell receptor signaling and/or T cell activation. Non-limiting examples of costimulatory domains are described herein. Additional examples of costimulatory
15 domains are known in the art. See, e.g., Chen et al., *Nature Reviews Immunol.* 13:227-242, 2013.

The term “immunoreceptor tyrosine-based activation motif” or “ITAM”) means an amino acid motif that includes a four amino-acid consensus sequence of a tyrosine separated from a leucine or an isoleucine by two other amino acids (YxxL/I). The
20 tyrosine residue in the four-amino acid consensus sequence becomes phosphorylated following interaction of a signaling pathway kinase (e.g., a lymphocyte signaling pathway kinase). Non-limiting examples of ITAMs are described herein. Additional examples of ITAMs are known in the art.

The term “hormone” means a naturally-occurring molecule that specifically binds
25 to a ligand binding domain of a hormone receptor and regulates the activity and/or location of the hormone receptor. Non-limiting examples of hormones are described herein. Additional examples of hormones are known in the art.

The term “hormone analogue” means a molecule that mimics the structure of a hormone and specifically binds to a ligand binding domain of a hormone receptor. Non-
30 limiting examples of hormone analogues are described herein. Additional examples of hormone analogues are known in the art.

The phrase “treatment of cancer” means a reduction in the number, frequency, or severity of one or more (e.g., two, three, four, or five) symptoms of a cancer in a subject having a cancer. Non-limiting symptoms of cancer are described herein. Additional symptoms of cancer are known in the art.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Methods and materials are described herein for use in the present invention; other, suitable methods and materials known in the art can also be used. The materials, methods, and examples are illustrative only and not intended to be limiting. All publications, patent applications, patents, sequences, database entries, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control.

Other features and advantages of the invention will be apparent from the following detailed description and figures, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a diagram of different constructs tested. The labels extracellular and intracellular refer to the cell membrane, which is depicted as a gray box between these labels. The extracellular scFv domain, and intracellular costimulatory (“Costim”), CD3zeta, and mCherry domains are indicated.

Fig. 2 is a set of flow cytometry dot plots for cells expressing one of the different constructs. The cells were either left untreated or were treated with 500 ng/mL 4-hydroxytamoxifen (“4-OHT”). (A) Jurkat T cells transduced with lentiviral vectors encoding the canonical CAR or with anti-CD19 (FMC63) ERa-LBD containing the v2, v3, and v4 CAR constructs. (B) Primary CD4 and CD8 human T cells were transduced with lentiviral vectors encoding the v4 CAR construct.

Fig. 3 is a set of flow cytometry dot plots for HEK-293T cells transduced with lentiviral vectors encoding ERa-LBD-containing FMC63 CAR fusions. The cells were either left untreated or were treated with 500 ng/mL 4-OHT.

Fig. 4 is a set of flow cytometry dot plots for primary human CD4 T cells transduced with lentiviral vectors encoding a FMC63 NHR LBD-CAR fusions and a

NHR LBD-CAR having the J6M0 scFv. The cells were either left untreated or were treated with 500 ng/mL 4-OHT.

Fig. 5A is a diagram of the V5 nuclear hormone receptor ligand binding domain NHR-LBD CAR construct lacking the costimulatory and CD3zeta domains, and a set of flow cytometry dot plots for cells transduced with a lentiviral vector encoding the V5 construct. The cells were either left untreated or were treated with 500 ng/mL 4-OHT.

Fig. 5B is a set of flow cytometry diagrams of untransduced Jurkat T cells or Jurkat T cells transduced with a lentiviral vector encoding a CAR in which the scFv domain was replaced with a FLAG tag. The transduced cells were either left untreated or were treated with 500 ng/mL 4-OHT.

Fig. 6 is a set of flow cytometry diagrams of Jurkat T cells transduced with CAR constructs having progesterone receptor LBDs. The cells were either left untreated or were treated with 500 ng/mL mifepristone.

Fig. 7A is a graph showing T cell activation of primary human T cells transduced with lentiviral vectors encoding J6M0-ERa-LBD CAR construct after overnight co-culture with antigen-negative (K562 cell line) and antigen-positive (MM1S cell line) targets.

Fig. 7B is a graph showing IFN- γ production by primary human T cells transduced with lentiviral vectors encoding J6M0-ERa-LBD CAR construct after overnight co-culture with antigen-negative (K562 cell line) and antigen-positive (MM1S cell line) targets.

Fig. 8A is a set of flow cytometry diagrams showing proliferation of primary human CD4 T cells that were transduced with lentiviral vectors encoding V4 FMC63-ERa-LBD CAR or canonical CAR controls, co-cultured with either antigen-negative (K562 cell line) or antigen-positive (Raji cell line) targets, and with increasing concentrations of ligand 4-OHT.

Fig. 8B is graph showing lysis of antigen-positive targets (MM1S cell line) mediated by primary human T cells transduced with lentiviral vectors encoding J6M0-ERa-LBD CAR constructs with increasing concentrations of 4-OHT.

Fig. 9 is a graph showing surface expression of various CAR constructs having a LBD at different locations relative to the cell membrane at increasing concentrations of 4-OHT.

Fig. 10A is a schematic showing timeline of the experimental procedure.

5 Fig. 10B is a bar graph showing surface expression of various CAR constructs before and after co-culture with 4-OHT.

Fig. 11A is a set of flow cytometry diagrams showing Jurkat T cells that were transduced with the FLAG-ERa-LBD CAR, and left untreated or treated with 4-OHT for 15 or 120 minutes.

10 Fig. 11B is a set of flow cytometry diagrams showing human T cells that were transduced with lentiviral vector encoding the FMC63-ERa-LBD CAR, and left untreated or treated with 4-OHT for 2 hours, 4 hours, or 24 hours.

Fig. 12 is a set of flow cytometry diagrams of primary human T cells expressing FMC63-CARs having ERa LBDs. The cells were either left untreated or were treated 15 with 500 ng/mL 4-OHT. Some samples were pretreated with 1 μ M Brefeldin A.

Fig. 13 is a diagram of the v2 CAR construct and ECD.v1 CAR (also called LBD-ECD CAR) construct tested. The cellular membrane is depicted as a gray box. The extracellular scFv domain, the extracellular ERa LBD, the transmembrane domain (embedded in the cellular membrane), the intracellular 4-1BB domain, and the 20 intracellular CD3 γ domain are depicted.

Fig. 14 depicts a set of flow cytometry dot plots for cells expressing the v2 CAR construct or LBD-ECD CAR construct. The cells were either left untreated or were treated with 500 ng/mL 4-hydroxytamoxifen ("4-OHT").

Fig. 15 is a graph showing the destruction of Nalm 6 tumor cells (% lysis) by T 25 cells transduced with a lentiviral vector encoding LBD-ECD CAR construct (ECD.v1). Cells were treated with between 1.5 ng/mL to 500 ng/mL 4-OHT. The positive control was T cells transduced with a lentiviral vector encoding constitutive CAR. The negative control was T cells with LBD-ECD CAR that were not treated with 4-OHT.

Fig. 16 depicts a set of flow cytometry dot plots for cells expressing a constitutive 30 CAR, LBD-ECD CAR, or v2 CAR. Cells were either left untreated, or stimulated with beads containing a CD3/CD28 for 48 hours prior to flow cytometry. Beads, Dynabeads

aCD3/aCD28, were from ThermoFisher. See, Trickett et al., *J. Immunol. Methods* 275:251-255, 2003. Each construct was fused to a cMyc tag.

Fig. 17 is a graph showing IL-2 production from ECD.v1 CAR-T cells or conventional CAR-T cells after overnight co-culture of the CAR-bearing T cells with
5 NALM-6 targets in the presence (500 ng/mL) or absence of 4-hydroxytamoxifen.

DETAILED DESCRIPTION

Provided herein are single-chain chimeric polypeptides, single-chain chimeric antigen receptors (CARs), and multi-chain chimeric antigen receptors; nucleic acids encoding the same; vectors including any of these nucleic acids; mammalian cells
10 including any of these vectors; and methods of reversibly inducing the extracellular membrane localization and methods of altering the membrane localization of these single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and multi-chain chimeric polypeptides.

Also provided herein are genetically modified mammalian cells having a chimeric
15 antigen receptor (CAR). In some cases, a genetically modified mammalian cell is derived from a stem cell, a progenitor cell, or a cell derived from a stem cell or a progenitor cell. In some cases, the mammalian cell is a T lymphocyte or an NK cell.

Non-limiting aspects of these single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and multi-chain chimeric antigen receptors, nucleic acids,
20 vectors, mammalian cells, and methods are described below, and can be used in any combination without limitation. Additional aspects of these single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and multi-chain chimeric antigen receptors, nucleic acids, vectors, mammalian cells, and methods are known in the art.

In some embodiments, compositions and/or methods disclosed herein can be used
25 to selectively kill cancer cells in a subject in the presence of a hormone or hormone analogue which binds to an LBD present in the polypeptide (e.g., a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, and/or a multi-chain chimeric antigen receptor). In some embodiments, in the presence of the hormone or hormone analogue, the polypeptide (e.g., the single-chain chimeric polypeptide, the single-chain
30 chimeric antigen receptor, and/or the multi-chain chimeric antigen receptor) localizes to

the extracellular surface, presenting an antigen binding domain (e.g., an scFv or other antigen-binding domain described herein or known in the art) on the exterior of the cell. The polypeptide (e.g., single-chain chimeric polypeptide, single-chain chimeric antigen receptor, or multi-chain chimeric antigen receptor) can recognize the antigen to which it binds, and thus can selectively kill a target cell expressing the antigen on its surface (e.g., a cancer cell).

In some embodiments, localization of the polypeptide (e.g., the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor) to the extracellular surface can cause toxicity in the subject.

In some embodiments, a subject experiencing toxicity to due hormone or hormone-analogue-induced localization of the polypeptide (e.g., the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor) to the extracellular surface can be treated or ameliorated by reducing the dose of the hormone or hormone analogue, or eliminating hormone or hormone analogue treatment of the subject altogether. Such reduction in dose or elimination of hormone or hormone analogue treatment can cause the polypeptide (e.g., the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric polypeptide) to be removed from the cell surface and reduce or eliminate presentation of the antigen binding domain on the cell surface, thus reducing or eliminating toxicity in the subject.

Single-Chain Chimeric Polypeptide

Single-Chain Chimeric Polypeptide – Intracellular Hormone Receptor LBD

Provided herein are single-chain chimeric polypeptides that include a transmembrane domain (e.g., any of the transmembrane domains described herein or known in the art) and a hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domains described herein or known in the art), where the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to about 800 amino acids (e.g., or any of the subranges of this range described herein), and the transmembrane domain and the hormone receptor

ligand binding domain are not both present in the same (a single) endogenous single-chain polypeptide in a mammal (e.g., a human).

In some examples of the single-chain chimeric polypeptides, the transmembrane domain directly abuts the hormone receptor ligand binding domain (i.e., no intervening amino acids between the transmembrane domain and the hormone receptor ligand binding domain). In some examples of the single-chain chimeric polypeptides, the transmembrane domain and the hormone receptor ligand binding domain are separated by: 1 amino acid to about 800 amino acids, about 780 amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids, about 700 amino acids, about 680 amino acids, about 660 amino acids, about 640 amino acids, about 620 amino acids, about 600 amino acids, about 580 amino acids, about 560 amino acids, about 540 amino acids, about 520 amino acids, about 500 amino acids, about 490 amino acids, about 480 amino acids, about 470 amino acids, about 460 amino acids, about 450 amino acids, about 440 amino acids, about 430 amino acids, about 420 amino acids, about 410 amino acids, about 400 amino acids, about 390 amino acids, about 380 amino acids, about 370 amino acids, about 360 amino acids, about 350 amino acids, about 340 amino acids, about 330 amino acids, about 320 amino acids, about 310 amino acids, about 300 amino acids, about 290 amino acids, about 280 amino acids, about 270 amino acids, about 260 amino acids, about 250 amino acids, about 240 amino acids, about 230 amino acids, about 220 amino acids, about 210 amino acids, about 200 amino acids, about 195 amino acids, about 190 amino acids, about 185 amino acids, about 180 amino acids, about 175 amino acids, about 170 amino acids, about 165 amino acids, about 160 amino acids, about 155 amino acids, about 150 amino acids, about 145 amino acids, about 140 amino acids, about 135 amino acids, about 130 amino acids, about 125 amino acids, about 120 amino acids, about 115 amino acids, about 110 amino acids, about 105 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids, about 35 amino acids, about 30 amino acids, about 25 amino acids, about 20 amino acids, about 18 amino acids, about 16 amino acids, about 14 amino acids, about 12 amino acids, about 10 amino acids, about 8 amino acids, about 6 amino

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about 540 amino acids, about 520 amino acids, about 500 amino acids, about 490 amino
acids, about 480 amino acids, about 470 amino acids, about 460 amino acids, about 450
amino acids, about 440 amino acids, about 430 amino acids, about 420 amino acids,
about 410 amino acids, about 400 amino acids, about 390 amino acids, about 380 amino
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amino acids, about 330 amino acids, about 320 amino acids, about 310 amino acids,
about 300 amino acids, about 290 amino acids, about 280 amino acids, about 270 amino
acids, about 260 amino acids, about 250 amino acids, about 240 amino acids, about 230
amino acids, about 220 amino acids, about 210 amino acids, about 200 amino acids,
25 about 195 amino acids, about 190 amino acids, about 185 amino acids, about 180 amino
acids, about 175 amino acids, about 170 amino acids, about 165 amino acids, about 160
amino acids, about 155 amino acids, about 150 amino acids, or about 145 amino acids
(inclusive); about 145 amino acids to about 800 amino acids, about 780 amino acids,
about 760 amino acids, about 740 amino acids, about 720 amino acids, about 700 amino
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amino acids, about 600 amino acids, about 580 amino acids, about 560 amino acids,

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amino acids, about 180 amino acids, about 175 amino acids, about 170 amino acids, or
about 165 amino acids (inclusive); about 165 amino acids to about 800 amino acids,
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acids, about 420 amino acids, about 410 amino acids, about 400 amino acids, about 390
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amino acids, or about 180 amino acids (inclusive); about 180 amino acids to about 800
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5 about 190 amino acids to about 800 amino acids, about 780 amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids, about 700 amino acids, about 680 amino acids, about 660 amino acids, about 640 amino acids, about 620 amino acids, about 600 amino acids, about 580 amino acids, about 560 amino acids, about 540 amino acids, about 520 amino acids, about 500 amino acids, about 490 amino acids,

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20 about 700 amino acids, about 680 amino acids, about 660 amino acids, about 640 amino acids, about 620 amino acids, about 600 amino acids, about 580 amino acids, about 560 amino acids, about 540 amino acids, about 520 amino acids, about 500 amino acids, about 490 amino acids, about 480 amino acids, about 470 amino acids, about 460 amino acids, about 450 amino acids, about 440 amino acids, about 430 amino acids, about 420

25 amino acids, about 410 amino acids, about 400 amino acids, about 390 amino acids, about 380 amino acids, about 370 amino acids, about 360 amino acids, about 350 amino acids, about 340 amino acids, about 330 amino acids, about 320 amino acids, about 310 amino acids, about 300 amino acids, about 290 amino acids, about 280 amino acids, about 270 amino acids, about 260 amino acids, about 250 amino acids, about 240 amino

30 acids, about 230 amino acids, about 220 amino acids, about 210 amino acids, or about 200 amino acids (inclusive); about 200 amino acids to about 800 amino acids, about 780

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amino acids, about 420 amino acids, about 410 amino acids, about 400 amino acids,
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 30 250 amino acids (inclusive); about 250 amino acids to about 800 amino acids, about 780
 amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids,

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about 310 amino acids, about 300 amino acids, or about 290 amino acids (inclusive);
about 290 amino acids to about 800 amino acids, about 780 amino acids, about 760
amino acids, about 740 amino acids, about 720 amino acids, about 700 amino acids,
about 680 amino acids, about 660 amino acids, about 640 amino acids, about 620 amino
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10 about 370 amino acids, about 360 amino acids, about 350 amino acids, about 340 amino
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amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids,
about 700 amino acids, about 680 amino acids, about 660 amino acids, about 640 amino
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amino acids, about 410 amino acids, about 400 amino acids, about 390 amino acids,
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acids, about 340 amino acids, about 330 amino acids, about 320 amino acids, or about
310 amino acids (inclusive); about 310 amino acids to about 800 amino acids, about 780
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amino acids, about 540 amino acids, about 520 amino acids, about 500 amino acids,
about 490 amino acids, about 480 amino acids, about 470 amino acids, about 460 amino
acids, about 450 amino acids, about 440 amino acids, about 430 amino acids, about 420
amino acids, about 410 amino acids, about 400 amino acids, about 390 amino acids,
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acids, about 340 amino acids, about 330 amino acids, or about 320 amino acids

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about 780 amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids, about 700 amino acids, about 680 amino acids, or about 660 amino acids (inclusive); about 660 amino acids to about 800 amino acids, about 780 amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids, about 700 amino acids, or about 680 amino acids (inclusive); about 680 amino acids to about 800 amino acids, about 780 amino acids, about 760 amino acids, about 740 amino acids, about 720 amino acids, or about 700 amino acids (inclusive); about 700 amino acids to about 800 amino acids, about 780 amino acids, about 760 amino acids, about 740 amino acids, or about 720 amino acids (inclusive); about 720 amino acids to about 800 amino acids, about 780 amino acids, about 760 amino acids, or about 740 amino acids (inclusive); about 740 amino acids to about 800 amino acids, about 780 amino acids, or about 760 amino acids (inclusive); about 760 amino acids to about 800 amino acids, or about 780 amino acids; (inclusive); or about 780 amino acids to about 800 amino acids (inclusive).

In some embodiments, one or more intervening amino acids between the transmembrane domain and the hormone receptor ligand binding domain can be or include a linker peptide. In some embodiments, a linker peptide can include one or more of the following amino acid sequences: GSGSGSGSGS (SEQ ID NO: 20), GSGSGSGS (SEQ ID NO: 21), RSGSGSGS (SEQ ID NO: 22), or GSGSGSGS (SEQ ID NO: 23). In some embodiments, linker peptide can be encoded by one or more of the following nucleic acid sequences: GGATCCGGCAGCGGATCTGGCAGTGGAAGC (SEQ ID NO: 24), GGATCTGGCTCTGGAAGCGGCAGC (SEQ ID NO: 25), AGATCCGGATCTGGAAGTGGCTCC (SEQ ID NO: 26), or GGAAGTGGATCTGGGAGCGGCTCT (SEQ ID NO: 27). In some embodiments, a linker peptide can include one or more (e.g., two, three, or four) copies of any one of SEQ ID NOs: 20-23, e.g., in tandem.

In some embodiments, one or more intervening amino acids between the transmembrane domain and the hormone receptor ligand binding domain can be or include an intracellular sequence that abuts the transmembrane domain in the endogenous polypeptide from which the transmembrane domain (e.g., any of the transmembrane domains described herein) is derived. In some embodiments, one or more intervening amino acids between the transmembrane domain and the hormone receptor ligand

binding domain can be or include one or more additional domains (e.g., any of the exemplary additional domains described herein or known in the art). In some embodiments, a single-chain chimeric polypeptide can be a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein). In some embodiments, the chimeric polypeptide can further include one or more additional domains. Non-limiting examples of additional domains that can be included in a single-chain chimeric polypeptide include one or more of: an extracellular ligand binding domain (e.g., an antigen-binding domain, e.g., any of the antigen-binding domains described herein), an ITIM (e.g., any of the ITIMs known in the art), an ITAM (e.g., any of ITAMs described herein or known in the art), a dimerization domain (e.g., capable of dimerizing with another dimerization domain present in another polypeptide (e.g., a recombinant polypeptide) expressed in a mammalian cell, e.g., any of the dimerization domains known in the art), and a peptide tag (e.g., a poly-His tag).

Single-Chain Chimeric Polypeptide- Extracellular Hormone Receptor LBD

Provided herein are single-chain chimeric polypeptides that include an extracellular hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domains described herein or known in the art) and a transmembrane domain (e.g., any of the transmembrane domains described herein or known in the art), where the transmembrane domain and the extracellular hormone receptor ligand binding domain directly abut each other or are separated by 1 to about 800 amino acids (e.g., or any of the subranges of this range described herein), and the transmembrane domain and the hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal (e.g., a human).

In some examples of the single-chain chimeric polypeptides, the transmembrane domain directly abuts the hormone receptor ligand binding domain (i.e., no intervening amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain). In some examples of the single-chain chimeric polypeptides, the transmembrane domain and the extracellular hormone receptor ligand binding domain are separated by: 1 amino acid to about 800 amino acids (e.g., any of the subranges of this range described herein).

In some embodiments, one or more intervening amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain can be or include a linker peptide. In some embodiments, a linker peptide can include one or more of the following amino acid sequences: GSGSGSGSGS (SEQ ID NO: 20),
 5 GSGSGSGS (SEQ ID NO: 21), RSGSGSGS (SEQ ID NO: 22), or GSGSGSGS (SEQ ID NO: 23). In some embodiments, linker peptide can be encoded by one or more of the following nucleic acid sequences: GGATCCGGCAGCGGATCTGGCAGTGGAAAGC (SEQ ID NO: 24), GGATCTGGCTCTGGAAGCGGCAGC (SEQ ID NO: 25),
 AGATCCGGATCTGGAAGTGGCTCC (SEQ ID NO: 26), or
 10 GGAAGTGGATCTGGGAGCGGCTCT (SEQ ID NO: 27). In some embodiments, a linker peptide can include one or more (e.g., two, three, or four) copies of any one of SEQ ID NOs: 20-23, e.g., in tandem. In some embodiments, a linker peptide can be or can include one or more of SEQ ID NO: 45, 47, 49, 58, 60, 62, and 106. In some embodiments, a linker peptide can be or include GS.

15 In some embodiments, one or more intervening amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain can be or include a sequence that abuts the transmembrane domain in the endogenous polypeptide from which the transmembrane domain (e.g., any of the transmembrane domains described herein) is derived. In some embodiments, one or more intervening
 20 amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain can be or include one or more additional domains (e.g., any of the exemplary additional domains described herein or known in the art). In some embodiments, a single-chain chimeric polypeptide can be a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein). In
 25 some embodiments, the chimeric polypeptide can further include one or more (e.g., two, three, four, or five) additional domains. Non-limiting examples of additional domains that can be included in a single-chain chimeric polypeptide include one or more of: an extracellular ligand binding domain (e.g., an antigen-binding domain, e.g., any of the antigen-binding domains described herein), an ITIM (e.g., any of the ITIMs known in the
 30 art), an ITAM (e.g., any of ITAMs described herein or known in the art), a dimerization domain (e.g., capable of dimerizing with another dimerization domain present in another

polypeptide (e.g., a recombinant polypeptide) expressed in a mammalian cell, e.g., any of the dimerization domains known in the art), and a peptide tag (e.g., a poly-His tag).

In some embodiments, when going in the N-terminal to C-terminal direction, the single-chain chimeric polypeptide includes the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

In some embodiments, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain. In some embodiments, when going in the N-terminal to the C-terminal direction, the single-chain chimeric polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain. In some embodiments, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide includes the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

Single-Chain Chimeric Antigen Receptor

Single-Chain Chimeric Antigen Receptor – Intracellular Hormone Receptor LBD

Also provided herein are single-chain chimeric antigen receptors that include: an extracellular antigen-binding domain (e.g., any of the antigen-binding domains described herein or known in the art), a transmembrane domain (e.g., any of the transmembrane domains described herein or known in the art), a hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domain described herein or known in the art), a costimulatory domain (e.g., any of the costimulatory domains described herein or known in the art), and an immunoreceptor tyrosine-based activation motif (ITAM), where: the transmembrane domain and the hormone ligand binding domain directly abut each other or are separated by 1 to about 800 amino acids (e.g., any of the subranges of this range described herein), and the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same (a single) endogenous single-chain polypeptide in a mammal. The single-chain chimeric antigen receptors described

herein can bind to any of the exemplary antigens described herein or any other antigen known in the art. In some embodiments, the single-chain chimeric antigen receptor binds specifically to a single antigen (e.g., any of the exemplary antigens described herein). In some embodiments, the single-chain chimeric antigen receptor binds specifically to two
5 different antigens (e.g., any combination of the exemplary antigens described herein).

In some embodiments of these single-chain chimeric antigen receptors, the transmembrane domain abuts the hormone receptor ligand binding domain. In some embodiments of these single-chain chimeric antigen receptors, the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to about 800
10 amino acids (e.g., or any of the subranges of this range described herein). In some embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain do not comprise a domain. In other embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain includes one or more intervening domain (e.g., one or more
15 costimulatory domains and/or one or more ITAMs). In some embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain includes a sequence from the same endogenous transmembrane protein from which the transmembrane domain is derived. In some embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain
20 include a linker sequence.

Some embodiments of these single-chain chimeric antigen receptors can include one or more (e.g., two, three, four, or five) costimulatory domain(s) (e.g., any combination of any of the exemplary costimulatory domains described herein or known in the art). Some embodiments of these single-chain chimeric antigen receptors include
25 one or both of a 4-1BB costimulatory domain and a CD28 costimulatory domain.

Some embodiments of these single-chain chimeric antigen receptors can include one or more (e.g., two, three, four, or five) ITAMs (e.g., any of the ITAMs described herein or known in the art). In some embodiments of these single-chain chimeric antigen receptors, the ITAM includes a cytoplasmic signaling sequence from CD3 ζ (e.g., human
30 CD3 ζ).

In some embodiments of any of these single-chain chimeric antigen receptors, any two neighboring domains can be separated by 1 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, about 400 amino acids, about 380 amino acids, about 360 amino acids, about 340 amino acids, about 320 amino acids, about 300 amino acids, about 280 amino acids, about 260 amino acids, about 240 amino acids, about 220 amino acids, about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids, about 35 amino acids, about 30 amino acids, about 25 amino acids, about 20 amino acids, about 15 amino acids, about 10 amino acids, about 8 amino acids, about 6 amino acids, about 4 amino acid, or about 3 amino acids (inclusive); about 2 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, about 400 amino acids, about 380 amino acids, about 360 amino acids, about 340 amino acids, about 320 amino acids, about 300 amino acids, about 280 amino acids, about 260 amino acids, about 240 amino acids, about 220 amino acids, about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids, about 35 amino acids, about 30 amino acids, about 25 amino acids, about 20 amino acids, about 15 amino acids, about 10 amino acids, about 8 amino acids, about 6 amino acids, or about 4 amino acid (inclusive); about 3 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, about 400 amino acids, about 380 amino acids, about 360 amino acids, about 340 amino acids, about 320 amino acids, about 300 amino acids, about 280 amino acids, about 260 amino acids,

about 240 amino acids, about 220 amino acids, about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids, about 35 amino acids, about 30 amino acids, about 25 amino acids, about 20 amino acids, about 15 amino acids, about 10 amino acids, about 8 amino acids, about 6 amino acids, or about 5 amino acids (inclusive); about 4 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, about 400 amino acids, about 380 amino acids, about 360 amino acids, about 340 amino acids, about 320 amino acids, about 300 amino acids, about 280 amino acids, about 260 amino acids, about 240 amino acids, about 220 amino acids, about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino

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15 acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110
amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about
85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about
65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about
45 amino acids, about 40 amino acids, about 35 amino acids, about 30 amino acids, about
20 25 amino acids, or about 20 amino acids (inclusive); about 20 amino acids to about 500
amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids,
about 420 amino acids, about 400 amino acids, about 380 amino acids, about 360 amino
acids, about 340 amino acids, about 320 amino acids, about 300 amino acids, about 280
amino acids, about 260 amino acids, about 240 amino acids, about 220 amino acids,
25 about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino
acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130
amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids,
about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids,
about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids,
30 about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids,
about 35 amino acids, about 30 amino acids, or about 25 amino acids (inclusive); about

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

amino acids, about 400 amino acids, about 380 amino acids, about 360 amino acids, or about 340 amino acids (inclusive); about 340 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, about 400 amino acids, about 380 amino acids, or about 360 amino acids

(inclusive); about 360 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, about 400 amino acids, or about 380 amino acids (inclusive); about 380 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, about 420 amino acids, or about 400 amino acids (inclusive); about 400 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, about 440 amino acids, or about 420 amino acids (inclusive); about 420 amino acids to about 500 amino acids, about 480 amino acids, about 460 amino acids, or about 440 amino acids (inclusive); about 440 amino acids to about 500 amino acids, about 480 amino acids, or about 460 amino acids (inclusive); about 460 amino acids to about 500 amino acids or about 480 amino acids (inclusive); or about 480 amino acids to about 500 amino acids (inclusive).

In some embodiments, one or more amino acids between the extracellular antigen-binding domain and the transmembrane domain is a sequence from the same endogenous single-chain polypeptide from which the transmembrane domain is derived (e.g., a CD8 α hinge region, e.g., SEQ ID NO: 112). In some embodiments, a sequence comprising SEQ ID NO: 42, 55, or 112 is positioned between the extracellular antigen-binding domain and the transmembrane domain. In some embodiments, one or more amino acids between the extracellular antigen-binding domain and the transmembrane domain is or includes a hinge region sequence of an antibody such as, without limitation, a human antibody (e.g., IgG1, IgG2, IgG3, or IgG4). In some embodiments, one or more amino acids between the extracellular antigen-binding domain and the transmembrane domain is or comprises a linker sequence (e.g., a non-naturally occurring linker sequence, e.g., GS or any of the other linker sequences described herein).

In some embodiments of the single-chain chimeric antigen receptors, after the hormone receptor ligand binding domain, the next domain is a costimulatory domain followed by an ITAM. In some of these embodiments, one or more amino acids between the hormone receptor ligand binding domain and the costimulatory domain is or includes

a sequence from the same endogenous single-chain polypeptide from which the costimulatory domain is derived or the ITAM is derived. In some of these embodiments, one or more amino acids between the hormone receptor ligand binding domain and the costimulatory domain is or includes a linker sequence (e.g., a non-naturally occurring linker sequence). In some embodiments, one or more amino acids between the costimulatory domain and the ITAM is or includes a sequence from the same endogenous single-chain polypeptide from which the costimulatory domain is derived or the ITAM is derived.

In some embodiments of the single-chain chimeric antigen receptors, after the hormone receptor ligand binding domain, the next domain is a costimulatory domain followed by an ITAM. In some embodiments of the single-chain chimeric antigen receptors, after the ligand binding domain, the next domain is an ITAM, followed by the costimulatory domain. In some of these embodiments, one or more amino acids between the hormone receptor ligand binding domain and the ITAM is or includes a sequence from the same endogenous single-chain polypeptide from which the costimulatory domain is derived or the ITAM is derived. In some of these embodiments, one or more amino acids between the hormone receptor ligand binding domain and the ITAM is or includes a linker sequence (e.g., a non-naturally occurring linker sequence). In some embodiments, one or more amino acids between the ITAM and the costimulatory domain is or includes a sequence from the same endogenous single-chain polypeptide from which the ITAM is derived or the costimulatory domain is derived.

In some embodiments, where two or more costimulatory domains are included in the single-chain chimeric antigen receptor, the two or more costimulatory domains can be placed between the hormone receptor ligand binding domain and one or more ITAMs. In some embodiments of the single-chain chimeric antigen receptors described herein, the costimulatory domains and ITAMs can alternate in the primary amino acid sequence of the single-chain chimeric antigen receptor.

Some embodiments of any of the single-chain chimeric antigen receptors described herein can further include a dimerization domain and/or a peptide tag.

In some examples, a single-chain chimeric antigen receptor can comprise a sequence that is at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%,

at least 90%, at least 92%, at least 94%, at least 96%, at least 98%, at least 99%, or 100%) identical to: SEQ ID NO: 31, 33, 35, 37, 39, or 52.

Single-Chain Chimeric Antigen Receptor – Extracellular Hormone Receptor LBD

Also provided herein are single-chain chimeric antigen receptors that include: an extracellular antigen-binding domain (e.g., any of the antigen-binding domains described herein or known in the art), an extracellular hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domain described herein or known in the art), a transmembrane domain (e.g., any of the transmembrane domains described herein or known in the art), a costimulatory domain (e.g., any of the costimulatory domains described herein or known in the art), and an immunoreceptor tyrosine-based activation motif (ITAM), where: the transmembrane domain and the extracellular hormone ligand binding domain directly abut each other or are separated by 1 to about 800 amino acids (e.g., any of the subranges of this range described herein), and the transmembrane domain and the extracellular hormone receptor ligand binding domain are not present in the same endogenous single-chain polypeptide in a mammal. The single-chain chimeric antigen receptors described herein can bind to any of the exemplary antigens described herein or any other antigen known in the art. In some embodiments, the single-chain chimeric antigen receptor binds specifically to a single antigen (e.g., any of the exemplary antigens described herein). In some embodiments, the single-chain chimeric antigen receptor binds specifically to two different antigens (e.g., any combination of the exemplary antigens described herein).

In some embodiments of these single-chain chimeric antigen receptors, the transmembrane domain abuts the extracellular hormone receptor ligand binding domain. In some embodiments of these single-chain chimeric antigen receptors, the transmembrane domain and the extracellular hormone receptor ligand binding domain are separated by 1 to about 800 amino acids (e.g., or any of the subranges of this range described herein). In some embodiments, the amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain do not comprise a domain. In other embodiments, the amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain includes one or more

intervening domain (e.g., the antigen-binding domain or an additional antigen-binding domain). In some embodiments, the amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain includes a sequence from the same endogenous transmembrane protein from which the transmembrane domain is derived. In some embodiments, the amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain include a linker sequence.

Some embodiments of these single-chain chimeric antigen receptors can include one or more (e.g., two, three, four, or five) costimulatory domain(s) (e.g., any combination of any of the exemplary costimulatory domains described herein or known in the art). Some embodiments of these single-chain chimeric antigen receptors include one or both of a 4-1BB costimulatory domain and a CD28 costimulatory domain.

Some embodiments of these single-chain chimeric antigen receptors can include one or more (e.g., two, three, four, or five) ITAMs (e.g., any of the ITAMs described herein or known in the art). In some embodiments of these single-chain chimeric antigen receptors, the ITAM includes a cytoplasmic signaling sequence from CD3 ζ (e.g., human CD3 ζ).

In some embodiments of any of these single-chain chimeric antigen receptors, any two neighboring domains can be separated by 1 amino acids to about 500 amino acids (e.g., or any of the subranges of this range described herein).

In some embodiments, one or more amino acids between the extracellular hormone receptor ligand binding domain or the extracellular antigen-binding domain and the transmembrane domain is a sequence from the same endogenous single-chain polypeptide from which the transmembrane domain is derived (e.g., a hinge sequence from human CD8 α , e.g., SEQ ID NO: 112). In some embodiments, a sequence comprising SEQ ID NO: 42, 55, or 112 is positioned between the extracellular hormone receptor ligand binding domain or the extracellular antigen-binding domain and the transmembrane domain. In some embodiments, one or more amino acids between the extracellular antigen-binding domain or the extracellular hormone receptor ligand binding domain and the transmembrane domain is or includes a hinge region sequence of an antibody such as, without limitation, a human antibody (e.g., IgG1, IgG2, IgG3, or IgG4). In some embodiments, one or more amino acids between the extracellular

antigen-binding domain or the extracellular hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domain described herein or known in the art) and the transmembrane domain is or comprises a linker sequence (e.g., a non-naturally occurring linker sequence). In some embodiments, one or more amino acids
 5 between the extracellular antigen-binding domain and the extracellular hormone receptor ligand binding domain is or comprises a linker sequence (e.g., a non-naturally occurring linker sequence, e.g., GS or any of the other linker sequences described herein)).

In some embodiments of the single-chain chimeric antigen receptors, after the transmembrane domain, the next domain is a costimulatory domain followed by an
 10 ITAM. In some embodiments of the single-chain chimeric antigen receptors, after the transmembrane domain, the next domain is an ITAM, followed by the costimulatory domain. In some of these embodiments, one or more amino acids between the transmembrane domain and the costimulatory domain or the ITAM is or includes a sequence from the same endogenous single-chain polypeptide from which the
 15 costimulatory domain is derived or the ITAM is derived, respectively. In some of these embodiments, one or more amino acids between the transmembrane domain and the costimulatory domain or the ITAM is or includes a linker sequence (e.g., a non-naturally occurring linker sequence). In some of these embodiments, one or more amino acids between the the costimulatory domain and the ITAM is or includes a linker sequence
 20 (e.g., a non-naturally occurring linker sequence). In some embodiments, one or more amino acids between the costimulatory domain and the ITAM is or includes a sequence from the same endogenous single-chain polypeptide from which the costimulatory domain is derived or the ITAM is derived.

In some embodiments, where two or more costimulatory domains are included in
 25 the single-chain chimeric antigen receptor, the two or more costimulatory domains can be placed between the one or more ITAMs. In some embodiments, where two or more ITAMs are included in the single-chain chimeric antigen receptor, the two or more ITAMs can be placed between the one or more costimulatory molecules. In some embodiments of the single-chain chimeric antigen receptors described herein, the
 30 costimulatory domains and ITAMs can alternate in the primary amino acid sequence of the single-chain chimeric antigen receptor.

Some embodiments of any of the single-chain chimeric antigen receptors described herein can further include a dimerization domain and/or a peptide tag.

In some embodiments, when going in the N-terminal to C-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM. In some embodiments, when going in the C-terminal to the N-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM. In some embodiments, when going in the N-terminal to the C-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM. In some embodiments, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM.

In some examples, a single-chain chimeric antigen receptor can comprise a sequence that is at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%, at least 90%, at least 92%, at least 94%, at least 96%, at least 98%, at least 99%, or 100%) identical to SEQ ID NO: 98.

Multi-Chain Chimeric Antigen Receptor

Multi-Chain Chimeric Antigen Receptors – Intracellular Hormone Receptor LBD

Also provided herein are multi-chain chimeric antigen receptors that include at least one first polypeptide including: an extracellular antigen-binding domain (e.g., any of the antigen-binding domains described herein or known in the art), a transmembrane domain (e.g., any of the transmembrane domains described herein or known in the art), and a hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domains described herein or known in the art), where the transmembrane domain

and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to about 800 amino acids (e.g., any of the subranges of this range described herein), and the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same (a single) endogenous single-chain polypeptide. The antigen specifically bound by the antigen-binding domain in any of these multi-chain chimeric antigen receptors can be any of the antigens described herein or known in the art. In some embodiments, the multi-chain chimeric antigen receptor only binds specifically to a single antigen (e.g., any of the exemplary antigens described herein). In some embodiments, the multi-chain chimeric antigen receptor binds specifically to two different antigens (e.g., any combination of any of the exemplary antigens described herein).

In some embodiments of the multi-chain chimeric antigen receptors, the extracellular antigen-binding domain and the transmembrane domain in the at least one first polypeptide abut each other. In some embodiments of the multi-chain chimeric antigen receptors, 1 to about 500 amino acids (e.g., any of the subranges of this range described herein) are between the extracellular antigen-binding domain and the transmembrane domain in the at least one first polypeptide. In some embodiments, one or more amino acids between the extracellular antigen-binding domain and the transmembrane domain in the at least one first polypeptide is a sequence from the same endogenous single-chain polypeptide from which the transmembrane domain is derived. In some embodiments, one or more amino acids between the extracellular antigen-binding domain and the transmembrane domain of the at least one first polypeptide is or includes a hinge region sequence of human antibody (e.g., IgG1, IgG2, IgG3, or IgG4). In some embodiments, one or more amino acids between the extracellular antigen-binding domain and the transmembrane domain in the at least one first polypeptide is or includes a linker sequence (e.g., a non-naturally occurring linker sequence).

In some embodiments of these multi-chain chimeric antigen receptors, the transmembrane domain abuts the hormone receptor ligand binding domain in the at least one first polypeptide. In some embodiments of these multi-chain chimeric antigen receptors, the transmembrane domain and the hormone receptor ligand binding domain in the at least one first polypeptide are separated by 1 to about 800 amino acids (e.g., or any

of the subranges of this range described herein). In some embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain in the at least one first polypeptide do not comprise a domain. In other embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain in the at least one first polypeptide includes one or more intervening domain (e.g., one or more costimulatory domains (e.g., any of the costimulatory domains described herein) and/or one or more ITAMs (e.g., any of the ITAMs described herein)). In some embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain in the at least one first polypeptide includes a sequence from the same endogenous transmembrane protein from which the transmembrane domain is derived. In some embodiments, the amino acids between the transmembrane domain and the hormone receptor ligand binding domain in the at least one first polypeptide include a linker sequence (e.g., a non-naturally occurring linker sequence).

In some embodiments of these multi-chain chimeric antigen receptors, the at least one first polypeptide can further include one or more (e.g., two or three) of: a dimerizing domain (e.g., any dimerizing domain known in the art), a costimulatory domain (e.g., any of the costimulatory domains described herein), and/or a peptide tag (e.g., any peptide tag known in the art).

Some embodiments of these multi-chain chimeric antigen receptors further include a second polypeptide that can include one or more (e.g., two, three, or four) of: a transmembrane domain (e.g., any of the transmembrane domains described herein), a dimerizing domain (e.g., a dimerizing domain that can interact with a dimerizing domain in the at least one first polypeptide in a mammalian cell), one or more costimulatory domains (e.g., any of the costimulatory domains described herein), and one or more ITAM (e.g., any of the ITAMs described herein). As can be appreciated by those in the art, a pair or each pair of neighboring domains in the second polypeptide can abut each other or can be separated by 1 to about 800 amino acids (e.g., any of the subranges of this range described herein). The one or more amino acids between a pair of neighboring domains in the second polypeptide can be a sequence from an endogenous single-chain

polypeptide from which a transmembrane, a costimulatory domain, or an ITAM present in the second polypeptide has been derived.

Multi-Chain Chimeric Antigen Receptors – Extracellular Hormone Receptor LBD

Also provided herein are multi-chain chimeric antigen receptors that include at least one first polypeptide including: an extracellular antigen-binding domain (e.g., any of the antigen-binding domains described herein or known in the art), an extracellular hormone receptor ligand binding domain (e.g., any of the hormone receptor ligand binding domains described herein or known in the art), and a transmembrane domain (e.g., any of the transmembrane domains described herein or known in the art), where the transmembrane domain and the extracellular hormone receptor ligand binding domain directly abut each other or are separated by 1 to about 800 amino acids (e.g., any of the subranges of this range described herein), and the transmembrane domain and the hormone receptor ligand binding domain are both not present in a single endogenous single-chain polypeptide. The antigen specifically bound by the antigen-binding domain in any of these multi-chain chimeric antigen receptors can be any of the antigens described herein or known in the art. In some embodiments, the multi-chain chimeric antigen receptor only binds specifically to a single antigen (e.g., any of the exemplary antigens described herein). In some embodiments, the multi-chain chimeric antigen receptor binds specifically to two different antigens (e.g., any combination of any of the exemplary antigens described herein).

In some embodiments of the multi-chain chimeric antigen receptors, the extracellular hormone receptor ligand binding domain and the transmembrane domain in the at least one first polypeptide abut each other. In some embodiments of the multi-chain chimeric antigen receptors, 1 to about 700 amino acids (e.g., any of the subranges of this range described herein) are between the extracellular hormone receptor ligand binding domain and the transmembrane domain in the at least one first polypeptide. In some embodiments, one or more amino acids between the extracellular hormone receptor ligand binding domain and the transmembrane domain in the at least one first polypeptide is a sequence from the same endogenous single-chain polypeptide from which the transmembrane domain is derived. In some embodiments, one or more amino acids

between the extracellular hormone receptor ligand binding domain and the transmembrane domain of the at least one first polypeptide is or includes a hinge region sequence of human antibody (e.g., IgG1, IgG2, IgG3, or IgG4). In some embodiments, one or more amino acids between the extracellular hormone receptor ligand binding domain and the transmembrane domain in the at least one first polypeptide is or includes a linker sequence (e.g., a non-naturally occurring linker sequence). In some embodiments, one or more amino acids between the extracellular hormone receptor ligand binding domain and the antigen-binding domain is or includes a linker sequence (e.g., a non-naturally occurring linker sequence).

In some embodiments of these multi-chain chimeric antigen receptors, the transmembrane domain abuts the extracellular hormone receptor ligand binding domain in the at least one first polypeptide. In some embodiments of these multi-chain chimeric antigen receptors, the transmembrane domain and the extracellular hormone receptor ligand binding domain in the at least one first polypeptide are separated by 1 to about 800 amino acids (e.g., or any of the subranges of this range described herein). In some embodiments, the amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain in the at least one first polypeptide do not comprise a domain.

In some embodiments, the amino acids between the transmembrane domain and the extracellular hormone receptor ligand binding domain in the at least one first polypeptide includes one or more intervening domain (e.g., the antigen-binding domain). In some embodiments, the amino acids between the transmembrane domain and the antigen-binding domain in the at least one first polypeptide includes a sequence from the same endogenous transmembrane protein from which the transmembrane domain is derived. In some embodiments, the amino acids between the transmembrane domain and the antigen-binding domain in the at least one first polypeptide include a linker sequence (e.g., a non-naturally occurring linker sequence). In some embodiments, one or more amino acids between the antigen-binding domain and the transmembrane domain of the at least one first polypeptide is or includes a hinge region sequence of human antibody (e.g., IgG1, IgG2, IgG3, or IgG4). In some embodiments, one or more amino acids between the antigen-binding domain and the extracellular hormone receptor ligand

binding domain in the at least one first polypeptide is or includes a linker sequence (e.g., a non-naturally occurring linker sequence).

In some embodiments, when going in the N-terminal to C-terminal direction, the at least one first polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

In some embodiments, when going in the C-terminal to N-terminal direction, the at least one first polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

In some embodiments, when going in the N-terminal to C-terminal direction, the at least one first polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain. In some embodiments, when going in the C-terminal to N-terminal direction, the at least one first polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

In some embodiments of these multi-chain chimeric antigen receptors, the at least one first polypeptide can further include one or more (e.g., two or three) of: a dimerizing domain (e.g., any dimerizing domain known in the art), a costimulatory domain (e.g., any of the costimulatory domains described herein), and/or a peptide tag (e.g., any peptide tag known in the art).

Some embodiments of these multi-chain chimeric antigen receptors further include a second polypeptide that can include one or more (e.g., two, three, or four, in any order or combination) of: a transmembrane domain (e.g., any of the transmembrane domains described herein), a dimerizing domain (e.g., a dimerizing domain that can interact with a dimerizing domain in the at least one first polypeptide in a mammalian cell), one or more costimulatory domains (e.g., any of the costimulatory domains described herein), and one or more ITAM (e.g., any of the ITAMs described herein). As can be appreciated by those in the art, a pair or each pair of neighboring domains in the second polypeptide can abut each other or can be separated by 1 to about 800 amino acids (e.g., any of the subranges of this range described herein). The one or more amino acids between a pair of neighboring domains in the second polypeptide can be a sequence from an endogenous single-chain polypeptide from which a transmembrane, a costimulatory

domain, or an ITAM present in the second polypeptide has been derived. The one or more amino acids between a pair of neighboring domains in the second polypeptide can be or include a linker sequence (e.g., a non-naturally occurring linker sequence).

As can be appreciated in the art, the two or more polypeptides present in a multi-chain chimeric antigen receptor can associate via pair of domains that interact with each other (through dimerizing domains). In some embodiments, the interaction between dimerizing domains can be triggered by the addition of a small molecule. In some embodiments, the two or more polypeptides present in a multi-meric chimeric antigen receptor can associate through non-covalent interactions (e.g., between associations between dimerizing domains). In some embodiments, the two or more polypeptides present in a multi-meric chimeric antigen receptor can be through a covalent interaction (e.g., through a disulfide bond, through an ester bond, through an amide bond, through a thioester bond, or a combination thereof).

Transmembrane Domains

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a transmembrane domain, or portion thereof, from an endogenous polypeptide, where the endogenous polypeptide is selected from the group g of: an α chain of a T cell receptor, a β chain of the T cell receptor, a ζ chain of the T cell receptor, CD28 (also known as Tp44), CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37 (also known as GP52-40 or TSPAN26), CD64 (also known as FCGR1A), CD80 (also known as B7, B7-1, B7.1, BB1, CD28LG, CD28LG1, and LAB7), CD45 (also known as PTPRC, B220, CD45R, GP180, L-CA, LCA, LY5, T200, and protein tyrosine phosphatase, receptor type C), CD4, CD5 (also known as LEU1 and T1), CD8 α (also known as Leu2, MAL, and p32), CD9 (also known as BTCC-1, DRAP-27, MIC3, MRP-1, TSPAN-29, and TSPAN29), CD16 (also known as FCGR3 and FCG3), CD22 (also known as SIGLEC-2 and SIGLEC2), CD86 (also known as B7-2, B7.2, B70, CD28LG2, and LAB72), CD134 (also known as TNFRSF4, ACT35, RP5-902P8.3, IMD16, OX40, TXGP1L, and tumor necrosis factor receptor superfamily member 4), CD137 (also known as TNFRSF9, 4-1BB, CDw137, ILA, and tumor necrosis factor receptor superfamily member 9), CD27 (also known as S152,

S152.LPFS2, T14, TNFRSF7, and Tp55), CD152 (also known as CTLA4, ALPS5, CELIAC3, CTLA-4, GRD4, GSE, IDDM12, and cytotoxic T-lymphocyte associated protein 4), PD1 (also known as PDCD1, CD279, PD-1, SLEB2, hPD-1, hPD-l, hSLE1, and Programmed cell death 1), ICOS (also known as AILIM, CD278, and CVID1),
 5 CD272 (also known as BTLA and BTLA1), CD30 (also known as TNFRSF8, D1S166E, and Ki-1), GITR (also known as TNFRSF18, RP5-902P8.2, AITR, CD357, and GITR-D), HVEM (also known as TNFRSF14, RP3-395M20.6, ATAR, CD270, HVEA, HVEM, LIGHTR, and TR2), DAP10, and CD154 (also known as CD40LG, CD40L, HIGM1, IGM, IMD3, T-BAM, TNFSF5, TRAP, gp39, hCD40L, and CD40 ligand). The letters
 10 “CD” is the previous sentence stand for “Cluster of Differentiation.” E.g., CD3 stands for “Cluster of Differentiation 3.” In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a transmembrane domain, or portion thereof, from an endogenous mammalian (e.g., human) polypeptide (e.g., a mammalian or human homolog of any of
 15 the polypeptides listed above).

Any transmembrane domain, or portion thereof, that serves to anchor an endogenous polypeptide in a lipid bilayer (e.g., plasma membrane) of a mammalian cell is suitable for use in accordance with compositions and methods disclosed herein. In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen
 20 receptor, or a multi-chain chimeric antigen receptor includes a transmembrane domain, or portion thereof, from human CD28, e.g., Accession No. P01747, e.g., amino acids 153 to 179 of SEQ ID NO: 1. In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a transmembrane domain that is at least 80% (e.g., at least 82%, at least 84%, at
 25 least 85%, at least 86%, at least 88%, at least 90%, at least 92%, at least 94%, at least 95%, at least 96%, at least 98%, or at least 99% identical) to amino acids 153 to 179 of SEQ ID NO: 1, or a portion thereof.

In some embodiments, transmembrane domain can comprise a sequence at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%, at least 90%, at least
 30 92%, at least 94%, at least 96%, at least 98%, at least 99%, or 100% identical) to SEQ ID NO: 114 (or a portion thereof).

SEQ ID NO: 1

MLRLLLALNLFPSIQVTGNKILVKQSPMLVAYDNAVNLSCKYSYNLFSREFRASL
 HKGLDSAVEVCVVYGNYSQQLQVYSKTGFNCDGKLGNESVTFYLQONLYVNQT
 5 DIYFCKIEVMYPPPYLDNEKSNGTIIHVKGKHLCPSPFPGPSKPFWVLVVVGGVL
 ACYSLLVTVAFIIFWVRSKRSRLHSDYMNMTPRRPGPTRKHYPYAPPRDFAA
 YRS

In some embodiments, a single-chain chimeric polypeptide, a single-chain
 10 chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a
 transmembrane domain, or portion thereof, from human CD3, e.g., Accession No.
 P20963, e.g., amino acids 31 to 51 of SEQ ID NO: 2. In some embodiments, a single-
 chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain
 chimeric antigen receptor includes a transmembrane domain that is or includes a
 15 sequence that is at least 80% (e.g., at least 82%, at least 84%, at least 85%, at least 86%,
 at least 88%, at least 90%, at least 92%, at least 94%, at least 95%, at least 96%, at least
 98%, or at least 99% identical) to amino acids 31 to 51 of SEQ ID NO: 2.

SEQ ID NO: 2

20 MKWKALFTAAILQAQLPITEAQSFGLLDPKLCYLLDGILFIYGVILTALFLRVKFS
 RSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPEMGGKPQRRKNPQE
 GLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQA
 LPPR

25 In some embodiments, a single-chain chimeric polypeptide, a single-chain
 chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a
 transmembrane domain, or portion thereof, of any one of SEQ ID Nos. 3-9.

LGLLVAGVLVLLVSLGVAIHLCC (SEQ ID NO: 3);

VAAILGLGLVLGLLGPLAILLALYLL (SEQ ID NO: 4);

30 ALIVLGGVAGLLFIGLGIFFCVRC (SEQ ID NO: 5);

LCYLLDGILFIYGVILTALFLRV (SEQ ID NO: 6);

WVLVVVGGVLACYSLLVTVAFIIFWV (SEQ ID NO: 7);

IYIWAPLAGTCGVLLLSLVITLYC (SEQ ID NO: 8); and

ALPAALAVISFLLGLGLGVACVLA (SEQ ID NO: 9).

In some embodiments, a single-chain chimeric polypeptide, a single-chain
 5 chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a
 transmembrane domain that is or includes a sequence that is at least 80% (e.g., at least
 82%, at least 84%, at least 85%, at least 86%, at least 88%, at least 90%, at least 92%, at
 least 94%, at least 95%, at least 96%, at least 98%, or at least 99% identical) to any one
 of SEQ ID Nos. 3-9.

10 In some embodiments, a single-chain chimeric polypeptide, a single-chain
 chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a
 transmembrane domain that is or includes a sequence that is at least 80% (e.g., at least
 82%, at least 84%, at least 85%, at least 86%, at least 88%, at least 90%, at least 92%, at
 least 94%, at least 95%, at least 96%, at least 98%, or at least 99% identical) to SEQ ID
 15 NO: 43, 56, or 114.

As will be appreciated by those of ordinary skill in the art, certain endogenous
 polypeptides have two or more isoforms that differ at least in their primary polypeptide
 sequence. A single-chain chimeric polypeptide, a single-chain chimeric antigen receptor,
 or a multi-chain chimeric antigen receptor disclosed herein can include a transmembrane
 20 domain that includes a sequence of amino acids from any isoform of an endogenous
 transmembrane protein (e.g., an endogenous mammalian, e.g., human, transmembrane
 protein) including, e.g., an isoform (e.g., a human isoform) of: an α chain of a T cell
 receptor, a β chain of the T cell receptor, a ζ chain of the T cell receptor, CD28, CD3 ϵ ,
 CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22,
 25 CD86, CD134, CD137, CD27, CD152, PD1, or CD154.

In some embodiments, a transmembrane domain, or portion thereof, of a single-
 chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain
 chimeric antigen receptor includes a sequence of amino acids that exhibits at least 85%,
 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more
 30 sequence identity to the transmembrane domains from one or more of the following
 endogenous mammalian (e.g., human) transmembrane proteins: an α chain of a T cell

receptor, a β chain of the T cell receptor, a ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, CD27, CD152, PD1, or CD154. In some embodiments, a transmembrane domain, or portion thereof, of a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a sequence of amino acids having one or more amino acid substitutions, deletions, or additions as compared to the transmembrane domain of an endogenous mammalian (e.g., human) transmembrane protein: an α chain of a T cell receptor, a β chain of the T cell receptor, a ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, CD27, CD152, PD1, or CD154.

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a synthetic transmembrane domain. In some cases, a synthetic transmembrane domain can include predominantly hydrophobic residues such as, without limitation, leucine and valine. In some embodiments, a synthetic transmembrane domain includes a triplet of phenylalanine, tryptophan, and valine at each end of the domain.

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a transmembrane domain that is a chimeric transmembrane domain having portions of a transmembrane domain from two or more endogenous mammalian (e.g., human) transmembrane polypeptides such as, without limitation, an α chain of a T cell receptor, a β chain of the T cell receptor, a ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, CD27, CD152, PD1, and CD154, such that the two or more portions of transmembrane domains together constitute a functional transmembrane domain. In some embodiments, such a portion of a chimeric transmembrane domain can include one or more amino acid substitutions, deletions, or additions as compared to a corresponding portion of a wild type transmembrane domain.

A transmembrane domain can include one, two, three, four, five, six, seven, eight, nine, or ten contiguous amino acid sequences that each traverse a lipid bilayer when

present in the corresponding endogenous polypeptide when expressed in a mammalian cell. As is known in the art, a transmembrane domain can, e.g., include at least one (e.g., two, three, four, five, six, seven, eight, nine, or ten) contiguous amino acid sequence (that traverses a lipid bilayer when present in the corresponding endogenous polypeptide when expressed in a mammalian cell) that has α -helical secondary structure in the lipid bilayer. In some embodiments, a transmembrane domain can include two or more contiguous amino acid sequences (that each traverse a lipid bilayer when present in the corresponding endogenous polypeptide when expressed in a mammalian cell) that form a β -barrel secondary structure in the lipid bilayer. Additional examples and features of transmembrane domains are known in the art.

Hormone Receptor Ligand Binding Domains

In some embodiments, the hormone receptor ligand binding domain is or comprises an estrogen receptor ligand binding domain, or a fragment thereof. Additional examples of hormone receptor ligand binding domains that can be used in any of the polypeptides described herein (e.g., single-chain chimeric polypeptide, single-chain chimeric antigen receptor, or multi-chain chimeric antigen receptor) include the ligand binding domains of, e.g., an estrogen receptor, an ecdysone receptor, a PPAR γ receptor, a glucocorticoid receptor, an androgen receptor, a thyroid hormone receptor, a mineralocorticoid receptor, a progesterone receptor, a vitamin D receptor, a PPAR receptor α , a PPAR β/δ receptor, a pregnane X receptor, a liver X receptor, a farnesoid X receptor, a retinoid X receptor, a RAR-related orphan receptor, and a retinoic acid receptor.

A non-limiting example of a human estrogen receptor ligand binding domain is amino acids 10 of 247 of SEQ ID NO: 10. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 10 to 247 of SEQ ID NO: 10.

SEQ ID NO: 10 (Human)

1 skknslalsl tadqmvsa11 daeppilyse ydptrpfsea smmglltnla drelvhminw
 61 akrvpqgfvdl tlhdqvh11e cawleilmig lvwrsmehpg kllfapn111 drnqgkcveg
 121 mveifdml1a tssrfrmmn1 qgeefvclks iillnsgvyt flsstlksle ekdhihrvld
 5 181 kitdtlihl1m akagltlqqg hqrlaq111i lshirhmsnk gmehlysmkc knvvplydll
 241 lemldahrlh

Another non-limiting example of an estrogen receptor ligand binding domain is amino acids 4 to 241 of SEQ ID NO: 11. In some embodiments, a hormone receptor
 10 ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 4 to 241 of SEQ ID NO: 11.

SEQ ID NO: 11 (Human)

1 als1tadqmv salldaep1i lyseydptrp fseasmmg1l tnladrelvh minwakrvpg
 61 fvd1tlhdq1v h11lecawlei lmiglvwrsm ehpgkllfap n111ldrnqgk cveg1mveifd
 121 m11latssrfr mmn1lqgeefv clksi11l1ns gvytflsst1 ksleekdhih rvldkitdt1
 20 181 i1hlmakaglt lqqqhqr1aq 111ilshirh msnkgmehly smkcknvvpl yd111leml1da
 241 hrlhapt1s

In some embodiments, the estrogen receptor ligand binding domain has a wildtype sequence, except that it comprises one or more (e.g., two, three, four, five, or
 25 six) amino acid substitutions. In some embodiments, the estrogen receptor ligand binding domain has a wildtype sequence, except that it comprises an amino acid substitution(s) at one or both of amino acid position 521 (e.g., a G521R substitution) and 537 (e.g., a G537F substitution) (each numbered relative to the full-length wildtype sequence of human estrogen receptor, e.g., SEQ ID NO: 119 below).

SEQ ID NO: 119 (Human)

1 mtmtlhtkas gmallhqi1g neleplnrpq lkiplerplg evyldsskpa vynypegaay
 61 efnaaaaaana qvygqtglpy gpgseaaafg snglggfppl nsvspsplm1 lhpppqlsp1f
 121 lqphgqqvpy ylenepsgyt vreagppafy rpsndnrrqg grerlastnd kgsmamesak

181 etrycavcnd yasgyhygvw scegckaffk rsiqghndym cpatnqctid knrrkscqac
 241 rlrkcyevgm mkggirkdr rddgegrgev gsagdmraan lwpsplmikr
 301 skknsllsl tadqmvslall daeppilyse ydptrpfsea smmglltnla drelvhminw
 361 akrvpqgfvdl tlhdqvhllle cawleilmig lvwrsmehpg kllfapnlll drnqgkcevg
 5 421 mveifdmla tssrfrmmnl qgeefvclks iillnsgvyt flsstlksle ekdhihrvld
 481 kitdtlihl akagltlqqq hqrlaqllli lshirhmsnk gmehlysmkc knvvpdydl
 541 lemldahrlh aptsrqgasv eetdqshlat agstssshslq kyyitgeaeg fpatv

Non-limiting examples of an estrogen receptor ligand binding domain can include a sequence at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%, at least 90%, at least 92%, at least 94%, at least 96%, at least 98%, at least 99% or 100%) identical to: SEQ ID NO: 110 (or a fragment thereof).

Additional non-limiting examples of a hormone receptor ligand binding domain is or includes a sequence at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%, at least 90%, at least 92%, at least 94%, at least 96%, at least 98%, at least 99% or 100%) identical to SEQ ID NO: 46, 59, or 110.

Another non-limiting example of an estrogen receptor ligand binding domain is amino acids 314 to 551 of SEQ ID NO: 88. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 314 to 551 of SEQ ID NO: 88.

SEQ ID NO: 88 (Mouse)

1 mtmtlhtkas gmallhqi qg neleplnrpq lkmpmeralg evyvdnskpt vfnypegaay
 61 efnaaaaaaaaa aasapvygqs giaygpgsea aafsanslga fpqlnsvsps plmlhpppq
 121 lspflhphgq qvpylenep sayavrdtgp pafyrsnsdn rrqngrerls ssnekgnmim
 181 esaketryca vcndyasgyh ygvwscegck affkrsiqgh ndymcpatnq ctidknrrks
 241 cqacrlrkcy evgmkggir kdrgrgrrlk hkrqrdleg rnemgasgdm raanlwpspl
 301 vikhtkknsp alsltadqmv salldaepm iyseydpsrp fseasmgll tnladrelvh
 361 minwakrvpg fgdlnlhdqv hllecawlei lmiglvwrsm ehpgkllfap nllldrnqgk
 421 cvegmveifd mllatssrfr mmnlqgeefv clksiillns gvytflsstl ksleekdhih
 481 rvldkitdtl ihlmakaglt lqqqhrrlaq lllilshirh msnkgmehly nmckknvvp
 541 ydlillemla hrlhapasrm gvppeepsqt qlattsstsa hslqtyyipp eaegfpnti

Another non-limiting example of an estrogen receptor ligand binding domain is amino acids 315 to 552 of SEQ ID NO: 89. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 315 to 552 of SEQ ID NO: 89.

SEQ ID NO: 89 (Rat)

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10      1 mtmtlhtkas gmallhqi qg neleplnrpq lkmpmeralg evyvdnska vfnypegaay
      61 efnaaaaaaa agasapvygq ssitygpgse aaafganslg afpqlnsvsp splmllhppp
121     hvspflhphg hqvpyylene psayavrdtg ppafyrsnsd nrrqngrerl ssssekgnmi
181     mesaketryc avcndyasgy hygvwscegc kaffkrsiqg hndymcpatn qctidknrrk
241     scqacrlrkc yevgmmkggi rkdrgrgml khkrqrddle grnemgtsgd mraanlwpsp
15     301 lvikhtkkns palsltadqm vsalldaep liyseydpsr pfseasmmgl ltnladrelv
      361 hminwakrvp gfgdlnlhdq vhllecawle ilmiglvwrs mehpgkllfa pnlldrnqg
      421 kcevgmveif dmlatssrf rmmnlqgeef vclksiilln sgvytflsst lksleekdhi
      481 hruldkindt lihlmakagl tlqqqhrrla qlllilshir hmsnkgmehl ynmkcknvvp
      541 lydlilleld ahrhlapasr mgvppeepsq sqlttssts ahsqttyyip peaegfpnti

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Another non-limiting example of an estrogen receptor ligand binding domain is amino acids 310 to 547 of SEQ ID NO: 90. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 310 to 547 of SEQ ID NO: 90.

SEQ ID NO: 90 (Baboon)

```

30      1 mtmtlhtkas gmallhqi qg neleplnrpq lkiplerplg evyvdsska vysypegaay
      61 efnaaaaana qvygqtglpy gpgseaaafg snglggfppl nsvspsplml lhpppqslspf
121     lqphgqqvpy ylenepsgyt vreagppafy rpnsdnrrqg grerlastnd kgsmamesak
181     etrycavcnd yasgyhygvw scegckaffk rsiqghndym cpatnqctid knrrkscqac
241     rlrkcyevgm mkggirkdr rgrmlkhkrq rddgegrgev gsagdmraan lwpsplmikh
35     301 skknspalsl tadqmvsall daeppilyse ydptrpfsea smmglltnla drelvhminw

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361 akrvpqgfvdl tlhdqvhllle cawleilmig lvwrsmehpg kllfapnlll drnqgkcveg
 421 mveifdmlla tssrfrmmnl qgeefvclks iillnsgvyt flsstlksle ekdhihrvld
 481 kitdtlihlml akagltlqqq hrllaqllli lshirhmsnk gmehlysmkc knvvpdydl
 541 lemldahrlh aptsrsggapm eetdqshlat agstssshslq kyyitgdaeg fpatv

5

In some embodiments, the hormone receptor ligand binding domain is or comprises a progesterone receptor ligand binding domain, or a fragment thereof. A non-limiting example of a human progesterone receptor ligand binding domain is amino acids 11 to 258 of SEQ ID NO: 12. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 11 to 258 of SEQ ID NO: 12.

15

SEQ ID NO: 12 (Human)

1 spgqdiqlip plinllmsie pdviyaghdn tkpdtsssl1 tslnqlgerq llsvvkwsks
 61 lpgfrnlhid dqitliqysw mslmvfglgw rsykhvsgqm lyfapdliln eqrmkessfy
 121 slcltmwqip qefvklqvsq eeeflcmkvll llntiplegl rsqtqfeemr ssyirelika
 181 iglrqkgvvs ssqrftyqltk lldnlhdlvk qlhlyclntf iqsralsevef pemmseviaa
 241 qlpkilagmv kp1lfhkk

20

Another non-limiting example of a progesterone receptor ligand binding domain is amino acids 14 to 261 of SEQ ID NO: 13. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 14 to 261 of SEQ ID NO: 13.

30

SEQ ID NO: 13 (Human)

1 ftfspgqdiq lipplinllm siepdviyag hdntkpdts slltslnqlg erqllsvvkws
 61 skslpgfrnl hiddqitliq yswmslmvfg lgwrsykhvs gqmlyfapdl ilneqrmkes
 121 sfyslcltmw qipqefvklq vsqeeflcmk vllllntipl eglrsqtqfe emrssyirel

181 ikaiglrqkg vvsssqrifyq ltklldnlhd lvkqlhlycl ntfigsrals vefpemmsev
 241 iaaqlpkila gmvkpllfhk k

Another non-limiting example of a progesterone receptor ligand binding domain is amino acids 679 to 926 of SEQ ID NO: 91. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 679 to 926 of SEQ ID NO: 91.

SEQ ID NO: 91 (Mouse)

1 mtelqakdpq vlhtsgasps pphigsplla rldsgpfqgs qhsdvssvvs pipisldgll
 61 fprscrgpel pdgktgdqqs lsdvegafsg veathreggr nsrapekdsr lldsvldsll
 121 tpsgteqsha sppaceaits wclfgpelpe dprsvpatkg llsplmsrpe ikagdssgtg
 181 agqkvlpkgl spprqlllpt sgshwpgag vkpsppaag eveedsglet eggaapllks
 241 kpralegtgs gggvaanaas aapggvtlvp kedsrfsapr vsleqdspia pgrsplattv
 301 vdfihvpilp lnhallaart rqllegdsyd ggataqgpfa pprgspsaps ppvpcgdfpd
 361 ctyplegdpk edvfplygdf qtpglkikee eegadaavrs prpylsagas sstfpdfpla
 421 papqrapssr pgeaavaggp ssaavspass sgalecily kaegapptqg sfaplpckpp
 481 aagscllprd slpaapataa apaiyqplgl nglpqlgyqa avlkdsllpqv yppylnylrp
 541 dseasqspqy gfdslpqkic licgdeasgc hygvltcgsc kvffkrameg qhnylcagr
 601 dcivdkirrk ncpacrlrk cqagmvlgr kfkfkfkvr mrtldgvalp qsvglpnesq
 661 algqritfsp ngeiqlvpl inllmsiepd vvyaghdntk pdtssslts lnqlgerqll
 721 svvkwskslp gfrnlhiddq itliqyswms lmvfglgws ykhvsgqmly fapdlilneq
 781 rmkelsfysl cltmwqipqe fvklqvthee flcmkvllll ntiplegrls qsqfeemrss
 841 yirelikaig lrqkgvvpss qrifyqltkll dslhdlvkql hlyclntfiq srtlavefpe
 901 mmseviaaql pkilagmvkp llfhkk

Another non-limiting example of a progesterone receptor ligand binding domain is amino acids 676 to 923 of SEQ ID NO: 92. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 676 to 923 of SEQ ID NO: 92.

SEQ ID NO: 92 (Rat)

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5      1 mtelqakdpr tlhtsgaaps pthvgsplla rldpdpfqgs qhsdassvvs pipisldrll
      61 fsrscqaqel pdektqnqqs lsdvegafsg veasrrrsrn prapekdsrl ldsvaldtlla
     121 psgpeqsqts ppaceaitsw clfgpelped prsvpatkgl lsplmsrpes kagdssgtga
     181 gqkvlpkavs pprqlllpts gsahwpgagv kpsqqpatve veedgglete gsagpllksk
     241 pralegmcsq ggvtanapga apggvtlvpk edsrf saprv sleqdapvap grsplattvv
10    301 dfihvpilpl nhallaartr qllegdsydg gaaaqvpfap prgspsapsp pvpcgdfpdc
     361 typpegdpke dgfpvygef q ppglkikkee egteaasrsp rpyllagasa atfpdfplpp
     421 rpprappsrp geaavaapsa avspvsssgs alecilykae gapptqgsfa plpckppaas
     481 scllprdsld aaptssaapa iypplglngl pqlgyqaavl kdsllpqvyp ylnylrpdse
     541 asqspqygfd slpqkiclic gdeasgchyg vltcgscckvf fkramegqhn ylcagrndci
15    601 vdkirrkncp acrlrkccqa gmvlggrkfk kfnkvrvmra ldgvalpqsv afpnesqtlg
     661 qritfspnqe iqlvpplnl lmsiepdvvy aghdntkpd t ssslltslnq lgerqllsvv
     721 kwskslpgfr nlhiddqitl iqyswmslmv fglgwrsykh vsgqmlyfap dlilneqrnk
     781 elsfyslclt mwqipqefvk lqvtheeflc mkvllllnti pleglrsqsq feemrssyir
     841 elikaiglrq kgvvpssqrf yqltklldsl hdlvkqlhly clntfigsra lavefpemms
20    901 eviaaqlpki lagmvkpllf hkk

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Another non-limiting example of a progesterone receptor ligand binding domain is amino acids 686 to 933 of SEQ ID NO: 93. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 686 to 933 of SEQ ID NO: 93.

SEQ ID NO: 93 (Baboon)

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30    1 mtelkakgpr aphvaggpps pevgspllcr paagpfqgsq tsdtlpevsa ipisldgllf
      61 prpcqgqdp l dektqdqql sdvegaysra eatrgtgss srppekdsl lhsvaldtlla
     121 psgpgqsqps ppacevtssw clfgpelped ppaapatqgv lsplmsrsgc kagdssgtaa
     181 ahkvlprgls psrqlllpas gsphwsgapv kpsqpaaave veeedgsese esagpllkgk
35    241 pralggaaag ggaaavppga aaggvalvpk edsrf saprv alveqdapma pgrsplattt
     301 mdfthvpilp lshallaart rqlleesydg ggagaasafa pprsspsass tpvavgd fdpd

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361 cayppdadpk ddayplygdf qppalkikee eegaevsars prsylvagan paafpdfplg
 421 pppplpprap psrpgeaavt aapagasvss asssgstlec ilykaegapp qggpfapppc
 481 kapgaggc11 prdglpsta saaaagaapa lypalglngl pqlgyqaavl keglqqvypp
 541 ylnylrpdse asqspqysfe slpqkiclic gdeasgchyg vltcgscckvf fkramegqhn
 5 601 ylcagrndci vdkirrknpc acrlrkccqa gmvlggrkfk kfnkvrvma ldavalppqv
 661 gipnesqals qrftfppgqd iqlipplinl lvsiepdviy aghdnskpdtd ssslltslnq
 721 lgerqllsvv kwskl1pgfr nlhiddqitl iqyswmslmv fglgwrsykh vsgqmlyfap
 781 dlilneqrmk essfyslclt mwqipqefvk lqvsqeeflc mkvllllnti pleglrsqtq
 841 feemrssyir elikaiglrq kgvvsssqrf yqltklldnl hdlvkqlhly clntfiqsra
 10 901 lsvefpemms eviaaqlpki lagmvkpllf hkk

In some embodiments, the hormone receptor ligand binding domain is or
 comprises an androgen receptor ligand binding domain, or a fragment thereof. A non-
 limiting example of a human androgen receptor ligand binding domain is amino acids 2
 of 247 of SEQ ID NO: 14. In some embodiments, a hormone receptor ligand binding
 15 domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least
 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 2 to 247 of SEQ
 20 ID NO: 14.

SEQ ID NO: 14 (Human)

1 piflnvleai epgvvcaghd nnqpdsfaal lsslnelger qlvhvkwak alpgfrnlhv
 61 ddqmaviqys wmg1mvfamg wrsftnvnsr mlyfapdlvf neyrmhksrm ysqcvrmrhl
 25 121 sqefgwlqit pqeflcmkal llfsiipvdg lknqkffdel rmnyikelldr iiackrknpd
 181 scsrrfyqlt klldsvqpia relhqftfdl likshmvsvd fpemmaeiis vqvpkilsgk
 241 vkpiyfhtq

Another non-limiting example of an androgen receptor ligand binding domain is
 30 amino acids 34 to 279 of SEQ ID NO: 15. In some embodiments, a hormone receptor
 ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least
 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at
 least 89%, 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%, or at least 99% identical to amino acids 34 to 279 of SEQ ID NO: 15.

SEQ ID NO: 15 (Human)

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5   1   sleegeasst tspteettqk ltvshiegye cqpiflnvle aiepgvvcag hdnnqpdsfa
    61  allsslnelg erqlvhvkw akalpgrnl hvddqmaviq yswmglmvfa mgwrsftnvn
    121 srmlyfapdl vfneyrmhks rmysqcvrmr hlsqefgwlg itpqeflcmk alllfsiipv

    181 dglknqkffd elrmnyikel driiackrkn ptscsrrfyq ltklldsvqp iarelhqftf
10  241 dlilikshmvs vdfpemmaei isvqvpkils gkvkpiyfht qeg

```

Another non-limiting example of an androgen receptor ligand binding domain is amino acids 19 to 264 of SEQ ID NO: 16. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 19 to 264 of SEQ ID NO: 16.

SEQ ID NO: 16 (Human)

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1   ettqkltvsh iegyecqipif lnvleaiepg vvcaghdnnq pdsfaallss lnelgerqlv
    61  hvvkwakalp gfrnlhvddq maviqyswmv lmvfamgwrs ftnvnsmrly fapdlvfney
    121 rmhksrmysq cvrmrhlsqe fgwlqitpqe flcmkalllf siipvdglkn qkffdelrmn
    181 yikeldriia ckrknptscs rrfyqltkll dsvqpiarel hqftfdllik shmvsvdfpe
25  241 mmaeiisvqv pkilsgkvkp iyfhtq

```

Another non-limiting example of an androgen receptor ligand binding domain is amino acids 652 to 897 of SEQ ID NO: 94. In some embodiments, a hormone receptor ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 652 to 897 of SEQ ID NO: 94.

SEQ ID NO: 94 (Mouse)

1 mevqlglgrv yprppsktyr gafqnlfqsv reaiaqnggpr hpeaaniapp gaciqqrqet
 61 sprrrrrrqh tedgspqahi rgptgylale eeqqpsqqqa aseghpessc lpepgaatap
 121 gkgllpqqppa pddqddsaap stlsllgptf pglsscsadi kdilneagtm qllqqqqqqq
 5 181 qhqqqhqqhq qqqevissegs sarareatga pssskdsylg gnstisdsak elckavsvsm
 241 glgvealehl spgeqlrgdc myasllggpp avrptpcapl peckglplde gpgksteeta
 301 eyssfkgya kglegeslgec sgsseagssg tleipsssls yksgaldea ayqnrddyfnf
 361 plalsgpphp pppthphari klenpldygs awaaaaaqcr ygdlsghgg svagpstgsp
 421 pattssswht lftaeegqly gpgggggss psdagpvapy gytrppqglt ssesdysase
 10 481 vwypggvvnv vpypspncvk semgpwmeny sgpygdmrld strdhvlpid yyfppqktcl
 541 icgdeasgch ygaltcgsc vffkraaegk qkylcasrnd ctidkfrkn cpscrlrkcy
 601 eagmtlgark lklglngklq eegensnags ptedpsqkmt vshiegyecq piflnvleai
 661 epgvvcaghd nnqpsfaal lsslnelger qlvhvkvkwak alpgfrnlhv ddqmaviqys
 721 wmgmlvmfamg wrsftnvnsr mlyfapdlvf neyrmhkrm ysqcvmrhl sqefgwlqit
 15 781 pqeflcmkal llfsiipvdg lknqkffdel rmnyikeldr iiackrknt sscrffyqlt
 841 klldsvqpia relhqftfdl likshmvsvd fpemmaeiis vqvpkilsgk vkpiyfhtq

Another non-limiting example of an androgen receptor ligand binding domain is
 amino acids 655 to 900 of SEQ ID NO: 95. In some embodiments, a hormone receptor
 20 ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least
 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at
 least 89%, 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%, or at least 99% identical to amino acids 655
 to 900 of SEQ ID NO: 95.

SEQ ID NO: 95 (Rat)

1 mevqlglgrv yprppsktyr gafqnlfqsv reaiaqnggpr hpeaasiapp gaciqqrqet
 61 sprrrrrrqh pedgspqahi rgttgylale eeqqpsqqqs aseghpesgc lpepgaatap
 121 gkgllpqqppa pddqddsaap stlsllgptf pglsscsadi kdilseagtm qllqqqqqqq
 30 181 qqqqqqqqqq qqqqqqevise gsssvrarea tgapssskds ylgnstisd sakelckavs
 241 vsmglgveal ehlspeqlr gdcmyasllg gppavrptpc aplaackgls ldegpgkgte
 301 etaeyssfkgyakgleges lgcsgseag ssgtleipss lslyksgavd eaaayqnrly
 361 ynfplalsgp phppppthph ariklenpsd ygsawaaaaa qcrygdasl hggsvagpst
 421 gsppatasss whtlftaeeg qlygpggggg ssspsdagpv apygytrppq glasqegdfs
 35 481 asevwypggv vnrvpypsp cvksemgpwm enysgpygdm rldstrdhvl pidyyfppqk
 541 tclicgdeas gchygaltcg sckvffkraa egkqkylcas rndctidkfr rkncpscrlr
 601 kcyeamtlig arkklklngl klqeegenss agsptedpsq kmtvshiegy ecqpiflnvl
 661 eaiepgvvca ghdnnpdsf aallsslnel gerqlvhvkv wakalpgfrn lhvdqmavi
 721 qyswmgmlvmf amgwrsftnv nsrmlyfapd lvfneyrmhk srmysqvmr rhlsqefgw
 40 781 qitpqeflcm kalllfsiip vdglknqkff delrmnyike ldriiackrk nptscsrrfy
 841 qltklldsvq piarelhqft fdllikshmv svdfemmae iisvqvpkil sgkvkpiyfh
 901 tq

Another non-limiting example of an androgen receptor ligand binding domain is
 45 amino acids 648 to 893 of SEQ ID NO: 96. In some embodiments, a hormone receptor

ligand binding domain is or include a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 648 to 893 of SEQ ID NO: 96.

SEQ ID NO: 96 (Baboon)

```

1  mevqlglgrv yprppsktyr gafqnlfsqv reviqnpgpr hpeaasaapp gaslqqqqqq
10  61  qqgetsprqq qqqqgedgsp qahrrgptgy lvldeeqqs qpqsapechp ergcvpepga
    121  avaagkglpq qlpappedd saapstlsll gptfpglssc sadlkdilse astmqllqqq
    181  qqeavsegss sgrareasga ptsskdnylg gtstisdsak elckavsvsm glgvealehl
    241  spgeqlrgdc myapvlgvpp avrptcapl aeckslldd sagkstedta eyspfkggyt
    301  klegeslgc sgsaaagssg tlelpstlsl yksgaldea ayqsrdyynf plalagpppp
15  361  pppphphari klenpldygs awaaaaaqcr ygelaslhga gaagpgsgsp saaassswht
    421  lftaeeggly gpcggggggg ggggggagaa gavapygytr ppqglagqeg dftapdvwy
    481  ggmvsrvpyp sptcvksemp pwndsysgpy gdmrletard hvlpidyyfp pqktclcgd
    541  easgchygal tcgsckvffk raaegkqkyl casrndctid kfrkncpsc rlrkcyeamg
    601  tlgarklklk gnlklqeege assttsptee taqklvtshi egyecqpifl nvleaiepgv
20  661  vcaghdnnpq dsfaallssl nelgerqlvh vkwakalpg frnlhvddqm aviqyswmg
    721  mvfamgwrsf tnvnsrmlfy apdlvfneyr mhksrmysqc vrmrhlsqef gwlqitpqef
    781  lcmkalllfs iipvdglknq kffdelrmny ikeldriiac krknptscsr rfyqltklld
    841  svqpiarelh qftfdlliks hmvsvdfpem maeiisvqvp kilsgkvkpi yfhtq

```

Another non-limiting example of a ligand binding domain is SEQ ID NO: 28. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 28.

SEQ ID NO: 28 (Human)

```

1  drrggrmlkh krqrddgegr gevgsagdmr aanlwpsplm ikrskknsla lsltadqmv
35  61  alldaepil yseydptrpf seasmgllt nladrelvhm inwakrvpgf vdltlhdqvh
    121  llecawleil miglvwrsme hpgkllfapn lldrnqgkc vegmveifdm llatssrfrm

```

181 mnlqgeefvc lksiillnsg vytflsstlk sleekdhihr vldkitdtli hlmakagltl
 241 qqghqrlaql llilshirhm snkrmehlys mkcknvvplf dlillemldah rlhapt

Another non-limiting example of a ligand binding domain is SEQ ID NO: 29. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to the amino acid sequence of SEQ ID NO: 29.

SEQ ID NO: 29 (Human)

1 gqdiqlippl inllmsiepd viyaghdntk pdtssslts lnqlgerqll svvkwskslp
 61 gfrnlhiddq itliqyswms lmvfglgwrs ykhvsgqmly fapdlilneq rmkessfysl
 121 cltmwqipqe fvkqlqvsqee flcmkvllll ntipleglrs qtqfeemrss yirelikaig
 181 lrqkgvvsss grfyqltkll dnlhdlvkql hlyclntfiq sralsvefpe mmseviaaql
 241 pkilagmvkp llfhkk

Another non-limiting example of a ligand binding domain is a ligand binding domain of an ecdysone receptor. For example, a ligand binding domain of an ecdysone receptor can be amino acids 256 to 467 of SEQ ID NO: 74. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 256 to 467 of SEQ ID NO: 74.

SEQ ID NO: 74 (Human)

1 merdepppsg ggggggsagf leppaalppp prngfcqdel aeldpgtisv sddraeqrtc
 61 licgdratgl hygiiscegc kgffkrsicn krvyrcsrdk ncvmsrkqrn rcqycrllkc
 121 lqmgmnrkai redgmpggrn ksigpvqise eeierimsgq efееeanhws nhgdsdhssp
 181 gnrasenqp spgstlsssr svelngfmaf reqymgmsvp phyqyiphlf sysghspllp
 241 qqarsldpqs yslihqllsa edleplgtpm liedgyavtq aelfallcrl adellfrqia
 301 wikklpffce lsikdytcll sstwqelill ssltvyskqi fgeladvtak yspseelhr
 361 fsdegmevie rliylyhkfz qlkvsneeya cmkainflnq dirgltsasq leqlnkrywy
 421 icqdfteyky thqpnrfpdl mmclpeiryi agkmvnvple qlpllfkvvl hsccktsvgke

Another non-limiting example of a ligand binding domain is a ligand binding domain of a PPAR γ receptor. For example, a ligand binding domain of a PPAR γ receptor can be amino acids 237 to 504 of SEQ ID NO: 75. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 237 to 504 of SEQ ID NO: 75.

SEQ ID NO: 75 (Human)

```

1 mgetlgsdspi dpesdsftdt lsanisqemt mvdtempfwp tnfgissvdl svmedhshsf
61 dikpfttvdf ssistphyed ipftrtdpvv adykydlklq eyqsaikvep asppyysekt
121 qlynkpheep snslmaiecr vcgdkasgfh ygvhacegck gffrirtirkl liydrctlnc
181 rihkksrnkc qycrfqkla vgmshnairf grmpqaekel llaeissdid qlnpesadlr
241 alakhlydsy iksfpltkak arailtgktt dkspfviydm nslmmgedki kfkhitplqe
301 qskevairif qgcqfrsvea vqeiteyaks ipgfvnlldn dqvtllkygv heiiytmlas
361 lmnkdgvlis egqgfmtref lkslrkpfgd fmepkfefav kfnaleldds dlaifiavii
421 lsgdrpglln vkpiediqdn llqalelqlk lnhpessqlf akllqkmtdl rqivtehvql
481 lqvikktted mslhplllqei ykdly

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a glucocorticoid receptor. For example, a ligand binding domain of a glucocorticoid receptor can be amino acids 531 to 777 of SEQ ID NO: 76. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 531 to 777 of SEQ ID NO: 76.

SEQ ID NO: 76 (Human)

```

1 mdskesltpg reenpssvla qergdvmdfy ktlrggatvk vsasspslav asqsdskqrr
61 llvdfpkgsv snaqqpdlsk avslsmglym getetkvmgn dlqfpqqgqi slssgetdlk
121 lleesianln rstsvpenpk ssastavsaa ptekefpkth sdvsseqqhl kgqgtnggn
181 vklytttdqst fdilqdlefs sgspgketne spwrsdllid encllsplay eddsfllegn
241 snedckplil pdtkpkikdn gdlvlsspsn vtlpqvktek edfielctpg vikqeklgv
301 ycqasfpgan iignkmsais vhgvtsggq myhydmtas lsqqdqkpi fnvippipvg
361 senwnrcqgs gddnltslgt lnfpgrtvfs ngyspsmrp dvssppssss tattgpppkl

```

```

421 clvcsdeasg chygvltcgs ckvffkrave gqhnylcagr ndciidkirr kncpacryrk
481 clqagmnlea rktkkkikgi qqattgvsqe tsenpgnkti vpatlpqltp tlvsllievie
541 pevlyagyds svpdstwrin ttlnmlggrq viaavkwaka ipgfrnlhld dqmtllqysw
601 mflmafalgw rsyrqssanl lcfapdliin eqrmtlpcmy dqckhmlyvs selhrlqvsy
5 661 eeylcmktl1 llssvpkdg1 ksqelfdeir mtyikelgka ivkregnessq nwqrfyqltk
721 lldsmhevve nllnycfqtfl dktmsiefp emlaeiitnq ipkysngnik kllfhqk

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a thyroid hormone receptor. For example, a ligand binding domain of a glucocorticoid receptor can be amino acids 162 to 370 of SEQ ID NO: 77. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 162 to 370 of SEQ ID NO: 77.

SEQ ID NO: 77 (Human)

```

1 meqkpskvec gsdpeensar spdgkrkrkn gqcslksms gyipsyldkd eqcvvcgdka
61 tgyhyrcitc egckgffrrt iqknlhptys ckydscavid kitrnqcqlc rfkkciavgm
20 121 amdvlvddsk rvakrklieq nrerrrkeem irslqqrpep tpeewdlihi ateahrstna
181 qgshwkqrrk flpddigqsp ivsmpdgdkv dleafseftk iitpaitrvv dfakklpmfs
241 elpcedqiil lkgccmeims lraavrydpe sdtltlsgem avkreqlkng glgvvsdaif
301 elgkslsafn lddtevallq avllmstdrs gllcvdkiek sqeayllafe hyvnhrkhni
361 phfwpkllmk erevqssily kgaaaegrpg gslgvhpegq qllgmhvvqg pqrqleqq1
25 421 geagslqgpv lqhqspskpq qrllellhrs gilharavcg eddsseadsp ssseepevc
481 edlagnaasp

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a mineralocorticoid receptor. For example, a ligand binding domain of a mineralocorticoid receptor can be amino acids 737 to 984 of SEQ ID NO: 78. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 737 to 984 of SEQ ID NO: 78.

SEQ ID NO: 78 (Human)

```

1 metkgyhslp egldmerrwg qvsqaverss lgptertden nymeivnvsc vsgaipnnst

```

```

    61 qgsskekqel lpclqqdnr pgiltsdikt eleskelsat vaesmglymd svrdadysye
  121 qqnqqgsm spakiyqnveql vkfykgnghr pstlscvntp lrsfmsdsgs svnggvrai
  181 vkspimchek spsvcsplnm tssvcspagi nsvsstasf gsfpvhspit qgtpltcspn
  241 aenrgsrshs pahasnvgsp lssplssmks sissppshcs vkspvsspnn vtlrsvssp
5   301 aninnsrCSV sspstnnrs tlsspaastv gsicspvna fsytasgtsa gsstlrdrvvp
    361 spdtqekgaq evfpkteev esaisngvtg qlnivqyikp epdgafsssc lggnskinsd
    421 ssfsvpikqe stkhscsgts fkgntvpnf pfmdgsyfsf mddkdyysls gilgppvpgf
    481 dgncegs gfp vgikqepddg syypeasips saivgvnsgg qsfhyrigaq gtislsrsar
    541 dqsfqhlssf ppvntlvsw kshgdlsrr sdgypvleyi penvsstlr svstgssrps
10  601 kiclvcgdea sgchygvtc gsckvffkra vegqhnylca grndciidki rrkncpacrl
    661 qkclqagmnl garkskklgk lkgiheeqpq qqpppppppp pqspeegtty iapakepsvn
    721 talvpqlsti sraltpspvm vleniepeiv yagydsckpd taenllstln rlagkqmiqv
    781 vkwakvlp gf knlpledqit liqyswmcsl sfalswrsyk htmsqflyfa pdlvfneekm
    841 hqsamyelcq gmhqlslqfv rlqltfeeyt imkvllllst ipkdglksqa afeemrtnyi
15  901 kelrkmtkc pnnsgqswqr fyqltkllld mhdvlsdle fcfytfresh alkvefpaml
    961 veiisdqlpk vesgnakply fhrk

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a vitamin D receptor. For example, a ligand binding domain of a vitamin D receptor can be amino acids 124 to 426 of SEQ ID NO: 79. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 124 to 426 of SEQ ID NO: 79.

SEQ ID NO: 79 (Human)

```

    1 meamaastsl pdpgdfdrnv pricgvcgdr atgfhnamt cegckgffrr smkrkalftc
  61 pfngdcritk dnrrhcqacr lkrcvdigmm kefiltdeev qrkremilkr keeealkdsl
30 121 rpklseeqqr iiailldahh ktydptysd f cqrppvrnv dgggshpsrp nsrhtsfsg
    181 dsssscsdhc itssdmmdss sfsnldlsee dsddpsvtle lsqslmplhl adlvsysiqk
    241 vigfakmipg frdltsedqi vllkssaiev imlrsnesft mddmswtcgn qdykyrvsdv
    301 tkaghsleli eplikfqvgl kklnlheeh vllmaicivs pdrpgvqdaa lieaiqdris
    361 ntlqtiyr cr hpppgshlly akmiqkladl rslneehskq yrclsfqpec smkltplvle
35 421 vfgneis

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a PPAR α receptor. For example, a ligand binding domain of a PPAR α receptor can be amino acids 201 to 467 of SEQ ID NO: 80. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 201 to 467 of SEQ ID NO: 80.

SEQ ID NO: 80 (Human)

```

5      1 mvdtesplcp lspleagdle splseeflqe mgniqeisqs igedssgsfg fteyqylgsc
      61 pgsgdgsvitd tlspasspss vtypvvpqsv despsgalni ecricgdkas gyhygvhace
     121 gckgffrfti rlklvydkcd rsckiqkknr nkcqycrfhk clsvgmshna irfgrmprse
     181 kaklkaeilt cehdiedset adlkslakri yeaylknfnm nkvkavrls gkasnpppfv
     241 ihdmetlcma ektlvaklva ngiqnkeaev rifhccqcts vetvteltef akaipgfanl
10    301 dlndqvtllk ygvyeaifam lssvmnkdgm lvaygngfit reflkslrkp fcdimepkfd
     361 famkfnael ddstdislfva aiiccgdrpg llnvghiekm qegivhvlrl hlqsnhpddi
     421 flfpkllqkm adlrqlvteh aqlvqiikkt esdaalhp11 qeiyr dmy

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a PPAR β/δ receptor. For example, a ligand binding domain of a PPAR β/δ receptor can be amino acids 173 to 440 of SEQ ID NO: 81. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 173 to 440 of SEQ ID NO: 81.

SEQ ID NO: 81 (Human)

```

25    1 meqpqeeape vreeeekeev aeaegapeln ggpqhalpss sytdlsrsss ppslldqlqm
     61 gcdgascgsl nmecrvcgdk asgfhygvha cegckgffrr tirmkleyek cersckiqkk
     121 nnnkcqycrf qkclalgmsh nairfgrmpe aekrklvag1 tanegsqynp qvadlkafsk
     181 hiynaylknf nmtkkkarsi ltgkashtap fvihdietlw qaekglvwkq lvnlgppyke
     241 isvhvfyrq cttvetvrel tefaksipsf ss1flndqvt llkygvheai famlasivnk
     301 dgllvangsg fvtreflrs1 rkpfdsiiep kfefavkfna lelddsdlal fiaaiilcgd
30    361 rpglmnpvrv eaiqdtilra lefhlqanhp daqylfpk11 qkmadlrqlv tehaqmmqri
     421 kktetetslh pllqei ykdm y

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a pregnane X receptor. For example, a ligand binding domain of a pregnane X receptor can be amino acids 143 to 428 of SEQ ID NO: 82. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 143 to 428 of SEQ ID NO: 82.

SEQ ID NO: 82 (Human)

```

5      1 mevrpkewsn hadfvhcedt esvpgkpsvn adeevggpqi crvcgdkatg yhfnvmtceg
      61 ckgffrramk rnarlrpfr kgaceitrkt rrqcqacrlr kclesgmkke mimsdeavee
121    rralikrkks ertgtqplgv qglteeqrm  irelmdaqmk tfdttfshfk nfrlpqvlss
181    gcelpeslqa psreeaakws qvrkdclsk vslqlrgedg svwnykppad sggkeifsl1
241    phmadmstym fkgiisfakv isyfrdlpie dqislkkaa felcqlrfnt vfnaetgtwe
10    301 cgrlsycled taggfqqlll epmlkfhym  kklqlheey vlmqaislfs pdrpgvlqhr
      361 vvdqlqeqfa itlksyiecn rpqpahrflf lkimamltel rsinaqhtqr llriqdi hpf
      421 atplmqelfg itgs

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a liver X receptor. For example, a ligand binding domain of a liver X receptor can be amino acids 20 to 255 of SEQ ID NO: 83. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 20 to 255 of SEQ ID NO: 83.

SEQ ID NO: 83 (Human)

```

      1 gshmsqgsge gegvqltaa elmiqqlvaa qlqcnkrsfs dqpkvtpwpl gadpqsrdar
25    61 qqrfahtel aiisvqeivd fakvpgflq lgredqiall kastieimll etarrynhet
121    ecitflkdft yskddfhrag lqvefinpif efsramrrlg lddaeyalli ainifsadrp
181    nvqepgrvea lqqpyveall sytrikrpd qlrfprmlmk lvslrtlssv hseqvfalrl
241    qdkklpplls eiwdvhe

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a farnesoid X receptor. For example, a ligand binding domain of a farnesoid X receptor can be amino acids 247 to 467 of SEQ ID NO: 84. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 247 to 467 of SEQ ID NO: 84.

SEQ ID NO: 84 (Human)

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5      1 mgskmnlieh shlpttdefs fsenlfgvlt eqvagplgqn levepysqys nvqfpqvqpq
      61 issssyysnl gfypqqpeew yspgiyelrr mpaetlyqge tevaempvtk kprmgasagr
121   ikgdelcvvc gdrasgyhyn altcegckgf frsitrknav ykcknggncv mdmymrrkcq
181   ecrlrkckem gmlaecllte iqckskrlrk nvkqhadtqv nedsegrdlr qvtsttkscr
241   ekteltpdqg tllhfimdsy nkqrmpeit nkilkeefsa eenfliltem atnhvqvlve
10    301 ftkklpgfqt ldhedqiall kgsaveamfl rsaeifnkk1 psghsdlllee rirnsgisde
      361 yitpmfsfyk sigelkmtqe eyalltaivi lspdrqyikd reaveklqep lldvlqklck
      421 ihqpenpqhf acllgrltel rtfnnhhaem lmswrvndhk ftplllceiwd vq

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Another non-limiting example of a ligand binding domain is a ligand binding domain of a RAR-related orphan receptor A. For example, a ligand binding domain of a RAR-related orphan receptor A can be amino acids 217 to 456 of SEQ ID NO: 85. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 217 to 456 of SEQ ID NO: 85.

SEQ ID NO: 85 (Human)

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25      1 mmyfviaamk aqieiipcki cgdksngihy gvitcegckg ffrsqqsna tyscprqknc
      61 lidrtsrnrc qhcrllqkla vgmsrdavkf grmskkqrds lyaevqkhrm qqqqrdrhqqq
121   pgeaep1tpt ynisan1lte lhddlsnyid ghtpegskad savssfyldi qpspdqsgld
181   ingikpepic dytpasgffp ycsftngets ptvsmaleh laqniskshl etcqylreel
241   qqitwqtflq eeienyqnkq revmwqlcai kiteaiqyv1 efakridgfm elcqdndqivl
301   lkagslevvf irmcrafdsq nntvyfdgky aspdvfkslg cedfisfvfe fgkslcsmlh
30    361 tedeialfsa fvlmsadrs1 lqekvk1ekl qqkiqlalqh vlqknhredg iltklickvs
      421 tlralcgrht eklmafka1y pdivrlhfp1 lykelftsef epamqidg

```

Another non-limiting example of a ligand binding domain is a ligand binding domain of a RAR-related orphan receptor C. For example, a ligand binding domain of a RAR-related orphan receptor C can be amino acids 268 to 506 of SEQ ID NO: 86. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 268 to 506 of SEQ ID NO: 86.

SEQ ID NO: 86 (Human)

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5      1 mdrapqrqhr asrellaakk thtsqievip ckicgdkssg ihygvitceg ckgffrrsq
61 cnaaysctrq qncpidrtsr nrcqhcrllqk clalgmsrda vkfgrmskkq rdsilhaevqk
121 qlqqrqqqqq epvvtppag aqgadtltyt lglpdgqlpl gsspdlpeas acppgllkas
181 gsgpsysnnl akaglngasc hleyspergk aegresfyst gsqtlpdrcl lrfeehrhpg
241 lgelgqgpps ygspsfrstp eapylaslei ehvqsvcks yretcqlrle dllrqrnsif
10    301 sreevtgyqr ksmwemwerc ahhlteaiqy vvefakrlsg fmelcndqi vllkagamev
361 vlvrncrayn adnrtvffeg kyggmelfra lgcselessi fdfshslsal hfsedeialy
421 talvlinahr pglqekrkve qlqynlelaf hhhlcckthrq silaklppkg klrsllsqhv
481 erlqifqhlh pivvqaafpp lykelfstet espvglsk

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15 Another non-limiting example of a ligand binding domain is a ligand binding domain of a retinoic acid receptor. For example, a ligand binding domain of retinoic acid receptor can be amino acids 156 to 385 of SEQ ID NO: 87. In some embodiments, a hormone receptor ligand binding domain is or includes a sequence that is at least 80%, at least 81%, at least 82%, at least 83%, at least 84%, at least 85%, at least 86%, at least 87%, at least 88%, at least 89%, 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%, or at least 99% identical to amino acids 156 to 385 of SEQ ID NO: 87.

SEQ ID NO: 87 (Human)

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25      1 mlgglsppga lttlqhqlpv sgystpspat ietqsssee ivpsppspvp lpriykpfcfv
61 cqdksqgyhy gvsacegvkg ffrrsiqknm vytvhrdknc iinkvtrnrc qycrlqkcfv
121 vgmskesvrn drnkkkkev kpecsesyvt tpevgeliek vrkahqetfp alcqlgkytt
181 nnsseqrvsl didlwdkfse lstkciikt efakqlpgft tltiadqitl lkaacldili
241 lrictrytpe qdtmtfsdgl tlnrtqmna gfgpltdlvf afanqlple mddaetglls
30    301 aiclicgdrq dleqpdrvdm lqepillealk vyvrkrrpsr hmfpkmlmki tdlrsisakg
361 aervitlkme ipgsmppliq emlensegld tlgqpgggg rdggglappp gscspslsps
421 snrsspaths p

```

35 As can be appreciated in the art, amino acids that are not conserved between different mammalian homologues of hormone receptor ligand binding domains are more likely to not play an important role in the hormone or hormone analogue binding activity of the ligand binding domain, while those amino acids that are conserved between

different mammalian homologues of hormone receptor ligand binding domains are more likely to play an important role in the hormone or hormone analogue binding activity of the ligand binding domain. Some ligand binding domains can include one or more (e.g., two, three, four, five, or six) amino acid substitutions of amino acids that are not conserved between different mammalian homologues of hormone receptor ligand binding domains.

Antigen-Binding Domains

In some embodiments of the single-chain chimeric antigen receptors or the multi-chain chimeric antigen receptors, the antigen-binding domain can be selected from a scFv, a scFv-Fc, a VHH domain, a VNAR domain, a (scFv)₂, and a BiTE. Additional examples of antigen-binding domains that can be used in a single-chain chimeric antigen receptor or a multi-chain chimeric antigen receptor are known in the art.

A single-chain Fv or scFv fragment includes a V_H domain and a V_L domain in a single polypeptide chain. The V_H and V_L are generally linked by a peptide linker. In other examples, the linker can be a single amino acid. In some examples, the linker can be a chemical bond. See, e.g., Pluckthun, Antibodies from *E. coli*. In Rosenberg M. & Moore G.P. (Eds.), The Pharmacology of Monoclonal Antibodies, Vol. 113, pp. 269-315, Springer-Verlag, New York, 1994. An exemplary V_L and V_H sequences that can be used in a scFv are shown in SEQ ID NOs: 104 and 108 in the Examples. An exemplary linker that can be used between the V_L and V_H domains in an scFv can be any of the exemplary linkers described herein (e.g., a linker having the sequence of SEQ ID NO: 106)

Sc-Fv-Fc fragments include an scFv attached to an Fc domain. For example, an Fc domain can be attached, e.g., to the C-terminus of the scFv. The Fc domain can follow the V_L or V_H, depending on the orientation of the variable domains in the scFv. The Fc domain can be any Fc domain known in the art. In some examples, the Fc domain is an IgG1, IgG2, IgG3, or IgG4 Fc domain (e.g., a human IgG1, IgG2, IgG3, or IgG4 Fc domain).

BiTEs are antigen-binding domains that include two V_L and two V_H in a single polypeptide that together form two scFvs, which can each bind to different epitopes on the same antigen or each bind to different antigens. See, e.g., Baeuerle et al., *Curr. Opin.*

Mol. Ther. 11:22-30, 2009; Wolf et al., *Drug Discovery Today* 10:1237-1244, 2005; and Huehls et al., *Immunol. Cell Biol.* 93:290-296, 2015.

A V_HH domain is a single monomeric variable antibody domain found in camelids, and a V_{NAR} domain is a single monomeric variable antibody domain found in cartilaginous fish. V_HH domains and V_{NAR} domains are described in, e.g., Van Audenhove et al., *EBioMedicine* 8:40-48, 2016; Krah et al., *Immunopharmacol. Immunotoxicol.* 38:21-28, 2016; Cromie et al., *Curr. Top. Med. Chem.* 15:2543-2557, 2016; Kijanka et al., *Nanomedicine* 10:161-174, 2015; Kovaleva et al., *Expert. Opin. Biol. Ther.* 14:1527-1539, 2014; De Meyer et al., *Trends Biotechnol.* 32:263-270, 2014; Mujic-Delic et al., *Trends Pharmacol. Sci.* 35:247-255, 2014; Muyldermans, *Ann. Rev. Biochem.* 82:775-797, 2013; Vincke et al., *Methods Mol. Biol.* 911:15-26, 2012; Rahbarizadeh et al., *Immunol. Invest.* 40:299-338, 2011; Van Bockstaele et al., *Curr. Opin. Investig. Drugs* 10:1212-1224, 2009; Wesolowski et al., *Med. Microbiol. Immunol.* 198:157-174, 2009; De Genst et al., *Dev. Comp. Immunol.* 30:187-198, 2006; Muyldermans, *J. Biotechnol.* 74:277-302, 2001; and Muyldermans et al., *Trends Biochem. Sci.* 26:230-235, 2001.

In some embodiments of the multi-chain chimeric antigen receptors, at least two of the polypeptides that make up the multi-chain chimeric antigen receptor can interact together to form an antigen-binding domain. In such embodiments, the antigen-binding domain can be selected from the group of an antigen-binding antibody fragment, a dual-affinity re-targeting antibody (DART), Fab-scFv-Fc, a triomab, a crossmab, an ortho-Fab IgG, , IgG-scFv, scFv₂-Fc, a bi-nanobody, tandem antibody, a DART-Fc, a scFv-HAS-scFv, DNL-Fab₃, DAF (two-in-one or four-in-one), DutaMab, DT-IgG, knobs-in-holes common LC, knobs-in-holes assembly, Fab-arm exchange antibody, SEEDbody, Triomab, LUZ-Y, scDiabody-Fc, Fcab, k λ -body, orthogonal Fab, DVD-IgG, IgG(H)-scFv, scFv-(H)IgG, IgG(L)-scFv, scFv-(L)-IgG, IgG (L,H)-Fc, IgG(H)-V, V(H)-IgG, IgG(L)-V, V(L)-IgG, KIH IgG-scFab, 2scFv-IgG, IgG-2scFv, scFv4-Ig, Zyboby, DVI-IgG, nanobody, nanobody-HSA, a diabody, a TandAb, scDiabody, scDiabody-CH3, charge pair antibody, diabody-CH3, Cov-X-Bod, Triple Body, miniantibody, a DVD-Ig, minibody, a 2-in-1-IgG TriBi minibody, scFv-CH3 KIH, Fab-scFv, scFv-CH-CL-scFv, F(ab')₂-scFv₂, scFv-KIH, tetravalent HCAb, diabody-Fc, tandem scFv-Fc, intrabody,

dock and lock bispecific antibody, ImmTAC, HSAbody, scDiabody-HAS, tandem scFv, IgG-IgG, and scFv1-PEG-scFv₂.

Non-limiting examples of an antigen-binding antibody fragments include an Fv fragment, a Fab fragment, a F(ab')₂ fragment, and a Fab' fragment. Additional examples of an antigen-binding antibody fragment is an antigen-binding fragment of an IgG (e.g., an antigen-binding fragment of IgG1, IgG2, IgG3, or IgG4) (e.g., an antigen-binding fragment of a human or humanized IgG, e.g., human or humanized IgG1, IgG2, IgG3, or IgG4); an antigen-binding fragment of an IgA (e.g., an antigen-binding fragment of IgA1 or IgA2) (e.g., an antigen-binding fragment of a human or humanized IgA, e.g., a human or humanized IgA1 or IgA2); an antigen-binding fragment of an IgD (e.g., an antigen-binding fragment of a human or humanized IgD); an antigen-binding fragment of an IgE (e.g., an antigen-binding fragment of a human or humanized IgE); or an antigen-binding fragment of an IgM (e.g., an antigen-binding fragment of a human or humanized IgM).

Examples of DVD-IgGs are described, e.g., in DiGiammarino et al., *Methods Mol. Biol.* 899:145-156, 2012; Jakob et al., *MABs* 5:358-363, 2013; and U.S. Patent Nos. 7,612,181; 8,258,268; 8,586,714; 8,716,450; 8,722,855; 8,735,546; and 8,822,645. Examples of DARTs are described in, e.g., Garber, *Nature Reviews Drug Discovery* 13:799-801, 2014. Examples of triomabs, kih IgG with a common LCs, crossmabs, ortho-Fab IgGs, 2-in-1-IgGs, IgG-ScFvs, scFv2-Fcs, bi-nanobodies, tanden antibodies, DART-Fcs, scFv-HAS-scFvs, and DNL-Fab3s are described in, e.g., Kontermann et al., *Drug Discovery Today* 20:838-847, 2015. Examples of DAFs (two-in-one or four-in-one), DutaMabs, DT-IgGs, knobs-in-holes common LCs, knobs-in-holes assemblies, charge pair antibodies, Fab-arm exchange antibodies, SEEDbodies, Triomabs, LUZ-Ys, Fcabs, k λ -bodies, orthogonal Fabs, DVD-IgGs, IgG(H)-scFvs, scFv-(H)IgGs, IgG(L)-scFvs, scFv-(L)-IgGs, IgG (L,H)-Fcs, IgG(H)-Vs, V(H)-IgGs, IgG(L)-Vs, V(L)-IgGs, KIH IgG-scFabs, 2scFv-IgGs, IgG-2scFvs, scFv4-Igs, Zybodies, DVI-IgGs, nanobodies, nanobody-HSAs, diabodies, TandAbs, scDiabodies, scDiabody-CH3s, Diabody-CH3s, Triple Bodies, miniantibodies, minibodies, TriBi minibodies, scFv-CH3 KIHS, Fab-scFvs, scFv-CH-CL-scFvs, F(ab')₂-scFV2s, scFv-KIHS, Fab-scFv-Fcs, tetravalent HCabs, scDiabody-Fcs, diabody-Fcs, tandem scFv-Fcs, intrabodies, dock and lock bispecific antibodies, ImmTACs, HSAbodies, scDiabody-HASs, tandem scFvs, IgG-

IgGs, Cov-X-Bodies, and scFv1-PEG-scFv2s are described in, e.g., Spiess et al., *Mol. Immunol.* 67:95-106, 2015.

Any of the antigen-binding domains described herein can bind to an antigen with a dissociation equilibrium constant (K_D) of less than 1×10^{-7} M, less than 1×10^{-8} M, less than 1×10^{-9} M, less than 1×10^{-10} M, less than 1×10^{-11} M, less than 1×10^{-12} M, or less than 1×10^{-13} M. In some embodiments, the antigen-binding protein complexes provided herein can bind to a first and/or second antigen with a K_D of about 1×10^{-4} M to about 1×10^{-6} M, about 1×10^{-5} M to about 1×10^{-7} M, about 1×10^{-6} M to about 1×10^{-8} M, about 1×10^{-7} M to about 1×10^{-9} M, about 1×10^{-8} M to about 1×10^{-10} M, or about 1×10^{-9} M to about 1×10^{-11} M (inclusive). A variety of different methods known in the art can be used to determine the K_D value of an antigen-binding domain (e.g., an electrophoretic mobility shift assay, a filter binding assay, surface plasmon resonance, and a biomolecular binding kinetics assay, etc.).

Antigens

In some embodiments, an antigen-binding domain described herein can bind to a single antigen (e.g., any of the exemplary antigens described herein or known in the art). In some embodiments, an antigen-binding domain described herein can bind to two or more different antigens (e.g., two or more of any of the exemplary antigens described herein or known in the art). Non-limiting examples of antigens include: HER2, A33 antigen, 9-0-acetyl-GD3, CA19-9 marker, BhCG, CA-125 marker, carbonic anhydrase IX (MN/CA IX), calreticulin, CCR5, CCR8, CD2, , CD3, CD5, CD16, CD19, CD20, CD22, CD24, CD25, CD27, CD28, CD30, CD33, CD38, CD40L, CD44, CD44V6, CD63, CD70, CD84, CD96, CD100, CC123, CD133, CD137, CD138, CD150, CD152 (CTLA-4), CD160, CRTAM, CS1 (CD319), DNAM-1 (CD226), CD229, CD244, CD272 (BTLA), CD274 (PDL-1, B7H1), CD279 (PD-1), CD319, CD352, CRTAM (CD355), CD358, DR3, GITR (TNFRSF 18), HVEM, ICOS, LIGHT, LTBR, OX40, activating forms of KIR, NKG2C, NKG2D, NKG2E, one or more natural cytotoxicity receptors, NTB-A, PEN-5, carcinoma embryonic antigen (CEA; CD66e), desmoglein 4, E-cadherin neoepitope, endosialin, ephrin A2 (EphA2), epidermal growth factor receptor (EGFR), epithelial cell adhesion molecule (EpCAM), fucosyl GM1, GD2, GD3, GM2, ganglioside

GM3, Globo H, glycoprotein 100, HER2/neu, HER3, HER4, insulin-like growth factor receptor 1, Lewis-Y, LG, Ly-6, melanoma-specific chondroitin-sulfate proteoglycan (MCSCP), mesothelin, MUC1, MUC2, MUC3, MUC4, MUC5AC, MUC5b, MUC7, MUC16, Mullerian inhibitory substance (MIS) receptor type II, plasma cell antigen, poly SA, PSCA, PSMA, sonic hedgehog (SHH), SAS, STEAP, sTn antigen, TNF- α precursor, 2B4 (CD244), β 2-integrins, KIR, KIR2DL1, KIR2DL2, KIR2DL3, KIR3DL2, KIR-L, KLRG1, LAIR-1, NKG2A, NKR-P 1A, Siglec-3, Siglec-7, Siglec-9, TCR α , TCR β , TCR5y, TIM1, LAG3, LAIR1, PD-1H, TIGIT, TIM2, and TIM3. Additional examples of antigens are known in the art.

Costimulatory Domains

In normal lymphocytes, T cell activation is mediated by two classes of intracellular signaling domains. Primary signaling is initiated via MHC-mediated antigen-dependent activation via the T cell receptor (e.g., a TCR/CD3 complex). A secondary or costimulatory signal is provided by a different receptor that includes a costimulatory signaling domain, which acts in an antigen-independent manner. Signals generated through the signaling domain of the TCR alone are insufficient for complete T cell activation; a co-stimulatory signal is also required.

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a costimulatory domain, or portion thereof, from an endogenous mammalian (e.g., human) transmembrane polypeptide selected from the group of: CD27(also known as S152, S152.LPFS2, T14, TNFRSF7, and Tp55), CD28 (also known as Tp44), 4-1BB (also known as TNFRSF9, CD137, CDw137, ILA, and tumor necrosis factor receptor superfamily member 9), OX40 (also known as TNFRSF4, ACT35, RP5-902P8.3, IMD16, CD134, TXGP1L, and tumor necrosis factor receptor superfamily member 4), CD30 (also known as TNFRSF8, D1S166E, and Ki-1), CD40L (also known as CD40LG, CD154, HIGM1, IGM, IMD3, T-BAM, TNFSF5, TRAP, gp39, hCD40L, and CD40 ligand), CD40 (also known as Bp50, CDW40, TNFRSF5, p50, CD40 (protein), and CD40 molecule), PD-1 (also known as PDCD1, CD279, PD-1, SLEB2, hPD-1, hPD-1, hSLE1, and Programmed cell death 1), PD-L1 (also known as CD274, B7-H, B7H1, PD-

L1, PDCD1L1, PDCD1LG1, PDL1, CD274 molecule, and Programmed cell death 1 ligand 1), ICOS (also known as AILIM, CD278, and CVID1), LFA-1 (also known as Lymphocyte function-associated antigen 1), CD2 (also known as LFA-2, SRBC, T11, and CD2 molecule), CD7 (also known as GP40, LEU-9, TP41, Tp40, and CD7 molecule), CD160 (also known as BY55, NK1, NK28, and CD160 molecule), LIGHT (also known as TNFSF14, CD258, HVEM, LIGHT, LTg, TR2, TNLG1D, and tumor necrosis factor superfamily member 14), BTLA (also known as CD272 and BTLA1), TIM3 (also known as HAVCR2, HAVcr-2, KIM-3, TIM3, TIMD-3, TIMD3, Tim-3, CD366, and hepatitis A virus cellular receptor 2), CD244 (also known as 2B4, NAIL, NKR2B4, Nmrk, SLAMF4, and CD244 molecule), CD80 (also known as B7, B7-1, B7.1, BB1, CD28LG, CD28LG1, LAB7, and CD80 molecule), LAG3 (also known as CD223 and lymphocyte activating 3), NKG2C (also known as CD314, D12S2489E, KLR, NKG2-D, NKG2D, and killer cell lectin like receptor K1), GITR (also known as TNFRSF18, RP5-902P8.2, AITR, CD357, and GITR-D), HVEM (also known as TNFRSF14, RP3-395M20.6, ATAR, CD270, HVEA, HVEM, LIGHTR, and TR2), TLR1, TLR2, TLR3, TLR4, TLR5, TLR6, TLR7, TLR8, TLR9, TLR10, CARD11, CD54 (ICAM), CD83, DAP10, LAT, SLP76, TRIM, ZAP70, and B7-H3 (also known as CD276, 4Ig-B7-H3, B7H3, B7RP-2, and CD276 molecule). The letters “CD” is the previous sentence stand for “Cluster of Differentiation.” For example, CD3 stands for “Cluster of Differentiation 3.” In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a costimulatory domain, or portion thereof, from an endogenous mammalian (e.g., human) transmembrane polypeptide (e.g., a mammalian or human homolog of any of the polypeptides listed above).

Any costimulatory domain, or portion thereof, that serves to provide a costimulatory signal is suitable for use in accordance with compositions and methods disclosed herein. In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a costimulatory domain, or portion thereof, from human CD28 (e.g. Accession No. P01747, e.g., from amino acids 180 to 220 of SEQ ID NO: 18). In some embodiments, a costimulatory domain is or includes a sequence that is at least 80%, 81%, 82%, 83%,

84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identical (or is identical) to amino acids 180 to 220 of SEQ ID NO: 18, or a fragment thereof. In some embodiments, a costimulatory domain is or includes a sequence that is at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% (or is identical) to SEQ ID NO: 116, or a fragment thereof.

SEQ ID NO: 18

MLRLLLALNLFPSIQVTGNKILVKQSPMLVAYDNAVNLSCKYSYNLFSREFRSL
HKGLDSAVEVCVVYGNYSQQQLQVYSKTGFNC DGKLGNESVTFYLQNLVYNQT
DIYFCKIEVMYPPPYLDNEKSNGTIIHVKGKHLCPSPLPGPSKPFWVLVVVGGVL
ACYSLLVTVAFIIFWVRSKRSRLHSDYMNMTPRRPGPTRKHYPYAPPRDFAA
YRS

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a costimulatory domain, or portion thereof, from human 4-1BB (e.g. Accession No. Q07011, e.g., from amino acids 214 to 255 of SEQ ID NO: 19). In some embodiments, a costimulatory domain is or includes a sequence that is at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identical to amino acids 214 to 255 of SEQ ID NO: 19, or a portion thereof.

SEQ ID NO: 19

MGNSCYNIVATLLLVLNFERTRSLQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSA
GGQRTCDICRQCKGVFRTRKECSSTSNAECDCTPGFHCLGAGCSMCEQDCKQGQ
ELTKKGCKDCCFGTFNDQKRGICRPWTNCSLDGKSVLVNGTKERDVVCGPSPA
DLSPGASSVTPPAPAREPGHSPQIISFFLALTSTALLFLLFLLTLRFSVVKRGRKKLL
YIFKQPFMRPVQTTQEEDGCSCRFPEEEEGGCEL

In some embodiments, a costimulatory domain is or includes a sequence that is at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%,

94%, 95%, 96%, 97%, 98%, or 99% identical to SEQ ID NO: 44, 57, or 116, or a portion thereof.

A single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor disclosed herein can include a costimulatory domain that includes a sequence of amino acids from any isoform of an endogenous mammalian (e.g., human) transmembrane polypeptide having a costimulatory domain including, e.g., an isoform of: CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3 (including, without limitation, a mammalian or human homolog of any of these polypeptides).

In some embodiments, a costimulatory domain, or portion thereof, of a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a sequence of amino acids that exhibits at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more sequence identity to a costimulatory domain from one or more of a mammalian (e.g., human) CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3. In some embodiments, a costimulatory domain, or portion thereof, of a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a sequence of amino acids having one or more amino acid substitutions, deletions, or additions as compared to a costimulatory domain of one or more of an endogenous mammalian (e.g., human) transmembrane polypeptide: an α chain of a T cell receptor, a β chain of the T cell receptor, a ζ chain of the T cell receptor, CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3 (including, without limitation, a mammalian or human homolog of any of these polypeptides).

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a costimulatory domain that is a chimeric costimulatory domain having portions of a costimulatory domain from two or more endogenous mammalian (e.g., human)

transmembrane polypeptides including, without limitation, CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3 (including, without limitation, a mammalian or human homolog of any of these polypeptides), such that the two or more portions of the transmembrane domains together constitute a functional costimulatory domain. In some embodiments, such a portion of a chimeric costimulatory domain can include one or more amino acid substitutions, deletions, or additions as compared to a corresponding portion of a wildtype costimulatory domain.

A costimulatory domain of a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor disclosed herein can be of any suitable length. For example, a costimulatory domain can have a length of about 20 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids, about 35 amino acids, about 30 amino acids, or about 25 amino acids (inclusive); about 25 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, about 40 amino acids, about 35 amino acids, or about 30 amino acids (inclusive); about 30 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino

acids, about 45 amino acids, about 40 amino acids, or about 35 amino acids (inclusive); about 35 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, about 45 amino acids, or about 40 amino acids (inclusive); about 40 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, about 55 amino acids, about 50 amino acids, or about 45 amino acids (inclusive); about 45 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, about 60 amino acids, or about 55 amino acids (inclusive); about 55 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, about 140 amino acids, about 130 amino acids, about 120 amino acids, about 110 amino acids, about 100 amino acids, about 95 amino acids, about 90 amino acids, about 85 amino acids, about 80 amino acids, about 75 amino acids, about 70 amino acids, about 65 amino acids, or about 60 amino acids (inclusive); about 60 amino

[illegible]

about 130 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, about 150 amino acids, or about 140 amino acids (inclusive); about 140 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, about 160 amino acids, or about 150 amino acids (inclusive); about 150 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, about 170 amino acids, or about 160 amino acids (inclusive); about 160 amino acids to about 200 amino acids, about 190 amino acids, about 180 amino acids, or about 170 amino acids (inclusive); about 170 amino acids to about 200 amino acids, about 190 amino acids, or about 180 amino acids (inclusive); about 180 amino acids to about 200 amino acids or about 190 amino acids (inclusive); or about 190 amino acids to about 200 amino acids (inclusive).

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes two or more costimulatory domains, e.g., two, three, four, or five, or more costimulatory domains. In some embodiments, the two or more costimulatory domains are identical (e.g., they have the same amino acid sequence). In some embodiments, the costimulatory domains are not identical. For example, the costimulatory domains can be selected from different endogenous mammalian (e.g., human) transmembrane polypeptides including, without limitation, CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, or B7-H3 (including, without limitation, a mammalian or human homolog of any of these polypeptides). In some embodiments, the two or more costimulatory domains can differ from each other by one or more (e.g., two, three, four, or five) amino acid substitutions, deletions, or additions. In some embodiments, the two or more costimulatory domains exhibit at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more sequence identity to each other.

Immunoreceptor Tyrosine-Based Activation Motifs (ITAMs)

ITAMs include a tyrosine separated from a leucine or isoleucine by any two other amino acids, and can thus be represented as, e.g., Tyr-X-X-Leu/Ile. ITAMs are typically

repeated (e.g., two or more times) in the cytoplasmic tails of certain cell surface proteins of the immune system, and are typically separated by between six and eight amino acids.

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes an ITAM, or portion thereof, from an endogenous mammalian (e.g., human) polypeptide, wherein endogenous mammalian (e.g., human) polypeptide is selected from the group of: CD3 ζ (also referred to as CD3 zeta), CD3 δ (CD3 delta), CD3 ϵ (CD3 epsilon), CD3 γ (CD3 gamma), DAP12, FC ϵ R1 γ (Fc epsilon receptor I gamma chain), FcR γ , FcR δ , CD35, CD22, CD79A (antigen receptor complex-associated protein alpha chain), CD79B (antigen receptor complex-associated protein beta chain), and CD66d. The letters “CD” is the previous sentence stand for “Cluster of Differentiation.” For example, CD3 stands for “Cluster of Differentiation 3.”

Any ITAM, or portion thereof, that serves to mediate signaling in an endogenous mammalian (e.g., human) transmembrane protein suitable for use in accordance with compositions and methods disclosed herein. In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes an ITAM, or portion thereof, from human CD3 zeta (e.g. Accession No. P20963, e.g., an ITAM present in amino acids 52 – 164 of SEQ ID NO: 17, or a portion thereof; or SEQ ID NO: 118 or a portion thereof). In some embodiments, an ITAM comprises a sequence that is at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%, at least 90%, at least 92%, at least 94%, at least 96%, at least 98%, at least 99%, or 100% identical to: the sequence of amino acids 52-165 of SEQ ID NO: 17 (or a portion thereof), or the sequence of SEQ ID NO: 118 (or a portion thereof).

SEQ ID NO: 17

MKWKALFTAAILQAQLPITEAQSFGLLDPKLCYLLDGILFIYGVILTALFLRVKFS
RSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPEMGGKPQRRKNPQE
GLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQA
LPPR

In some embodiments, an ITAM comprises a sequence that is or includes a sequence that is at least 80% (e.g., at least 82%, at least 84%, at least 86%, at least 88%, at least 90%, at least 92%, at least 94%, at least 96%, at least 98%, at least 99%, or 100%) identical to SEQ ID NO: 48, 61, or 118, or a portion thereof.

As will be appreciated by those of ordinary skill in the art, certain polypeptides have two or more isoforms that differ at least in their primary polypeptide sequence. For example, different isoforms can be generated as a result of alternative splicing. A single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor disclosed herein can include an ITAM that includes a sequence of amino acids from any isoform of an endogenous mammalian transmembrane polypeptide having an ITAM including, e.g., a mammalian (e.g., human) isoform of: CD3 ζ , CD3D, CD3E, CD3G, DAP12, FCER1G, FcR γ , FcR δ , CD35, CD22, CD79A, CD79B, or CD66d.

In some embodiments, an ITAM, or portion thereof, of a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes a sequence of amino acids having one or more (e.g., two, three, four, or five) amino acid substitutions, deletions, or additions as compared to an ITAM of one or more of an ITAM in an endogenous mammalian (e.g., human) transmembrane protein, such as, CD3 ζ , CD3D, CD3E, CD3G, DAP12, FCER1G, FcR γ , FcR δ , CD35, CD22, CD79A, CD79B, or CD66d. For example, the tyrosine and leucine or isoleucine of an ITAM could be retained, while the two amino acids separating them could be replaced with different amino acids.

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes an ITAM that is a chimeric ITAM having portions of an ITAM from two or more endogenous mammalian (e.g., human) transmembrane polypeptides including, without limitation, CD3 ζ , CD3D, CD3E, CD3G, DAP12, FCER1G, FcR γ , FcR δ , CD35, CD22, CD79A, CD79B, or CD66d (including, without limitation, a mammalian or human homolog of any of these polypeptides), such that the two or more ITAM portions together constitute a functional ITAM. In some embodiments, such a portion of a chimeric ITAM can include

one or more amino acid substitutions, deletions, or additions as compared to a corresponding portion of a wild type ITAM.

In some embodiments, a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor includes two or more ITAMs, e.g., two, three, four, or five, or more ITAMs. In some embodiments, the two or more ITAMs are identical (e.g., they have the same amino acid sequence). In some embodiments, the two or more ITAMs are not identical. For example, the ITAMs can be selected from different endogenous mammalian (e.g., human) transmembrane polypeptides including, without limitation, CD3 ζ , CD3D, CD3E, CD3G, DAP12, FCER1G, FcRy, FcRft, CD35, CD22, CD79A, CD79B (including, without limitation, a mammalian or human homolog of any of these polypeptides). In some embodiments, the two or more ITAMs can differ from each other by one or more amino acid substitutions, deletions, or additions.

Nucleic Acids

Also provided herein are nucleic acids that encode any of the single-chain chimeric polypeptides, single-chain chimeric antigen receptors, and multi-chain chimeric antigen receptors. Also provided herein are a set of nucleic acids that encode one or more single-chain polypeptides that make up a multi-chain chimeric polypeptide (e.g., where at least one single-chain polypeptide that makes up the multi-chain chimeric polypeptide is encoded by each nucleic acid in the set).

Vectors

Provided herein are vectors that include any of the nucleic acids provided herein. A “vector” according to the present disclosure is a polynucleotide capable of inducing the expression of a recombinant protein (e.g., a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor) in a mammalian cell. A vector provided herein can be, e.g., in circular or linearized form. Non-limiting examples of vectors include plasmids, SV40 vectors, adenoviral viral vectors, and adeno-associated virus (AAV) vectors. Non-limiting examples of vectors include lentiviral vectors or retroviral vectors, e.g., gamma-retroviral vectors. See, e.g.,

Carlens et al., *Exp. Hematol.* 28(10):1137-1146, 2000; Park et al., *Trends Biotechnol.* 29(11):550-557, 2011; and Alonso-Camino et al., *Mol. Ther. Nucleic Acids* 2:e93, 2013. Non-limiting examples of retroviral vectors include those derived from Moloney murine leukemia virus, myeloproliferative sarcoma virus, murine embryonic stem cell virus, murine stem cell virus, spleen focus forming virus, or adeno-associated virus. Non-limiting examples of retroviral vectors are described in, e.g., U.S. Patent Nos. 5,219,740 and 6,207,453; Miller et al., *BioTechniques* 7:980-990, 1989; Miller, *Human Gene Therapy* 1:5-14, 1990; Scarpa et al., *Virology* 180:849-852, 1991; Burns et al., *Proc. Natl. Acad. Sci. U.S.A.* 90:8033-8037, 1993; and Boris-Lawrie et al., *Cur. Opin. Genet. Develop.* 3:102-109, 1993. Exemplary lentiviral vectors are described in, e.g., Wang et al., *J. Immunother.* 35(9):689-701, 2003; Cooper et al., *Blood* 101:1637-1644, 2003; Verhoeyen et al., *Methods Mol. Biol.* 506:97-114, 2009; and Cavalieri et al., *Blood* 102(2):497-505, 2003.

Exemplary vectors, in which any of the nucleic acids provided herein can be inserted, are described in, e.g., Ausubel et al., Eds. "Current Protocols in Molecular Biology" Current Protocols, 1993; and Sambrook et al., Eds. "Molecular Cloning: A Laboratory Manual," 2nd ed., Cold Spring Harbor Press, 1989.

In some embodiments, the vectors further include a promoter and/or enhancer operably linked to any of the nucleic acids described herein. Non-limiting examples of promoters include promoters from human cytomegalovirus (CMV), mouse phosphoglycerate kinase 1, polyoma adenovirus, thyroid stimulating hormone α , vimentin, simian virus 40 (SV40), tumor necrosis factor, β -globin, α -fetoprotein, γ -globin, β -interferon, γ -glutamyl transferase, human ubiquitin C (UBC), mouse mammary tumor virus (MMTV), Rous sarcoma virus, glyceraldehyde-3-phosphate dehydrogenase, β -actin, metallothionein II (MT II), amylase, human EF1 α , cathepsin, MI muscarinic receptor, retroviral LTR (e.g. human T-cell leukemia virus HTLV), AAV ITR, interleukin-2, collagenase, platelet-derived growth factor, adenovirus E2, stromelysin, murine MX, rat insulin, glucose regulated protein 78, human immunodeficiency virus, glucose regulated protein 94, α -2-macroglobulin, MHC class I, HSP70, proliferin, immunoglobulin light chain, T-cell receptor, HLA DQ α , HLA DQ β , interleukin-2 receptor, MHC class II, prealbumin (transthyretin), elastase I, albumin, c-fos, neural cell

adhesion molecule (NCAM), H2B histone, rat growth hormone, human serum amyloid (SAA), muscle creatinine kinase, troponin I (TN I), and Gibbon Ape Leukemia Virus (GALV). In some embodiments, the promoter may be an inducible promoter or a constitutive promoter. Additional examples of promoters are known in the art.

5 In some examples, the vectors provided herein further include a poly(A) sequence, which is operably linked and positioned 3' to the sequence encoding the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or any of the polypeptides that make up the multi-chain chimeric antigen receptor. Non-limiting examples of a poly(A) sequence include those derived from bovine growth hormone
10 (Woychik et al., *Proc. Natl. Acad. Sci. U.S.A.* 81(13): 3944-3948, 1984, and U.S. Patent No. 5,122, 458), mouse- β -globin, mouse- α -globin (Orkin et al., *EMBO J.* 4(2): 453-456, 1985), human collagen, polyoma virus (Batt et al., *Mol. Cell Biol.* 15(9):4783-4790, 1995), the Herpes simplex virus thymidine kinase gene (HSV TK), IgG heavy chain gene polyadenylation signal (U.S. Patent Application Publication No. 2006/0040354), human
15 growth hormone (hGH) (Szymanski et al., *Mol. Therapy* 15(7):1340-1347, 2007), SV40 poly(A) site, e.g., SV40 late and early poly(A) site (Schek et al., *Mol. Cell Biol.* 12(12):5386-5393, 1992). In some embodiments, the poly(A) sequence includes a highly conserved upstream element (AATAAA). The this AATAAA sequence can, e.g., be substituted with other hexanucleotide sequences with homology to AATAAA which are
20 capable of signaling polyadenylation, including, e.g., ATTAAA, AGTAAA, CATAAA, TATAAA, GATAAA, ACTAAA, AATATA, AAGAAA, AATAAT, AAAAAA, AATGAA, AATCAA, AACAAA, AATCAA, AATAAC, AATAGA, AATTAA, and AATAAG. See, e.g., WO 06012414 A2).

A poly(A) sequence can, e.g., be a synthetic polyadenylation site. See, e.g., Levitt
25 et al, *Genes Dev.* 3(7): 1019-1025, 1989). In some examples, a poly(A) sequence can be the polyadenylation signal of soluble neuropilin-1: AAATAAAATACGAAATG. Additional examples of poly(A) sequences are known in the art. Additional examples and aspects of vectors are also known in the art.

Methods of Introducing a Nucleic Acid or Vectors into a Mammalian Cell

A variety of different methods known in the art can be used to introduce any of the nucleic acids and vectors disclosed herein into a mammalian cell (e.g., any of the mammalian cells described herein, e.g., any of the T cells (e.g., human T cells) described
 5 herein). Non-limiting examples of methods that can be used to introduce a nucleic acid or vector into a mammalian cell include lipofection, transfection, electroporation, microinjection, calcium phosphate transfection, dendrimer-based transfection, cationic polymer transfection, cell squeezing, sonoporation, optical transfection, impalection, hydrodynamic delivery, magnetofection, viral transduction (e.g., adenoviral and lentiviral
 10 transduction), and nanoparticle transfection. Additional methods of introducing a nucleic acid or vector into a mammalian cell are known in the art.

Mammalian Cells

Also provided herein are mammalian cells that include any of the nucleic acids or vectors described herein. In some embodiments, the mammalian cell is previously
 15 obtained from a subject (e.g., a human subject, e.g., a human subject identified or diagnosed as having a cancer).

Non-limiting examples of mammalian cells include a T cell (e.g., a human T cell). Non limiting examples of T cells (e.g., human T cells) include, e.g., an immature thymocyte, a peripheral blood lymphocyte, a naïve T cell, a pluripotent T_H cell precursor,
 20 a lymphoid progenitor cell, a T_{reg} cell, a memory T cell, a T_H17 cell, a T_H22 cell, a T_H9 cell, a T_H2 cell, a T_H1 cell, a T_H3 cell, $\gamma\delta$ T cell, an $\alpha\beta$ T cell, a Treg cell, and a tumor-infiltrating T cell. Additional examples of a T cell (e.g., a human T cell) include a CD8⁺ T cell, a CD4⁺ T cell, and natural killer T cell. Additional examples of mammalian cells
 25 include a mast cell, a macrophage, a neutrophil, a dendritic cell, a basophil, an eosinophil, and a natural killer cell.

Hormones and Hormone Analogues

Non-limiting examples of hormones include estrogen (17 β -estradiol), progesterone, testosterone, and dihydrotestosterone. Non-limiting examples of hormone
 30 analogues include estrogen hormone analogues, progesterone hormone analogues, and androgen hormone analogues.

Non-limiting examples of estrogen hormone analogues include: afimoxifene (also known as 4-hydroxytamoxifen, 4-OHT, 4-HT, and OHTAM); selective estrogen receptor modulators (SERMs), such as clomifene, ormeloxifene, raloxifene, tamoxifen, toremifene, lasofoxifene, and ospemifene; estradiol; estrone; raloxifene; estriol; genistein; phytoestrogens (e.g., isoflavones, such as genistein, daidzein, formononetin, and glycitein; coumestans, such as coumestrol and repensol and trifoliol; and lignans, such as lariciresinol, matairesinol, pinoresinol, secoisolariciresinol, podophyllotoxin, and steganacin); and xenoestrogens (e.g., diethylstilbestrol, ethinyl estradiol, butylated hydroxyanisole, erythrosine, camphors (e.g., 4-methylbenzylidene camphor), parabens (e.g., methylparaben, ethylparaben and propylparaben), atrazine, dichlorodiphenyldichloroethylene, dichlorodiphenyltrichloroethane, methoxychlor, dieldrin, endosulfan, heptachlor, lindane, phenols (e.g., bisphenol A and nonylphenol), biphenyls (e.g., monochlorobiphenyl and dichlorobiphenyl), phthalates (e.g., di-2-ethylhexyl phthalate, diisodecyl phthalate and diisononyl phthalate), and metalloestrogens). In some embodiments, an estrogen hormone analogue can be, e.g., mifepristone (also known as RU-486). In some embodiments, an estrogen hormone analogue can be a selective progesterone receptor modulator (SPRM), such as onapristone (ZK98299), lonaprisan (ZK230211, BAY86-5044), APR19, EC304, WAY-255348, ORG31710, asoprisnil (J867), telapristone (Proellex, CDB-4124), and CDB-2914 (ulipristal acetates).

Non-limiting examples of progesterone hormone analogues include selective progesterone receptor modulators (SPRMs), such as onapristone (ZK98299), lonaprisan (ZK230211, BAY86-5044), APR19, EC304, WAY-255348, ORG31710, asoprisnil (J867), telapristone (Proellex, CDB-4124), and CDB-2914 (ulipristal acetates).

Non-limiting examples of androgen hormone analogues include enobosarm (also known as ostarine, MK-2866, GTx-024, and S-22), BMS-564,929, LGD-4033 (ligandrol), AC-262,356, JNJ-28330835, LGD-2226, LGD-3303, S-40503, S-23, RAD140, acetothiolutamide, Andarine, LG-121071, TFM-4AS-1, and YK-11.

As can be appreciated in the art, estrogen or an estrogen hormone analogue can be used in together with a single-chain chimeric polypeptide, a single-chain chimeric antigen

receptor, or a multi-chain chimeric antigen receptor that includes an estrogen receptor ligand binding domain.

Compositions and Kits

Also provided herein are compositions (e.g., pharmaceutical compositions) that include any of the nucleic acids, vectors, sets of nucleic acids, sets of vectors, or mammalian cells described herein. For example, provided herein is a composition that includes any of the nucleic acids or sets of nucleic acids described herein, or any of the vectors or sets of vectors provided herein and a pharmaceutically acceptable solvent or carrier.

In some embodiments, a composition can be any of the mammalian cells described herein (e.g., any of the mammalian cells described herein previously obtained from a subject, e.g., a subject identified or diagnosed as having a cancer) comprising a nucleic acid encoding any of the single-chain chimeric polypeptides, single-chain chimeric antigen receptors, or multi-chain chimeric antigen receptors described herein. In a composition including any of the mammalian cells described herein, the composition can further include a cell culture medium or a pharmaceutically acceptable buffer (e.g., phosphate-buffered saline). A composition that includes any of the mammalian cells described herein can be formulated for intravenous or intraarterial administration.

Also provided are kits that include one or more of any of the compositions described herein. For example, a kit can include any of the compositions described herein and one or more doses of a hormone or hormone analogue formulated for administration to a subject (e.g., formulated for oral, intravenous, intramuscular, or subcutaneous administration). In some embodiments, a kit can further include instructions for performing any of the methods described herein.

Methods of Inducing the Membrane Localization of a Single-Chain Chimeric Polypeptide, a Single-Chain Chimeric Antigen Receptor, or a Multi-Chain Chimeric Polypeptide in a Mammalian Cell

Also provided herein are methods of inducing the membrane localization of a single-chain chimeric polypeptide (e.g., any of the single-chain chimeric polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain

chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) in a mammalian cell (e.g., any of the mammalian cells described herein) that include: contacting a mammalian cell expressing a single-chain chimeric polypeptide (e.g., any of the single-chain chimeric polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide, the single-chain chimeric antigen-binding receptor, or the multi-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell, respectively.

Some embodiments of these methods further include introducing a nucleic acid encoding the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor into a mammalian cell (e.g., any of the mammalian cells described herein or known in the art) to generate the mammalian cell expressing the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor, respectively. In some examples of these methods, the mammalian cell is a T cell (e.g., a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell). In some examples, the mammalian cell (e.g., any of the mammalian cells described herein) is a mammalian cell previously obtained from a subject (e.g., a subject that has been identified or diagnosed as having a cancer, e.g., any of the cancers described herein). Some embodiments of these methods further include obtaining the mammalian cell from the subject.

In some embodiments of any of these methods, the contacting step is performed in vitro. In some embodiments of any of these methods, the contacting step is performed in a mammal (e.g., a mammal, e.g., a human, having a cancer, e.g., any of the cancers described herein). In some embodiments, the contacting step results in the treatment of the cancer in a mammal (e.g., a human).

Non-limiting examples of cancer that can be treated using any of the methods provided herein include: acute lymphoblastic leukemia, acute myeloid leukemia, adrenocortical carcinoma, Kaposi sarcoma, lymphoma, anal cancer, appendix cancer,

teratoid/rhabdoid tumor, basal cell carcinoma, bile duct cancer, bladder cancer, bone cancer, brain cancer, breast cancer, bronchial tumor, carcinoid tumor, cardiac tumor, cervical cancer, chordoma, chronic lymphocytic leukemia, chronic myeloproliferative neoplasm, colon cancer, colorectal cancer, craniopharyngioma, bile duct cancer, endometrial cancer, ependymoma, esophageal cancer, esthesioneuroblastoma, Ewing sarcoma, eye cancer, fallopian tube cancer, gallbladder cancer, gastric cancer, gastrointestinal carcinoid tumor, gastrointestinal stromal tumor, germ cell tumor, hairy cell leukemia, head and neck cancer, heart cancer, liver cancer, hypopharyngeal cancer, pancreatic cancer, kidney cancer, laryngeal cancer, chronic myelogenous leukemia, lip and oral cavity cancer, lung cancer, melanoma, Merkel cell carcinoma, mesothelioma, mouth cancer, oral cancer, osteosarcoma, ovarian cancer, penile cancer, pharyngeal cancer, prostate cancer, rectal cancer, salivary gland cancer, skin cancer, small intestine cancer, soft tissue sarcoma, gastric cancer, testicular cancer, throat cancer, thyroid cancer, urethral cancer, uterine cancer, vaginal cancer, and vulvar cancer.

In some embodiments of any of these methods, the methods result in a decrease in the tumor burden (e.g., tumor mass and/or volume) in a subject. For example, any of the methods described herein can result in at least about 1% to about 99% (e.g., about 1% to about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, about 10%, or about 5% (inclusive); about 2% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, about 10%, or about 5% (inclusive); about 3% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, about 10%, or about 5% (inclusive); about 5% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%,

about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about
 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%,
 about 15%, or about 10% (inclusive); about 10% to about 99%, about 98%, about 96%,
 about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about
 5 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%,
 about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about
 20%, or about 15% (inclusive); about 15% to about 99%, about 98%, about 96%, about
 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%,
 about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about
 10 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, or about
 20% (inclusive); about 20% to about 99%, about 98%, about 96%, about 94%, about
 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%,
 about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about
 50%, about 45%, about 40%, about 35%, about 30%, or about 25% (inclusive); about
 15 25% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about
 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%,
 about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about
 40%, about 35%, or about 30% (inclusive); about 30% to about 99%, about 98%, about
 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%,
 20 about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about
 60%, about 55%, about 50%, about 45%, about 40%, or about 35% (inclusive); about
 35% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about
 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%,
 about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, or
 25 about 40% (inclusive); about 40% to about 99%, about 98%, about 96%, about 94%,
 about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about
 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%,
 about 50%, or about 45% (inclusive); about 45% to about 99%, about 98%, about 96%,
 about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about
 30 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%,
 about 55%, or about 50% (inclusive); about 50% to about 99%, about 98%, about 96%,

about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, or about 55% (inclusive); about 55% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, or about 60% (inclusive); about 60% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, or about 65% (inclusive); about 65% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, or about 70% (inclusive); about 70% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, or about 72% (inclusive); about 72% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, or about 74% (inclusive); about 74% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, or about 76% (inclusive); about 76% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, or about 78% (inclusive); about 78% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, or about 80% (inclusive); about 80% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, or about 82% (inclusive); about 82% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, or about 84% (inclusive); about 84% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, or about 86% (inclusive); about 86% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, or about 88% (inclusive); about 88% to about 99%, about 98%, about 96%, about 94%, about 92%, or about 90% (inclusive); about 90% to about 99%, about 98%, about 96%, about 94%, or about 92% (inclusive); about 92% to about 99%, about 98%, about 96%, or about 94% (inclusive); about 94% to about 99%, about 98%, or about 96% (inclusive); or about 96% to about 99% or about 98%

(inclusive)) reduction in the tumor burden in a subject (e.g., as compared to the tumor burden in the subject prior to treatment).

In some embodiments, the methods result in a decrease in the rate of progression of a cancer in the subject. For example, any of the methods described herein can result in at least about 1% to about 99% (e.g., about 1% to about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, about 10%, or about 5% (inclusive); about 2% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, about 10%, or about 5% (inclusive); about 3% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, about 10%, or about 5% (inclusive); about 5% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, about 15%, or about 10% (inclusive); about 10% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, about 20%, or about 15% (inclusive); about 15% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%, about 70%, about 65%, about 60%, about 55%, about 50%, about 45%, about 40%, about 35%, about 30%, about 25%, or about 20% (inclusive); about 20% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, about 74%, about 72%,

[illegible]

76%, about 74%, or about 72% (inclusive); about 72% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, about 76%, or about 74% (inclusive); about 74% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, about 78%, or about 76% (inclusive); about 76% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, about 80%, or about 78% (inclusive); about 78% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, about 82%, or about 80% (inclusive); about 80% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, about 84%, or about 82% (inclusive); about 82% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, about 86%, or about 84% (inclusive); about 84% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, about 88%, or about 86% (inclusive); about 86% to about 99%, about 98%, about 96%, about 94%, about 92%, about 90%, or about 88% (inclusive); about 88% to about 99%, about 98%, about 96%, about 94%, about 92%, or about 90% (inclusive); about 90% to about 99%, about 98%, about 96%, about 94%, or about 92% (inclusive); about 92% to about 99%, about 98%, about 96%, or about 94% (inclusive); about 94% to about 99%, about 98%, or about 96% (inclusive); or about 96% to about 99% or about 98% (inclusive)) reduction in the rate of progression of a cancer in a subject (e.g., as compared to the rate of progression of a cancer in the subject prior to treatment or in a control subject or a control population of subjects having the same cancer and administered no treatment or a different treatment).

In some embodiments of any of these methods, the methods result in an increase in the time of survival of a cancer in a subject. For example, any of the methods described herein can result in an about 1% to about 800% (e.g., about 1% to about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, about 150%, about 100%, about 80%, about 60%, about 40%, about 20%, about 10%, or about 5% (inclusive); about 5% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%,

about 200%, about 150%, about 100%, about 80%, about 60%, about 40%, about 20%, or about 10% (inclusive); about 10% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, about 150%, about 100%, about 80%, about 60%, about 40%, or about 20% (inclusive); about 20% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, about 150%, about 100%, about 80%, about 60%, or about 40% (inclusive); about 40% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, about 150%, about 100%, about 80%, or about 60% (inclusive); about 60% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, about 150%, about 100%, about 80% (inclusive); about 80% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, or about 100% (inclusive); about 100% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, about 250%, about 200%, or about 150% (inclusive); about 150% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, or about 200% (inclusive); about 200% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, about 300%, or about 250% (inclusive); about 250% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, about 350%, or about 300% (inclusive); about 300% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, about 400%, or about 350% (inclusive); about 350% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, about 450%, or about 400% (inclusive); about 400% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, about 500%, or about 450% (inclusive); about 450% to about 800%, about 750%, about 700%, about 650%, about 600%, about 550%, or about 500%

(inclusive); about 500% to about 800%, about 750%, about 700%, about 650%, about 600%, or about 550% (inclusive); about 550% to about 800%, about 750%, about 700%, about 650%, or about 600% (inclusive); about 600% to about 800%, about 750%, about 700%, or about 650% (inclusive); about 650% to about 800%, about 750%, or about 700% (inclusive); about 700% to about 800% or about 750% (inclusive); or about 750% to about 800% (inclusive)) increase in the time of survival of a cancer in a subject (e.g., as compared to the time of survival for a control subject or a population of control subjects having the same cancer and receiving no treatment or a different treatment).

Methods of Reversibly Altering the Membrane Localization of a Single-Chain Chimeric Polypeptide, a Single-Chain Chimeric Antigen Receptor, or a Multi-Chain Chimeric Polypeptide in a Mammalian Cell

Also provided herein are methods of reversibly altering the membrane localization of a single-chain chimeric polypeptide (e.g., any of the single-chain polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) in a mammalian cell that include: (a) contacting a mammalian cell (e.g., any of the mammalian cells described herein) expressing a single-chain chimeric polypeptide (e.g., any of the single-chain polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell, respectively; and (b) contacting the mammalian cell with a reduced amount of the hormone or the hormone analogue that results in a decreased level of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the mammalian cell (e.g., as compared to the level on the extracellular side of the plasma membrane in step (a)). In some

embodiments, the decreased level in step (b) is at least a 5% decrease, at least a 10% decrease, at least a 15% decrease, at least a 20% decrease, at least a 25% decrease, at least a 30% decrease, at least a 35% decrease, at least a 40% decrease, at least a 45% decrease, at least a 50% decrease, at least a 55% decrease, at least a 60% decrease, at least a 65% decrease, at least a 70% decrease, at least a 75% decrease, at least a 80% decrease, at least a 85% decrease, at least a 90% decrease, at least a 95% decrease, or at least a 99% decrease in the level of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane in step (a). In some embodiments, the decreased level in step (b) is a 100% decrease in the level of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane in step (a). In some embodiments, the mammalian cell is not contacted with any hormone or hormone analogue hormone in step (b). Some embodiments of these methods further include: (c) contacting the mammalian cell (e.g., any of the mammalian cells described herein) with an increased amount of the hormone or the hormone analogue that results in an increased level of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell as compared to the level of in step (b).

Some embodiments of any of these methods further include introducing a nucleic acid encoding the single-chain chimeric polypeptide into a mammalian cell (e.g., any of the mammalian cells described herein) to generate the mammalian cell expressing the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor. In some embodiments of any of the methods described herein, the mammalian cell is a T cell (e.g., a human T cell). In some embodiments, the T cell (e.g., human T cell) is selected from the group of a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell. In some embodiments, the mammalian cell is a mammalian cell previously obtained from a subject (e.g., a human). In some examples, the subject (e.g., human) has been identified or diagnosed as having a cancer (e.g., any of the types of cancer described herein). Some embodiments further include obtaining the mammalian cell from the subject.

In some embodiments of any of the methods described herein, the contacting step is performed *in vitro*. In some embodiments, the contacting step is performed in a mammal (e.g., in a subject). In some embodiments, the contacting step results in the treatment of the cancer in a mammal (e.g., a human).

Non-limiting examples of cancer that can be treated using any of the methods provided herein include: acute lymphoblastic leukemia, acute myeloid leukemia, adrenocortical carcinoma, Kaposi sarcoma, lymphoma, anal cancer, appendix cancer, teratoid/rhabdoid tumor, basal cell carcinoma, bile duct cancer, bladder cancer, bone cancer, brain cancer, breast cancer, bronchial tumor, carcinoid tumor, cardiac tumor, cervical cancer, chordoma, chronic lymphocytic leukemia, chronic myeloproliferative neoplasm, colon cancer, colorectal cancer, craniopharyngioma, bile duct cancer, endometrial cancer, ependymoma, esophageal cancer, esthesioneuroblastoma, Ewing sarcoma, eye cancer, fallopian tube cancer, gallbladder cancer, gastric cancer, gastrointestinal carcinoid tumor, gastrointestinal stromal tumor, germ cell tumor, hairy cell leukemia, head and neck cancer, heart cancer, liver cancer, hypopharyngeal cancer, pancreatic cancer, kidney cancer, laryngeal cancer, chronic myelogenous leukemia, lip and oral cavity cancer, lung cancer, melanoma, Merkel cell carcinoma, mesothelioma, mouth cancer, oral cancer, osteosarcoma, ovarian cancer, penile cancer, pharyngeal cancer, prostate cancer, rectal cancer, salivary gland cancer, skin cancer, small intestine cancer, soft tissue sarcoma, gastric cancer, testicular cancer, throat cancer, thyroid cancer, urethral cancer, uterine cancer, vaginal cancer, and vulvar cancer.

Methods of Controlling the Toxicity of a Single-Chain Chimeric Polypeptide, a Single-Chain Chimeric Antigen Receptor, or a Multi-Chain Chimeric Polypeptide in a Mammalian Cell by Reversibly Altering Membrane Localization of the Same

In some embodiments, compositions and/or methods disclosed herein can be used to selectively kill cancer cells in a subject (e.g., a human) in the presence of a hormone or a hormone analogue which binds to an LBD present in the polypeptide (e.g., a single-chain chimeric polypeptide, a single-chain chimeric antigen receptor, or a multi-chain chimeric antigen receptor). In some embodiments, in the presence of the hormone or hormone analogue, the polypeptide (e.g., the single-chain chimeric polypeptide, the

single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor) localizes to the extracellular surface of a mammalian cell, presenting its antigen binding domain (e.g., an scFv or any other antigen binding domain described herein or known in the art) on the exterior of the cell. The polypeptide can then recognize the antigen to which it binds, and thus can selectively kill a target cell expressing the antigen on its surface.

In some embodiments, localization of the polypeptide (e.g., the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, or the multi-chain chimeric antigen receptor) on the extracellular surface can cause toxicity in the subject. Such toxicity can be caused by, for example, a cytokine storm (also referred to as hypercytokinemia or cytokine release syndrome). In some embodiments, a subject experiencing toxicity due hormone- or hormone analogue-induced localization of the polypeptide to the extracellular surface can be treated by reducing the dose of the hormone or hormone analogue administered to the subject, or eliminating hormone or hormone analogue treatment altogether. Such reduction in dose or elimination of the hormone or hormone analogue treatment can cause the polypeptide to be removed from the cell surface and reduce or eliminate presentation of the antigen binding domain on the cell surface, thus reducing or eliminating toxicity in the subject.

Exemplary symptoms of toxicity include, without limitation, high fever, swelling, chills, hypotension, tachycardia, asthenia, headache, rash, scratchy throat, dyspnea, redness, extreme fatigue, nausea, and cerebral edema (swelling in the brain). In some embodiments, toxicity in a subject can be determined by assessing the presence or severity of one or more of these symptoms in a subject following administration of one or more doses of the hormone or hormone analogue to the subject. In some embodiments, one or more of these or other symptoms associated with toxicity can be determined after introducing into a subject a mammalian cell (e.g., a T cell) that includes a single-chain chimeric polypeptide (e.g., any of the single-chain polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) having a LBD, and a hormone or hormone analogue that binds the LBD. In some embodiments, the determined level of

one or more of these or other symptoms associated with toxicity can be compared to a baseline level that is associated with lack of a toxicity or a reduced level of toxicity. Such a baseline level can be, for example, the level of one or more of these or other symptoms in the subject prior to administration of the mammalian cell, the hormone or hormone analogue, or both. Additionally or alternatively, such a baseline level can be the level of one or more of these or other symptoms in a different subject that has not been administered the mammalian cell, the hormone or hormone analogue, or both. Those of ordinary skill in the art will be aware of suitable clinical and laboratory methods to determine the level of one or more symptoms associated with toxicity.

In some embodiments, toxicity can be the result of a cytokine storm. Both pro-inflammatory cytokines and anti-inflammatory cytokines are elevated in the serum of subjects experiencing a cytokine storm. Non-limiting examples of cytokines that are elevated in the serum of subjects experiencing a cytokine storm include tumor necrosis factor- α , IFN γ , IL-10, IL-1 β , IL-2, IL-6, IL-8, and IL-10, granulocyte macrophage-colony-stimulating factor (GM-CSF), and IL-5. In some embodiments, one or more of these or other cytokines associated with a cytokine storm are determined after introducing into a subject a mammalian cell (e.g., a T cell) that includes a single-chain chimeric polypeptide (e.g., any of the single-chain polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) having a LBD, and a hormone or hormone analogue that binds the LBD. In some embodiments, the determined level of one or more of these or other cytokines associated with a cytokine storm can be compared to a baseline level that is associated with lack of a cytokine storm or a reduced level of a cytokine storm. Such a baseline level can be, for example, the level of one or more of these or other cytokines in the subject prior to administration of the mammalian cell, the hormone or hormone analogue, or both. Additionally or alternatively, such a baseline level can be the level of one or more of these or other cytokines in a different subject that has not been administered the mammalian cell, the hormone or hormone analogue, or both. The level of a cytokine (e.g., the level of cytokine after administering to a subject the mammalian cell and the hormone or hormone analogue and/or the baseline level of a

cytokine), can be determined by any of a variety of methods and techniques, including, without limitation, ELISAs, Western blots, antibody array panels, multiplex arrays, Elispot assays, immunohistochemistry, or any of the variety of commercial assays available to determine cytokine levels.

5 In some embodiments, methods of treating cancer (e.g., any of the variety of cancers described herein) in a subject (e.g., a mammal, e.g., a human) are provided. In some embodiments, methods of treating cancer include: (a) administering to a subject a mammalian cell (e.g., a T cell) that includes a nucleic acid encoding a single-chain chimeric polypeptide (e.g., any of the single-chain polypeptides described herein), a
10 single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) having a hormone receptor LBD, (b) administering to the subject a hormone or hormone analogue that binds the LBD, (c) determining the level of one or more symptoms associated with toxicity and/or
15 the level of one or more cytokines associated with a cytokine storm, (d) comparing the determined level of one or more symptoms associated with toxicity and/or the level of one or more cytokines associated with a cytokine storm to a baseline level of the symptom or cytokine, and (e) reducing the amount of the hormone or hormone analogue administered to the subject, such that the determined level of one or more symptoms
20 associated with toxicity and/or the level of one or more cytokines associated with a cytokine storm is reduced. In some embodiments the level of the hormone or hormone analogue administered to the subject is reduced in step (e) by at least 5%, at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at
25 least 80%, at least 85%, at least 90%, at least 95%, or at least 99%. In some embodiments, the level of the hormone or hormone analogue administered to the subject is reduced in step (e) by 100% (e.g., no mammalian cell is administered to the subject in step (e)). In some embodiments, after administering the hormone or hormone analogue in step (b), the single-chain chimeric polypeptide, the single-chain chimeric antigen
30 receptor, and/or the multi-chain chimeric antigen receptor localizes the extracellular surface of the mammalian cell in a reversible manner. In some embodiments, after

reducing the amount of the hormone or hormone analogue administered to the subject in step (e), the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, and/or the multi-chain chimeric antigen receptor is removed from the extracellular surface, thus reducing the toxicity (e.g., one or more symptoms associated with toxicity and/or one or more cytokines associated with a cytokine storm). In some embodiments, after reducing the amount of the hormone or hormone analogue administered to the subject in step (e), the toxicity (e.g., one or more symptoms associated with toxicity and/or one or more cytokines associated with a cytokine storm) is reduced by at least 5%, at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, or at least 99%. In some embodiments, after reducing the amount of the hormone or hormone analogue administered to the subject in step (e), the toxicity (e.g., one or more symptoms associated with toxicity and/or one or more cytokines associated with a cytokine storm) is reduced by 100% (e.g., the subject experiences no toxicity, or only a baseline level of toxicity). In some embodiments, after reducing the amount of the hormone or hormone analogue administered to the subject in step (e), the toxicity (e.g., one or more symptoms associated with toxicity and/or one or more cytokines associated with a cytokine storm) normalizes towards a baseline level of toxicity (e.g., a level that is associated with lack of a cytokine storm or a reduced level of a cytokine storm). For example, after reducing the amount of the hormone or hormone analogue administered to the subject in step (e), the toxicity can normalize to a level that is less than 10-fold higher, 9-fold higher, 8-fold higher, 7-fold higher, 6-fold higher, 5-fold higher, 4-fold higher, 3-fold higher, 2-fold higher, or less than the baseline level of toxicity.

In some embodiments, a subject can be treated by administering to the subject a mammalian cell (e.g., a T cell) that includes a single-chain chimeric polypeptide (e.g., any of the single-chain polypeptides described herein), a single-chain chimeric antigen receptor (e.g., any of the single-chain chimeric antigen receptors described herein), and/or a multi-chain chimeric antigen receptor (e.g., any of the multi-chain chimeric antigen receptors described herein) having a LBD and a hormone or hormone analogue that binds the LBD. The level of toxicity in the subject can be monitored, and toxicity

can be reduced by any of the methods described herein, e.g., by reducing the level of the hormone or hormone analogue. After toxicity has been reduced (e.g., to a baseline level, or a level above the baseline level that is sufficiently low), the level of the hormone or hormone analogue can be subsequently increased to increase the efficacy of treatment. In some embodiments, the level of the hormone or hormone analogue is decreased and subsequently increased multiple times to control toxicity while still providing an effective course of treatment. In some embodiments, the level of the hormone is subsequently increased to 100% of the level at which the hormone or hormone analogue was originally administered. In some embodiments, the level of the hormone or hormone analogue is subsequently increased to a level that is at least 5%, at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, or at least 99% of the level at which the hormone or hormone analogue was originally administered. In some embodiments, the level of the hormone or hormone analogue is subsequently increased to a level that is higher than the level at which the hormone or hormone analogue was originally administered. For example, the subsequently administered hormone or hormone analogue can be administered at a level that is at least 100%, at least 110%, at least 120%, at least 130%, at least 140%, at least 150%, at least 160%, at least 170%, at least 180%, at least 190%, at least 200%, at least 300%, at least 400%, or at least 500% of the level at which the hormone or hormone analogue was originally administered.

In some embodiments, toxicity arising after administering a first hormone or hormone analogue to a subject can be reduced by administering a second hormone or hormone analogue to the subject. For example, the second hormone or hormone analogue can have a reduced affinity for the LBD present in the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, and/or the multi-chain chimeric antigen receptor, such that plasma membrane localization of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, and/or the multi-chain chimeric antigen receptor is reduced as compared to the plasma membrane localization facilitated by the first hormone or hormone analogue. In some embodiments, the second hormone or hormone analogue can be less effective than the first hormone or hormone analogue at

facilitating plasma membrane localization of the single-chain chimeric polypeptide, the single-chain chimeric antigen receptor, and/or the multi-chain chimeric antigen receptor. In some embodiments, the second hormone or hormone analogue competes with the first hormone or hormone analogue for binding to the LBD.

5 In some embodiments, in addition to or as an alternative to reducing the level of hormone or hormone analogue to reduce toxicity, toxicity can be further reduced by administering a composition that inactivates or sequesters the hormone or hormone analogue. For example, exogenous LBD can be administered to the subject (e.g., as a pharmaceutically acceptable formulation) to sequester the hormone or hormone analogue that was previously administered to the subject. As another example, a composition that inactivates, degrades, or otherwise sequesters the administered hormone or hormone analogue can be administered to the subject. A non-limiting example of such a composition is an antibody or antibody fragment that binds the administered hormone or hormone analogue and renders it unable to penetrate a cell membrane, renders it unable to bind the LBD, or facilitates its degradation.

EXAMPLES

The invention is further described in the following examples, which do not limit the scope of the invention described in the claims.

Example 1 – Generation of Constructs.

20 A canonical chimeric antigen receptor (“Canonical CAR”, Figure 1, left) was modified to include the estrogen receptor alpha (“ERα”) ligand binding domain (“ERα-LBD,” in green and indicated by arrows) at various locations within the protein. The ERα-LBD was introduced at different positions in the CAR (Figure 1, right) to create different versions of the ERα-LBD, denoted as: “v.2” (also denoted as “v2” or “V2”), “v.3” (also denoted as “v3” or “V3”), and “v.4” (also denoted as “v4” or “V4”). An mCherry fusion was also included to allow tracking of cells containing the engineered protein. The nucleic acid and polypeptide sequences of v.2 (SEQ ID NOs: 30 and 31, respectively), v.3 (SEQ ID NOs: 32 and 33, respectively), and v.4 (SEQ ID NOs: 34 and 35, respectively) are provided below.

SEQ ID NO: 30

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 5 ACCCAGACCACCAGCAGCCTGAGCGCCAGCCTGGGCGATAGAGTGACCATCA
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 CGGCGTGCCCAGCAGATTTTCTGGCAGCGGCTCCGGCACCGACTACAGCCTG
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 10 GCAACACCCTGCCCTACACCTTCGGCGGAGGACCAAGCTGGAAATCACAGG
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AACTGTATAAGTGCGTGACCGACTAG

SEQ ID NO: 31

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25

SEQ ID NO: 32

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SEQ ID NO: 33

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SEQ ID NO: 34

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SEQ ID NO: 35

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 30 KLLFAPNLLLDNRNQKCVEGMVEIFDMLLATSSRFRMMNLQGEEFVCLKSIILLN
 SGVYTFLSSTLKSLEEKDHIHRVLDKITDTLIHLMAKAGLTLQQQHQRQAQLLLIL

SHIRHMSNKRMEHLYSMKCKNVVPLFDLLEMLDAHRLHAPTSGSGSGSGSKRG
 RKLLLYIFKQPFMRPVQTTQEEDGCSCRFPEEEEGGCELRSGSGSGSLRVKFSRSA
 DAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPEMGGKPRRKNPQEGLYNE
 LQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPRGS
 5 GSGSGSMVSKGEEDNMAIIKEFMRFKVHMEGSVNGHEFEIEGEGEGRPYEGTQT
 AKLKVTKGGPLPFAWDILSPQFMYGSKAYVKHPADIPDYLKLSFPEGFKWERVM
 NFEDGGVVTVTQDSSLQDGEFIYKVKLRTNFPDGPVMQKKTMGWEASSERM
 YPEDGALKGEIKQRLKLKDGGHYDAEVKTTYKAKKPVQLPGAYNVNIKLDITSH
 NEDYTIVEQYERAEGRHSTGGMDELYKCVTD

10 Example 2 - NHR-LBD containing anti-CD19 chimeric antigen receptors exhibit ligand-induced surface expression of the CAR.

Jurkat T cells were transduced with lentiviral vectors encoding the canonical CAR or with anti-CD19 (FMC63) ERa-LBD containing the v2, v3, and v4 CAR constructs described in Example 1. The cells were then either left untreated, or were treated with, a
 15 ligand for the ERa-LBD. After one hour of drug treatment, the cells were stained with Protein L-biotin (Protein L binds to the extracellular scFv), and then with streptavidin-BV421 to detect surface expression of the CAR. The cells were subsequently analyzed by flow cytometry for mCherry expression and for the presence of CAR on the cell surface (Figure 2A). Canonical CAR was expressed on the surface at identical levels
 20 regardless of the presence or absence of the drug (Figure 2A, dot plots under the heading “Canonical CAR”). In contrast, ERa-LBD-containing v2 and v4 CARs (exemplary single-chain chimeric antigen receptors described herein) are expressed in the presence of the ligand (as assayed by mCherry-positive expression), but in the absence of the ligand, no CAR is detected on the cell surface (Figure 2A, top row, Protein L staining, dot plots
 25 under the headings “v2” and “v4”). After treatment with 500 ng/mL 4-OHT, CAR is detected on cell surface (Figure 2A, bottom row, Protein L staining) at levels comparable to control CAR. Notably, not all designs behave identically: v3 has some basal surface expression of CAR in the absence of ligand (Figure 2A, top dot plot under the heading “v3”), and expression is further increased upon ligand addition (Figure 2A, bottom dot
 30 plot under the heading “v3”).

Primary CD4 and CD8 human T cells were transduced with lentiviral vectors encoding the v4 CAR constructs. Cells were treated as described in this Example, and were stained using an anti-cMyc antibody to detect the cMyc-tagged scFv on the cell surface. Surface induction was observed in both CD4 and CD8 T cells after co-culture of the T cells with 500 ng/mL 4-OHT ligand (Figure 2B), demonstrating that the surface induction phenotype extends from Jurkat to primary human T cells.

Example 3 - NHR-LBD fusion proteins exhibit ligand-induced surface expression in diverse cell types.

HEK-293T cells were transduced with lentiviral vectors encoding ERa-LBD-containing FMC63 CAR fusions described in Example 1. The cells were either left untreated, or were incubated with 500 ng/mL 4-OHT for two hours, and then stained for surface CAR expression. Consistent with ERa LBD results in Jurkat cells and primary T cells demonstrated in Example 2, several ERa-LBD CAR fusions exhibited minimal surface expression of CAR in the absence of ligand, and strongly up-regulated surface CAR upon ligand treatment (Figure 3). These data indicate that ligand-induced surface expression of NHR-LBD CAR fusions operates in diverse cell types including immortalized (Jurkat and HEK-293T) and primary cells (Human CD4 and CD8 T cells), as well as lymphoid (Jurkat and human T) and non-lymphoid (HEK-293T) cell types.

Example 4 - Ligand-induced surface expression of NHR LBD-CAR fusions is conserved between different scFvs.

To demonstrate the conserved function and modularity of NHR LBD-CAR fusion proteins, the FMC63 scFv in V4 was replaced with a different scFv (J6M0) that recognizes B-cell maturation antigen ("BCMA"). Primary human CD4 T cells were transduced with lentiviral vectors encoding the NHR-LBD CAR fusions, and were either left untreated, or were treated with 500 ng/mL of the ERa ligand 4-OHT. Similar to the FMC63 NHR LBD-CAR fusions, the NHR LBD-CAR having the J6M0 scFv displayed ligand-induced surface expression (Figure 4).

Example 5 – Ligand-induced surface trafficking of NHR LBD fusion proteins does not require scFv or intracellular domains from the canonical CAR.

The LBD-CAR fusions tested in Example 2 contain a number of protein motifs in addition to the NHR LBD domain, including a CD137 intracellular domain, a CD3z intracellular signaling domain, and an scFv domain. To determine if the intracellular portions of the CAR constructs (the CD137 intracellular domain and CD3z intracellular domain) were involved in ligand-induced surface trafficking, a construct lacking these regions (“v5”, Figure 5A, left) was generated and tested in primary human T cells.

Construct v5 includes the scFv domain and the mCherry domain. Construct v5 exhibited ligand-induced trafficking comparable to that of constructs v2 and v4 in Example 2, indicating the CAR intracellular motifs were not responsible for the ligand-induced trafficking (Figure 5A, right). The nucleotide (SEQ ID NO: 36) and amino acid (SEQ ID NO: 37) sequence of v5 are shown below.

SEQ ID NO: 36

ATGGCTCTGCCTGTGACAGCTCTGCTGCTGCCTCTGGCCCTGCTGCTGCATGC
CGCTAGACCTGAGCAGAAGCTGATCTCCGAAGAGGACCTGGACATCCAGATG
ACCCAGACCACCAGCAGCCTGAGCGCCAGCCTGGGCGATAGAGTGACCATCA
GCTGCAGAGCCAGCCAGGACATCAGCAAGTACCTGAACTGGTATCAGCAGAA
ACCCGACGGCACCGTGAAGCTGCTGATCTACCACACCAGCAGACTGCACAGC
GGCGTGCCCAGCAGATTTTCTGGCAGCGGCTCCGGCACCGACTACAGCCTGA
CCATCTCCAACCTGGAACAGGAAGATATCGCTACCTACTTCTGTCAGCAAGGC
AACACCCTGCCCTACACCTTCGGCGGAGGCACCAAGCTGGAAATCACAGGGCG
GCGGAGGATCTGGCGGAGGCGGAAGTGGCGGAGGGGGATCTGAAGTGAAAC
TGCAGGAAAGCGGCCCTGGCCTGGTGGCCCCATCTCAGTCTCTGAGCGTGAC
CTGTACCGTGTCCGGCGTGTCCCTGCCTGACTATGGCGTGTCCCTGGATCAGAC
AGCCCCCAGAAAGGGCCTGGAATGGCTGGGAGTGATCTGGGGCAGCGAGAC
AACCTACTACAACAGCGCCCTGAAGTCCCGGCTGACCATCATCAAGGACAACCT
CCAAGAGCCAGGTGTTTCCTGAAGATGAACAGCCTGCAGACCGACGACACCGC
CATCTACTACTGCGCCAAGCACTACTACTACGGCGGCAGCTACGCCATGGACT

ACTGGGGCCAGGGCACAAGCGTGACCGTGTCTAGCACAACCACCCCTGCCCC
 TAGACCTCCAACCCCAGCCCCTACAATCGCCAGCCAGCCTCTGTCTCTGAGGC
 CCGAGGCTTGTAGACCAGCTGCTGGCGGAGCCGTGCACACCAGAGGACTGGA
 TTTCGCCTGCGACATCTACATCTGGGCCCCCTCTGGCCGGCACATGTGGCGTGCT
 5 GCTGCTGAGCCTCGTGATCACCCTGTACTGCGGATCCGGCAGCGGATCTGGCA
 GTGGAAGCGATAGAAGAGGGCGGCAGAATGCTGAAACACAAGCGGCAGAGGG
 ACGACGGGGAAGGCAGAGGCGAAGTGGGATCTGCCGGCGATATGAGAGCCGC
 CAACCTGTGGCCTAGCCCCCTGATGATCAAGCGGAGCAAGAAGAACTCCCTG
 GCCCTGAGCCTGACCGCCGACCAGATGGTGTCTGCCCTGCTGGATGCCGAGCC
 10 CCCATCCTGTACAGCGAGTACGACCCCAACCAGACCCTTCAGCGAGGCCAGCA
 TGATGGGCCTGCTGACCAACCTGGCCGACCGGGAAGTGGTGCACATGATCAA
 CTGGGCCAAGCGGGTGCCCGGCTTCGTGGATCTGACACTGCACGACCAGGTG
 CACCTGCTGGAATGCGCTTGGCTGGAAATCCTGATGATCGGCCTCGTGTGGCG
 GAGCATGGAACACCCTGGCAAGCTGCTGTTCGCCCCCAACCTGCTGCTGGAC
 15 CGGAACCAGGGCAAATGCGTGGAAGGCATGGTGGAAATCTTCGACATGCTGC
 TGGCCACCTCCAGCCGGTTCCGGATGATGAACCTGCAGGGCGAAGAGTTCGT
 GTGTCTGAAGTCCATCATCCTGCTGAATAGCGGCGTGTACACCTTCCTGAGCA
 GCACCCTGAAAAGCCTGGAAGAAAAGGACCACATCCACCGGGTGCTGGACA
 AGATCACCGACACCCTGATTCACCTGATGGCCAAGGCCGGACTGACCCTGCA
 20 GCAGCAGCATCAGAGACTGGCTCAGCTGCTGCTGATCCTGTCCCACATCCGGC
 ACATGAGCAACAAGCGGATGGAACATCTGTACAGCATGAAGTGCAAGAACGT
 GGTGCCTCTGTTTCGATCTGCTGCTGGAAATGCTGGACGCCCACAGGCTGCACG
 CCCCAACATCCGGATCTGGCTCTGGAAGCGGCAGCATGGTGTCTAAGGGGGA
 AGAGGACAACATGGCCATCATCAAAGAATTCATGCGGTTCAAGGTGCACATGG
 25 AAGGCTCCGTGAATGGCCACGAATTCGAGATCGAGGGGGAGGGCGAGGGCA
 GACCTTATGAGGGAACCCAGACCGCCAAGCTGAAAGTGACCAAGGGCGGACC
 CCTGCCTTTCGCCTGGGATATCCTGTCTCCCCAGTTTATGTACGGCAGCAAGGC
 CTACGTGAAGCACCCCGCCGACATCCCCGACTACCTGAAGCTGAGCTTCCCTG
 AGGGCTTCAAGTGGGAGAGAGTGATGAATTTTCGAGGACGGCGGAGTCGTGAC
 30 AGTGACCCAGGATAGCTCTCTGCAGGACGGCGAGTTCATCTACAAAGTGAAG
 CTGCGGGGCACCAACTTCCCCAGCGACGGACCCGTGATGCAGAAAAAGACCA

TGGGCTGGGAGGCCAGCTCCGAGAGAATGTACCCAGAGGACGGGGGCCCTGAA
 GGGGGAGATCAAGCAGCGGCTGAAACTGAAGGATGGCGGCCACTACGACGC
 AGAAGTGAAAACCACCTACAAGGCCAAGAAACCTGTGCAGCTGCCTGGCGCC
 TACAATGTGAACATCAAGCTGGACATTACCAGCCACAACGAGGACTACACCAT
 5 CGTGGAACAGTACGAGCGGGCCGAGGGCAGGCATTCTACAGGCGGAATGGAT
 GAACTGTATAAGTGCGTGACCGACTAG

10 **SEQ ID NO: 37**

MALPVTALLLPLALLLHAARPEQKLISEEDLDIQMTQTTSSLSASLGDRVTISCRA
 SQDISKYNWYQQKPDGTVKLLIYHTSRLHSGVPSRFSGSGSGTDYSLTISNLEQE
 DIATYFCQQGNTLPYTFGGGTKLEITGGGGSGGGGSGGGGSEVKLQESGPGLVAP
 SQSLSVTCTVSGVSLPDYGVSWIRQPPRKGLEWLGVIWGSETTYNSALKSRLTII
 15 KDNSKSQVFLKMNSLQTDDTAIYYCAKHYYYGGSYAMDYWGQGSVTVSSTTT
 PAPRPPTPAPTIASQPLSLRPEACRPAAGGAVHTRGLDFACDIYIWAPLAGTCGVLL
 LSLVITLYCGSGSGSGSGSDRRGGRMLKHKRQRDDGEGRGEVGSAGDMRAANL
 WPSPLMIKRSKKNSLALSLTADQMVSALLDAEPPILYSEYDPTRPFSEASMMGLLT
 NLADRELVHMINWAKRVPGFVDLTLHDQVHLLLECAWLEILMIGLVWRSMEHPG
 20 KLLFAPNLLLDNRNQGKCEGMVEIFDMLLATSSRFRMMNLQGEEFVCLKSIILLN
 SGVYTFLSSTLKSLEEKDHIHRVLDKITDTLIHLMAKAGLTLQQQHQRQAQLLLIL
 SHIRHMSNKRMEHLYSMKCKNVVPLFDLLEMLDAHRLHAPTS GSGSGSGSMV
 SKGEEDNMAIIKEFMRFKVHMEGSVNGHEFEIEGEGEGRPYEGTQTAKLKVTKG
 GPLPFAWDILSPQFMYGSKAYVKHPADIPDYCLKLSFPEGFKWERVMNFEDGGVV
 25 TVTQDSSLQDGEFIYKVKLRGTNFPDGPVMQKKTMGWEASSERMYPEDGALK
 GEIKQRLKLKDGGHYDAEVKTTYKAKKPVQLPGAYNVNIKLDITSHNEDYTIVE
 QYERAEGRHSTGGMDELYKCVTD

To test whether the extracellular scFv was involved in the ligand-induced surface
 30 expression, constructs lacking the scFv were generated; in its place a FLAG tag was
 inserted to allow surface detection of the protein (nucleic acid and polypeptide sequences

for this construct are shown below as SEQ ID NOs: 38 and 39, respectively). Jurkat T cells were transduced with a lentiviral vector encoding the ERa-LBD fusion protein, and were stained for surface expression of the polypeptide in the presence and absence of the ERa ligand 4-OHT. Ligand treatment induced robust surface detection of the polypeptide (Figure 5B), indicating that NHR-LBD-mediated surface expression does not require an scFv, and that the technology is broadly generalizable to diverse polypeptides.

SEQ ID NO: 38

ATGATCCACCTGGGACACATCCTGTTTTTGCTGCTGCTGCCAGTGGCTGCCGC
 CgattacaaagacgacgatgataaaCAGACAACACCAGGCGAGAGATCTAGCCTGCCCCGCC
 TTCTACCCTGGCACCAGCGGCTCTTGTTCTGGCTGTGGCAGCCTGTCTCTGCC
 CatctatatttgggcacccctggctggaacctgcggagtgtgtgtgtgtctctctgtgattacactgtattgcAAAAGGGG
 CCGGAAAAAGCTGCTGTATATTTCAAACAGCCTTTTATGAGGCCTGTGCAGA
 CAACACAGGAAGAGGACGGCTGTAGCTGTTCGGTTCCCCGAAGAGGAAGAGG
 GGGGCTGCGAACTGggatcaggcagtggtctgtggcagcGATAGAAGAGGCGGCAGAATGC
 TGAAACACAAGCGGCAGAGGGACGACGGGGAAGGCAGAGGCGAAGTGGGAT
 CTGCCGGCGATATGAGAGCCGCCAACCTGTGGCCTAGCCCCCTGATGATCAAG
 CGGAGCAAGAAGAACTCCCTGGCCCTGAGCCTGACCGCCGACCAGATGGTGT
 CTGCCCTGCTGGATGCCGAGCCCCCATCCTGTACAGCGAGTACGACCCACC
 AGACCCTTCAGCGAGGCCAGCATGATGGGCCTGCTGACCAACCTGGCCGACC
 GGGAACCTGGTGCACATGATCAACTGGGCCAAGCGGGTGCCCGGCTTCGTGGA
 TCTGACACTGCACGACCAGGTGCACCTGCTGGAATGCGCTTGGCTGGAAATCC
 TGATGATCGGCCTCGTGTGGCGGAGCATGGAACACCCTGGCAAGCTGCTGTTC
 GCCCCCAACCTGCTGCTGGACCGGAACCAGGGCAAATGCGTGGAAGGCATGG
 TGGAATCTTCGACATGCTGCTGGCCACCTCCAGCCGGTTCCGGATGATGAAC
 CTGCAGGGCGAAGAGTTCGTGTGTCTGAAGTCCATCATCCTGCTGAATAGCGG
 CGTGTACACCTTCCTGAGCAGCACCTGAAAAGCCTGGAAGAAAAGGACCAC
 ATCCACCGGGTGCTGGACAAGATCACCGACACCCTGATTCACCTGATGGCCAA
 GGCCGGACTGACCCTGCAGCAGCAGCATCAGAGACTGGCTCAGCTGCTGCTG

ATCCTGTCCCACATCCGGCACATGAGCAACAAGCGGATGGAACATCTGTACAG
 CATGAAGTGCAAGAACGTGGTGCCTCTGTTCGATCTGCTGCTGGAAATGCTGG
 ACGCCCACAGGCTGCACGCCCCAACATCCaGATCCggatctggaagtggctccCTGAGA
 GTGAAGTTTAGCAGAAGCGCCGACGCCCCTGCCTATCAGCAGGGACAGAACC
 5 AGCTGTATAACGAGCTGAACCTGGGCAGGCGGGAAGAGTACGACGTGCTGGA
 TAAGAGGCGGGGCAGGGACCCTGAAATGGGCGGCAAACCCAGACGGAAGAA
 CCCCCAGGAAGGCCTGTACAACGAACTGCAGAAAGACAAGATGGCCGAGGC
 CTACAGCGAGATCGGAATGAAGGGCGAGCGGCGGAGAGGCAAGGGACATGAT
 GGCCTGTACCAGGGCCTGTCCACCGCCACCAAGGACACCTATGACGCCCTGC
 10 ACATGCAGGCCCTGCCTCCAAGAggaagtggatctgggagcggctctatggtgtctaagggggaagagg
 acaacatggccatcatcaaagaattcatgcggttcaaggtgcacatggaaggctccgtgaatggccacgaattcgagatcgagg
 gggagggcgagggcagacctatgagggaaaccagaccgccaagctgaaagtaccaagggcggaccctgcctttgcct
 gggatatcctgtctccccagtttatgtacggcgagcaaggcctacgtgaagcaccccgccgacatccccgactacctaagctga
 gcttccctgagggcttcaagtgggagagagtgatgaatttcgaggacggcggagtcgtgacagtgaccaggatagctctctgc
 15 aggacggcgagttcatctacaaagtgaagctgcggggcaccaacttcccagcgacggaccctgatgcagaaaaagacat
 gggctgggagggcagctccgagagaatgtaccagaggacggggccctgaagggggagatcaagcagcggctgaaactg
 aaggatggcgggcactacgacgcagaagtgaaaaccacctacaaggccaagaaacctgtgcagctgcctggcgcctacaatg
 tgaacatcaagctggacattaccagccacaacgaggactacaccatcgtggaacagtacgagcgggccgagggcaggcattc
 tacaggcggaatggatgaactgtataagtgcgtgaccgacTAG

20

SEQ ID NO: 39

MIHLGHILFLLLLPVAAADYKDDDDKQTPGERSSLPafYPGTSGSCSGCSLSLP
 IYIWAPLAGTCGVLLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEEDGCSCRF
 PEEEEGGCELGSGSGSGSDRRGGRMLKHKRQRDDGEGRGEVGSAGDMRAANL
 25 WPSPLMIKRSKKNSLALSLTADQMVSALLDAEPPILYSEYDPTRPFSEASMMGLLT
 NLADRELVHMINWAKRVPGFVDLTLHDQVHLLCAWLEILMIGLVWRSMEHPG
 KLLFAPNLLLDNRNQKCVEGMVEIFDMLLATSSRFRMMNLQGEEFVCLKSIILLN
 SGVYTFLSSTLKSLEEKDHIHRVLDKITDTLIHLMAKAGLTLQQQHQRQAQLLLIL
 SHIRHMSNKRMEHLYSMKCKNVVPLFDLLEMLDAHRLHAPTSRSGSGSGSLRV
 30 KFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPEMGGKPRRKNPQ
 EGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQA

LPPRGSGSGSGSMVSKGEEDNMAIIKEFMRFKVHMEGSVNGHEFEIEGEGEGRPY
 EGTQTAKLKVTKGGPLPFAWDILSPQFMYGSKAYVKHPADIPDYLKLSFPEGFKW
 ERVMNFEDGGVVTVTQDSSLQDGEFIYKVKLRTNFPDGPVMQKKTMGWEAS
 SERMYPEDGALKGEIKQRLKLKDGGHYDAEVKTTYKAKKPVQLPGAYNVNIKL
 5 DITSHNEDYTIVEQYERAEGRHSTGGMDELYKCVTD

The polypeptide of SEQ ID NO: 39 includes the following domains: Dap10 signal
 peptide (MIHLGHILFLLLLPVAAA, SEQ ID NO: 40), flag tag (DYKDDDDK, SEQ ID
 NO: 41), Dap10 extracellular domain (QTTPGERSSLPAFYPGTSGSCSGCSLSLP,
 10 SEQ ID NO: 42), CD8 transmembrane domain (IYIWAPLAGTCGVLLLSLVITLYC,
 SEQ ID NO: 43), 4-1BB costimulatory domain (KRGRKKLLYIFKQPFMRPVQTTQ
 EEDGCSCRFPEEEEEGGCEL, SEQ ID NO: 44), first linker (GSGSGSGS, SEQ ID NO:
 45), modified ERa domain (DRRGGRMLKHKRQRDDGEGRGEVGSAGDMRAANL
 WPSPLMIKRSKKNLALSLTADQMVSALLDAEPPILYSEYDPTRPFSEASMMGLLT
 15 NLADRELVHMINWAKRVPGFVDLTLHDQVHLLECAWLEILMIGLVWRSMEHPG
 KLLFAPNLLLDNRNQKCVEGMVEIFDMLLATSSRFRMMNLQGEEFVCLKSIILLN
 SGVYTFLSSTLKSLEEKDHIHRVLDKITDTLIHLMAKAGLTLQQQHQRQAQLLLIL
 SHIRHMSNKRMEHLYSMKCKNVVPLFDLLEMLDAHRLHAPTS, SEQ ID NO:
 46), second linker (RSGSGSGS, SEQ ID NO: 47), CD3 zeta signaling domain
 20 (LRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPPEMGGKPRRK
 NPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALH
 MQALPPR, SEQ ID NO: 48), third linker (GSGSGSGS, SEQ ID NO: 49), mCherry
 (MVSKGEEDNMAIIKEFMRFKVHMEGSVNGHEFEIEGEGEGRPYEGTQTAKLKV
 TKGGPLPFAWDILSPQFMYGSKAYVKHPADIPDYLKLSFPEGFKWERVMNFEDG
 25 GVVTVTQDSSLQDGEFIYKVKLRTNFPDGPVMQKKTMGWEASSERMYPEDG
 ALKGEIKQRLKLKDGGHYDAEVKTTYKAKKPVQLPGAYNVNIKL DITSHNEDYT
 IVEQYERAEGRHSTGGMDELYKCVTD, SEQ ID NO: 50).

Example 6 – Ligand-induced surface expression of NHR-LBD fusion constructs extends
 30 to different NHRs including progesterone receptor (PR)

To test whether progesterone receptor (“PR”) LBD fusions exhibited ligand-induced surface expression, a construct (v33) was generated (nucleic acid and polypeptide sequences for this construct are shown below as SEQ ID NOs: 51 and 52, respectively). The tested construct contained an N-terminal FLAG tag for surface detection. Jurkat T cells were transduced with lentiviral vectors encoding the construct, and were either left untreated, or were treated with 500 ng/mL mifepristone, a PR ligand. The cells were stained for surface protein expression after two hours of drug treatment. The construct exhibited ligand-induced surface expression of the polypeptide as detected by flow cytometry (Figure 6), indicating that other NHR-LBDs (aside from ERa) could be used to generate constructs with ligand-inducible surface expression, and that ligand-induced surface expression of NHR-LBD fusions proteins is a generalizable phenomenon.

SEQ ID NO: 51

ATGATCCACCTGGGACACATCCTGTTTTTGCTGCTGCTGCCAGTGGCTGCCGC
 CgattacaaagacgacgatgataaaCAGACAACACCAGGCGAGAGATCTAGCCTGCCCCGCC
 TTCTACCCTGGCACCAGCGGCTCTTGTTCTGGCTGTGGCAGCCTGTCTCTGCC
 CatctatatttgggcaccctggctggaacctgcggagtgcgtgctgtctctcgtgattacactgtattgcAAAAGGGG
 CCGGAAAAAGCTGCTGTATATTTCAAACAGCCTTTTATGAGGCCTGTGCAGA
 CAACACAGGAAGAGGACGGCTGTAGCTGTTCGGTTCCCCGAAGAGGAAGAGG
 GGGGCTGCGAACTGggatcaggcagtggtctggtcaggcGGGCAAGACATTCAGCTCATACC
 TCCTTTGATAAATTTGCTGATGTCTATAGAACCAGATGTCATATACGCTGGTCAC
 GACAATACGAAACCGGACACATCTTCATCTTTGCTTACCTCTCTGAATCAACTG
 GGTGAACGACAGCTCCTGAGTGTGTAAAGTGGTCTAAAAGCCTCCCGGGCTT
 CAGGAATTTGCACATAGACGACCAAATCACGCTCATCCAATATTCCTGGATGAG
 TCTCATGGTCTTTGGTCTCGGTTGGCGCAGCTATAAGCACGTCTCTGGCCAGAT
 GTTGTATTTTCGCACCAGACCTGATCCTGAACGAACAGAGGATGAAGGAATCAA
 GCTTTTACTCTCTCTGCTTGACTATGTGGCAAATCCCCCAAGAATTCGTGAAAC
 TTCAAGTTTCCCAAGAAGAATTCCTCTGCATGAAAGTCCTTCTTTTGCTCAACA
 CGATTCCCCTGGAAGGCTTGAGGTCTCAAACGCAATTCGAGGAGATGCGGAGT
 AGCTATATACGCGAACTCATCAAGGCCATCGGTTTGCGGCAAAAGGGAGTGGT
 CTCTAGTAGCCAACGATTTTACCAGCTGACTAAGCTCCTTGACAACCTTCACGA

TCTCGTCAAACAACTGCACCTGTACTGTCTTAACACATTTATAACAATCACGGGC
 ACTTTCTGTAGAGTTCCCAGAGATGATGTCTGAGGTCATCGCAGCCCAACTTC
 CGAAAATTCTTGCAGGAATGGTGAAGCCACTTCTGTTCCATAAGAAAaGATCCg
 gatctggaagtggctccCTGAGAGTGAAGTTTAGCAGAAGCGCCGACGCCCCTGCCTAT
 5 CAGCAGGGACAGAACCAGCTGTATAACGAGCTGAACCTGGGCAGGCGGGAA
 GAGTACGACGTGCTGGATAAGAGGCGGGGCAGGGACCCTGAAATGGGCGGCA
 AACCAGACGGAAGAACCCCCAGGAAGGCCTGTACAACGAACTGCAGAAAG
 ACAAGATGGCCGAGGCCTACAGCGAGATCGGAATGAAGGGCGAGCGGCGGA
 GAGGCAAGGGACATGATGGCCTGTACCAGGGCCTGTCCACCGCCACCAAGGA
 10 CACCTATGACGCCCTGCACATGCAGGCCCTGCCTCCAAGAggaagtggatctgggagcgg
 ctctatggtgtctaagggggaaggacaacatggccatcatcaaagaattcatcggttcaaggtgcacatggaaggctccgt
 gaatggccacgaattcgagatcgagggggagggcgagggcagaccttatgaggaaccagaccgccaagctgaaagtga
 ccaagggcgaccctgccttgcctgggatctctgtctccccagtttatgtacggcagcaaggcctacgtgaagcaccg
 ccgacatccccgactacctaagctgagcttcctgagggctcaagtgggagagagtgaatttcgaggacggcgagtc
 15 gtgacagtgaccaggatagctctctgcaggacggcgagttcatctacaaagtgaagctcgggggcaccaactccccagcga
 cggaccgtgatgcagaaaaagaccatgggctgggagggcagctccgagagaatgtaccagaggacggggcctgaagg
 gggagatcaagcagcggtgaaactgaaggatggcgccactacgacgcagaagtgaaaaccactacaaggccaagaaa
 cctgtgcagctgcctggcgctacaatgtgaacatcaagctggacattaccagccacaacgaggactacaccatcgtggaaca
 gtacgagcggggcgagggcgaggcattctacaggcggaatggatgaactgtataagtgcgtgaccgac

20

SEQ ID NO: 52

MIHLGHILFLLLLPVAAADYKDDDDKQTPGERSSLPFYPGTSGSCSGCSLSLP
 IYIWAPLAGTCGVLLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEEDGCSCRF
 PEEEEGGCELGSGSGSGSGQDIQLIPPLINLLMSIEPDVIYAGHDNTKPDTSSSLTS
 25 LNQLGERQLLSVVKWSKSLPGFRNLHIDDQITLIQYSWMSLMVFGLGWRSYKHV
 SGQMLYFAPDLILNEQRMKESSFYSLCLTMWQIPQEFVKLQVSQEEFLCMKVLLL
 LNTIPLEGLRSQTQFEEMRSSYIRELIKAIGLRQKGVVSSSQRFYQLTKLLDNLHDL
 VKQLHLYCLNTFIQSRALSVFPEMMSEVIAAQLPKILAGMVKPLL FHKKRSGSG
 SGSLRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPGEMGGKP
 30 RRKNPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYD
 ALHMQALPPRGSGSGSGSMVSKGEEDNMAIIEFMRFKVHMEGSVNGHEFEIEG

EGEGRPYEGTQTAKLKVTKGGPLPFAWDILSPQFMYGSKAYVKHPADIPDYLKLS
 FPEGFKWERVMNFEDGGVVTVTQDSSLQDGEFIYKVKLRGTNFPDGPVMQKK
 TMGWEASSERMYPEDGALKGEIKQRLKLKDGGHYDAEVKTTYKAKKPVQLPG
 AYNVNIKLDITSHNEDYTIVEQYERAEGRHSTGGMDELYKCVTD

5

The polypeptide of SEQ ID NO: 52 includes the following domains: Dap10 signal peptide (MIHLGHILFLLLLPVAAA, SEQ ID NO: 53), flag tag (DYKDDDDK, SEQ ID NO: 54), Dap10 extracellular domain (QTPGERSSLPAFYPGTSGSCSGCSLSLP, SEQ ID NO: 55), CD8 transmembrane domain (IYIWAPLAGTCGVLLLSLVITLYC, SEQ ID NO: 56), 4-1BB costimulatory domain (KRGRKKLLYIFKQPFMRPVQTTQ EEDGCSCRFPEEEEGGCEL, SEQ ID NO: 57), first linker (GSGSGSGS, SEQ ID NO: 58), Progesterone receptor LBD (GQDIQLIPPLINLLMSIEPDVIYAGHDNTKP DTSSSLTSLNQLGERQLLSVVKWSKSLPGFRNLHIDDQITLIQYSWMSLMVFGL GWSYKHVSGQMLYFAPDLILNEQRMKESFYSLCLTMWQIPQEFVKLQVSQEE FLCMKVLLLLNTIPLEGLRSQTQFEEMRSSYIRELIKAIGLRQKGVVSSSQRFYQLT KLLDNLHDLVKQLHLYCLNTFIQSRALSVEFPEMMSEVIAAQLPKILAGMVKPLL FHKK, SEQ ID NO: 59), second linker (RSGSGSGS, SEQ ID NO: 60), CD3zeta signaling domain (LRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRR GRDPEMGGKPRRKNPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQ GLSTATKDTYDALHMQALPPR, SEQ ID NO: 61), third linker (GSGSGSGS, SEQ ID NO: 62), and mCherry (MVSKGEEDNMAIIKEFMRFKVHMEGSVNGHEFEIEGEGE GRPYEGTQTAKLKVTKGGPLPFAWDILSPQFMYGSKAYVKHPADIPDYLKLSFPE GFKWERVMNFEDGGVVTVTQDSSLQDGEFIYKVKLRGTNFPDGPVMQKKTMG WEASSERMYPEDGALKGEIKQRLKLKDGGHYDAEVKTTYKAKKPVQLPGAYN VNIKLDITSHNEDYTIVEQYERAEGRHSTGGMDELYKCVTD, SEQ ID NO: 63).

The nucleotide sequence of SEQ ID NO: 51 includes the following sequences encoding the indicated domains: Dap10 signal peptide (ATGATCCACCTGGGACACAT CCTGTTTTTGCTGCTGCTGCCAGTGGCTGCCGCC, SEQ ID NO: 63), flag tag (gattacaaagacgacgatgataaa, SEQ ID NO: 64), Dap10 extracellular domain (CAGACAAC ACCAGGCGAGAGATCTAGCCTGCCCCGCCTTCTACCCTGGCACCAGCGGCTCTT GTTCTGGCTGTGGCAGCCTGTCTCTGCCC, SEQ ID NO: 65), CD8 transmembrane

ggcagcaaggcctacgtgaagcaccgccgacatccccgactacctgaagctgagcttccctgagggcttcaagtgggaga
 gagtgatgaatttcgaggacggcgagtcgtgacagtgaccaggatagctctctgcaggacggcgagttcatctacaaagt
 aagctgcggggcaccaacttccccagcgacggaccctgatgcagaaaaagaccatgggctgggaggccagctccgagag
 aatgtaccagaggacggggccctgaagggggagatcaagcagcggctgaaactgaaggatggcggccactacgacgcag
 5 aagtgaaccacctacaaggccaagaaacctgtgcagctgcctggcgccctacaatgtgaacatcaagctggacattaccagc
 cacaacgaggactacaccatcgtggaacagtacgagcggggccgagggcaggcattctacaggcgggaatggatgaactgtata
 agtgcgtgaccgac, SEQ ID NO: 73).

Example 7 – Ligand-induced NHR-LBD CAR T cell activation is antigen- and drug-
 10 dependent.

Primary human T cells were transduced with lentiviral vectors encoding J6M0-
 ERa-LBD CAR construct. T cell activation was assessed by surface staining for the
 canonical T cell activation marker, CD69, after overnight co-culture with antigen-
 negative (K562 cell line) and antigen-positive (MM1S cell line) targets in the presence of
 15 increasing concentrations of 4-OHT (Figure 7A). A unique dose-dependent T cell
 response was observed for each construct, with the proximity of the LBD to the cell
 membrane correlating to background activation (activation in the absence of ligand) and
 sensitivity to ligand. All constructs displayed activation levels comparable to the positive
 control (canonical CAR) at increasing drug concentrations.

20 The ability of the J6M0-ERa-LBD CAR cells to produce inflammatory cytokines
 was assessed via IFN- γ ELISA on co-culture supernatants isolated from overnight co-
 cultures of T cells with antigen-negative (K562 cell line) and antigen-positive (MM1S
 cell line) targets in the presence of increasing concentrations of 4-OHT. IFN- γ
 production was shown to be dose-dependent, with all NHR-LBD constructs producing
 25 cytokine at increasing ligand concentrations (Figure 7B).

Example 8 - Ligand-induced NHR-LBD CAR T cell proliferation and killing are antigen-
 and ligand-dependent.

Primary human CD4 T cells were transduced with lentiviral vectors encoding V4
 30 FMC63-ERa-LBD CAR or canonical CAR controls. The cells were labeled with
 carboxyfluorescein succinimidyl ester (“CFSE”) prior to co-culture with either antigen-

negative (K562 cell line) or antigen-positive (Raji cell line) targets. The cells were also co-cultured with increasing concentrations of ligand (4-OHT). Three days after co-culture, cells were analyzed via flow cytometry and proliferation was assessed by dilution of CFSE dye on CD4⁺ T cells. FMC63-ERa-LBD CAR T cells proliferated only in the presence of antigen and ligand (Figure 8A).

Primary human T cells were transduced with lentiviral vectors encoding the J6M0-ERa-LBD CAR construct described in Example 7. The ability of T cells bearing the J6M0-ERa-LBD CAR construct to kill antigen-positive targets (MM1S cell line) in a drug-dependent manner was assessed via a flow cytometry-based killing assay. Target cells were labeled with CFSE prior to co-culture, and the number of cells remaining in each well after co-culture was determined via quantification of a fixed volume using the Intellicyt flow cytometer. Specific lysis was determined by comparing the number of targets remaining per experimental well to the number of targets remaining in control wells that contained both targets and non-antigen specific conventional CAR T cells (-CTRL). Specific lysis was reported as a percentage derived from the following equation: $1 - (\# \text{ events per experiment well} / \# \text{ average events} - \text{CTRL wells})$. Target cell killing was dependent on the dose of the ligand, with all constructs eliminating antigen-positive targets at levels comparable to the conventional CAR (+ CTRL) at higher drug doses (Figure 8B).

Example 9 - The location of the LBD within the CAR polypeptide determines sensitivity to ligand-induced surface expression of NHR-LBD CAR.

The dose responsiveness of the V2, V3, and V4 constructs shown in Figure 1 was compared in Jurkat T cells. Detection of surface expression of NHR-LBD CAR protein on Jurkat T cells was performed after incubation for one hour with 4-OHT ligand at the concentrations indicated on the x-axis of Figure 9. Surface receptor expression was detected using an anti-cMyc antibody, and was reported as a percentage of reporter-positive cells (as determined by mCherry expression). The ligand dose at which surface expression was detected for each construct corresponded to the location of the LBD, in relation to the surface membrane, for each construct. Construct V4, which harbors the LBD immediately adjacent to the surface membrane, showed no detectable surface

expression in the absence of ligand, with surface expression detected only at higher concentrations of 4-OHT. In contrast, when the LBD was located further from the membrane (see e.g., V2), a higher basal level of surface expression was detected (~20%), and enhanced sensitivity to 4-OHT was observed. Activation of Jurkat T cells with PMA/Ionomycin did not lead to ligand-independent NHR-LBD CAR surface expression, demonstrating that activation of the T cell alone (through the endogenous TCR, for example) does not result in trafficking of the receptor to the cell surface.

Example 10 - Duration of NHR-LBD CAR surface expression is dependent on the location of LBD in polypeptide.

T cells were transduced with FMC63-ERa-LBD CARs and were exposed to 4-OHT at 35 ng/mL for one hour before either being stained for surface expression using an anti-cMyc antibody, or being washed and cultured overnight in the absence of drug (timeline shown in Figure 10A).

The number of cells expressing surface protein was reported as a percentage of reporter-positive cells (as determined by mCherry expression). The duration of NHR-LBD CAR expression on the cell surface for constructs V2, V3, and V4 was determined. The construct that harbored the LBD most proximal to the membrane (V4) showed the most rapid and complete return to baseline 24 hours after ligand removal (Figure 10B, bars labeled “V4”).

Example 11 - Kinetics of surface expression in NHR-LBD-CAR constructs after ligand addition.

Jurkat T cells were transduced with the FLAG-ERa-LBD construct used in Example 5 were left untreated or were treated with 500 ng/mL 4-OHT for 15 minutes or 120 minutes, and surface expression was detected after ligand treatment. Ligand treatment induced surface expression within 15 minutes, and further upregulation was observed over time (Figure 11A).

Human T cells were transduced with lentiviral vector encoding the FMC63-ERa-LBD CAR (v2 as shown in Figure 1). The cells were treated with the ERa ligand 4-OHT for the indicated duration, and then stained for surface expression of the CAR (Figure

11B). The data in Figure 11B show similar kinetics for the ligand treatment induced surface expression as was observed for Jurkat T cells.

Example 12 - Brefeldin A treatment blocks ligand-induced surface trafficking of NHR LBD fusions.

Primary human T cells expressing FMC63-CAR with ERα LBD fusion were left untreated or were treated with 500 ng/mL 4-OHT ligand for two hours to induce surface expression of the CAR. Prior to 4-OHT treatment, half the cells were pre-treated with 1 uM Brefeldin A (Figure 12, bottom two panels) to inhibit protein export from the Golgi. Brefeldin A pre-treatment prevented 4-OHT-induced increase in surface protein expression. Without wishing to be bound by theory, these data suggest that increased surface expression arises from relocalization of a pool of polypeptides that is sequestered intracellularly in the absence of ligand.

Example 13 – Generation of Constructs

A conventional chimeric antigen receptor (“Conventional CAR”, Figure 13, left) was modified to include the estrogen receptor alpha (“ERα”) ligand binding domain (“ERα LBD,” Figure 1, in green) either in the intracellular portion of the protein (v2 CAR as described in Example 1) or in the extracellular portion of the protein (“Concealed Carry’ CAR ECD.v1” or “LBD-ECD CAR”). Point mutations were introduced into the ERα LBD domain of both v2 CAR and ECD.v1 CAR. The nucleic acid and polypeptide sequences of v2 CAR (are shown above as SEQ ID NOs: 30 and 31) and ECD.v1 (SEQ ID NOs: 97 and 98) are provided below.

SEQ ID NO: 97 (ECD v.1 CAR)

atgcttctcctggtgacaagccttctgctctgtgagttaccacaccagcattcctcctgattcctgaacagaagctgataagtgag
gaggacttggacatccagatgaccagaccaccagcagcctgagcgccagcctggcgatagagtgaccatcagctgcaga
gccagccaggacatcagcaagtacctgaactggtatcagcagaaacccgacggcaccgtgaagctgctgatctaccacacca
gcagactgcacagcggcgtgccagcagattttctggcagcggctccggcaccgactacagcctgaccatctccaacctggaa
caggaagatatcgctacctacttctgtcagcaaggcaacaccctgcctacaccttcggcgagggcaccaagctggaaatcaca
ggcgcgaggagatctggcgaggcggaagtggcgagggggatctgaagtgaaactgcaggaaagcgccctggcctgg

tggccccatctcagttctgagcgtgacctgtaccgtgtccggcgtgtccctgcctgactatggcgtgtcctggatcagacagcc
 cccagaaagggcctggaatggctgggagtgatctggggcagcgagacaacctactacaacagcgccctgaagtccggct
 gaccatcatcaaggacaactccaagagccaggtgttctgaagatgaacagcctgcagaccgacgacaccgccatctactact
 gcgccaagcactactactacggcggcagctacgccatggactactggggccagggcacaaagcgtgaccgtgtctagcggatc
 5 cgatagaagagggcggcagaatgctgaaacacaagcggcagagggacgacggggaaggcagagggcgaagtgggatctgcc
 ggcgatatgagagccgccaacctgtggcctagccccctgatgatcaagcggagcaagaagaactccctggccctgagcctga
 ccgccgaccagatggtgtctgcctgctggatgccgagccccccatcctgtacagcgagtacgacccaccagacccttcagc
 gaggccagcatgatgggcctgctgaccaacctggccgaccgggaactggtgcacatgatcaactgggccaagcgggtgccc
 ggcttcgtggatctgacactgcacgaccaggtgcacctgctggaatgcgcttggtggaatcctgatgatcggcctcgtgtggc
 10 ggagcatggaacacctggcaagctgctgttcgccccaaacctgctgctggaccggaaccagggcaaatgctggaaggcat
 ggtggaatcttcgacatgctgctggccacctccagccgggtccggatgatgaacctgcagggcgaagagttcgtgtgtctgaa
 gtccatcatcctgctgaatagcggcgtgtacaccttctgagcagcacctgaaaagcctggaagaaaaggaccacatccacc
 ggggtgctggacaagatcaccgacacctgattcacctgatggccaaggccggactgacctgcagcagcagcatcagagact
 ggctcagctgctgctgatcctgtccacatccggcacatgagcaacaagcggatggaacatctgtacagcatgaagtcaaga
 15 acgtggtgcctctgttcgatctgctgctggaaatgctggacgcccacaggctgcacgcccacatccggatccaccacgacg
 ccagcggcgcgaccaccaacaccggcggccaccatcgctcgacggcctgtccctgcgcccagaggcgtgccggccagc
 gggcggggggcgagtgacacgagggggctggacttcgctgtgatatctacatctggcgcccttgccggggacttgtggg
 gtcttctcctgtcactggttatccaccttactgcaaacggggcagaaagaaactcctgtatatattcaacaaccatttatgagac
 cagtacaaactactcaagaggaagatggctgtagctgccgattccagaagaagaaggaggatgtgaactgagagtgaag
 20 ttcagcaggagcgcagacgccccgcgtaccagcagggccagaaccagctctataacgagctcaatctaggacgaagagag
 gagtacgatgttttgacaagagacgtggccgggaccctgagatggggggaaagccgagaaggaagaacctcaggaagg
 cctgtacaatgaactgcagaaagataagatggcggaggcctacagtgagattgggatgaaaggcgagcgccggagggggcaa
 ggggcacgatggcctttaccaggggtctcagtacagccaccaaggacacctacgacggccttcacatgcaggccctgccccctc
 gctag

25

SEQ ID NO: 98 (ECD v.1 CAR)

MLLLVTSLLLCELPHPAFLIPEQKLISEEDLDIQMTQTSSLSASLGDRVTISCRASQDISKYLNWYQQ
 KPDGTVKLLIYHTSRLHSGVPSRFSGSGSGTDYSLTISNLEQEDIATYFCQQGNTLPYTFGGGKLEITG
 GGGSGGGSGGGGSEVKLQESGPGLVAPSQSLSVTCTVSGVSLPDYGVSWIRQPPRKGLEWLGI
 30 WGSETTYNSALKSRLTIKDNSKSQVFLKMNSLQTDDTAIYYCAKHYYYGGSYAMDYWGQTSVT
 VSSGSDRRGGRMLKHKRQRDDGEGRGEVGSAGDMRAANLWPSPLMIKRSKKNLALS LTADQM

VSALLDAEPPILYSEYDPTRPFSEASMMGLLTNLADRELVHMINWAKRVPGFVDLTLHDQVHLECA
WLEILMIGLVWRSMEHPGKLLFAPNLLDRNQGKCEGMVEIFDMLLATSSRFRMMNLQGEEFVC
LKSIILLNSGVYTFLSSTLKSLEEKDHIHRVLDKITDTLIHLMAGLTLQQHQRLAQLLLILSHIRHMS
NKRMEHLYSMKCKNVVPLFDLLEMLDAHRLHAPTSGSTTTPAPRPPTPAPTIASQPLSLRPEACRP
5 AAGGAVHTRGLDFACDIYWAPLAGTCGVLLSLVITLYCKRGRKKLLYIFKQPFMRPVQTTQEEDGC
SCRFPEEEEGGCELRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPEMGGKPRR
KNPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDALHMQALPPR

The protein and nucleic acid sequence of each domain in ECD.v1, going from the N-terminus to the C-terminus, in ECD.v1 are shown below.

10

SEQ ID NO: 99 (CSF2RA signal peptide)

atgcttctcctggtgacaagccttctgctgtgagttaccacaccagcattcctcctgattcct

SEQ ID NO: 100 (CSF2RA signal peptide)

15

MLLLVTSLLLCELPHPAFLIP

SEQ ID NO: 101 (cMyc tag)

gaacagaagctgataagtgaggaggacttg

20

SEQ ID NO: 102 (cMyc tag)

EQKLISEEDL

SEQ ID NO: 103 (FMC63 V_L)

25

gacatccagatgaccagaccaccagcagcctgagcgccagcctgggcgatatagtgaccatcagctgcagagccagccag
gacatcagcaagtacctgaactggtatcagcagaaacccgacggcaccgtgaagctgctgatctaccacaccagcagactgca
cagcggcggtgccagcagattttctggcagcggtccggcaccgactacagcctgaccatctccaacctggaacaggaagata
tcgctacctacttctgtcagcaaggcaacacctgcacctacaccttcggcggaggcaccaagctggaaatcaca

SEQ ID NO: 104 (FMC63 V_H)

30

DIQMTQTTSSLSASLGDRVTISCRASQDISKYLNWYQQKPDGTVKLLIYHTSRLH
SGVPSRFSGSGSGTDYSLTISNLEQEDIATYFCQQGNTLPYTFGGGKLEIT

SEQ ID NO: 105 ((G4S)₃ linker between V_L and V_H)

ggcggcggaggatctggcggaggcgggaagtggcggaggggggatct

5 SEQ ID NO: 106 ((G4S)₃ linker between V_L and V_H)

GGGGS GGGGS GGGGS

SEQ ID NO: 107 (FMC63 V_H)

gaagtgaaactgcaggaaagcggccctggcctggcggcccatctcagtccttgagcgtgacctgtaccgtgtccggcgtgtcc
 10 ctgcctgactatggcgtgtcctggatcagacagccccccagaaaggcctggaatggctgggagtgatctggggcagcgaga
 caacctactacaacagcgcctgaagtcccggtgacctcatcaaggacaactccaagagccaggtgttctgaagatgaac
 agcctgcgagaccgacgacaccgccatctactactgcgccaagcactactactacggcggcagctacgccatggactactggg
 gccagggcacaagcgtgaccgtgtctagc

15 SEQ ID NO: 108 (FMC63 V_H)

EVKLQESG PGLVAPSQSLSVTCTVSGVSLPDYGVSWIRQPPRKGLEWLGVWIGSE
 TTYYN SALKSRLTIKDNSKSQVFLKMNSLQTDDTAIYYCAKHYYYGGSYAMDY
 WGQGT SVTVSS

20 GS linker between V_H domain and estrogen receptor alpha ligand binding domain

ggatcc

GS linker between V_H domain and estrogen receptor alpha ligand binding domain

GS

25

SEQ ID NO: 109 (Estrogen receptor alpha ligand binding domain) (sequence encoding hinge underlined, sequence encoding helix 12 in bold)

gatagaagaggcggcagaatgctgaaacacaagcggcagagggacgacggggaaggcagaggcgaagtgggatctgccg
gcgatatgagagccccaacctgtggcctagccccctgatgatcaagcggagcaagaagaactccctggccctgagcctgac
 30 cgccgaccagatggtgtctgcctgctggatgccgagcccccatcctgtacagcgagtacgacccaccagaccttcagcg
 aggccagcatgatgggcctgtgaccaacctggccgaccgggaactggtgcacatgatcaactgggccaagcgggtgcccg

gcttcgtggatctgacactgcacgaccaggtgcacctgctggaatgcgcttggtggaaatcctgatgatcggcctcgtgtggcg
gagcatggaacacctggcaagctgctgttcgcccccaacctgctgctggaccggaaccagggcaaatgcgtggaaggcatg
gtggaaatcttcgacatgctgctggccacctccagccgggtccggatgatgaacctgcagggcgaagagttcgtgtgtctgaagt
ccatcatcctgctgaatagcggcgtgtacaccttctgagcagcacctgaaaagcctggaagaaaaggaccacatccaccgg
5 gtctggacaagatcaccgacacctgattcacctgatggccaaggccggactgacctgcagcagcagcatcagagactgg
ctcagctgctgctgatcctgtcccacatccggcacatgagcaacaagcggatggaacatctgtacagcatgaagtgaagaacg
tggtgcctctgttcgatctgctgctggaaatgctggacgcccacaggetgcacgcccacatcc

**SEQ ID NO: 110 (Estrogen receptor alpha ligand binding domain) (hinge
underlined, helix 12 in bold)**

DRRGGRMLKHKRQRDDGEGRGEVGSAGDMRAANLWPSPLMIKRSKKNLALS
LTADQMVSALLDAEPPILYSEYDPTRPFSEASMMGLLTNLADRELVHMINWAKR
VPGFVDLTLHDQVHLLCAWLEILMIGLVWRSMEHPGKLLFAPNLLDRNQKGC
VEGMVEIFDMLLATSSRFRMMNLQGEEFVCLKSILLNSGVYTFLSSTLKSLEEKD
15 HIHRVLDKITDTLIHLMAKAGLTQQHQRLAQLLLILSHIRHMSNKRMEHLYS
MKCKNVVPLFDLLEMLDAHRLHAPTS

**GS-linker between estrogen receptor alpha ligand binding domain and CD8 alpha
hinge region**

ggatcc

**GS-linker between estrogen receptor alpha ligand binding domain and CD8 alpha
hinge region**

GS

SEQ ID NO: 111 (CD8 alpha hinge)

accacgacgccagcgcgcgaccaccaacaccggcgccaccatcgctgcagcccctgtccctgcgccagaggcgtg
ccggccagcggcgggggggcgagtgacacgaggggggtggacttcgctgtgatattacatctggcgcccttgccgg
gacttggtgggtccttctcctgtcactggttatccctttactgc

SEQ ID NO: 112 (CD8 alpha hinge)

TTTPAPRPPTPAPTIASQPLSLRPEACRPAAGGAVHTRGLDFAC

SEQ ID NO: 113 (CD8 alpha transmembrane domain)

gatatctacatctggcgcccttgccgggacttggtggggctctctcctgtcactggttatcaccccttactgc

5

SEQ ID NO: 114 (CD8 alpha transmembrane domain)

DIYIWAPLAGTCGVLLSLVITLYC

SEQ ID NO: 115 (4-1BB costimulatory domain)

aaacggggcagaaagaaactcctgtatatattcaacaaccatttatgagaccagtacaaactactcaagaggaagatggctgta

10

gctgccgattccagaagaagaaggaggatgtgaa

SEQ ID NO: 116 (4-1BB costimulatory domain)

KRGRKKLLYIFKQPFMRPVQTTQEEDGCSCRFPEEEEGGCE

15

SEQ ID NO: 117 (CD3 zeta signaling domain)

ctgagagtgaagttcagcaggagcgcagacgccccgcgtaccagcagggccagaaccagctctataacgagctcaatctag

gacgaagagaggagtacgatgttttgacaagagacgtggccgggaccctgagatggggggaaagccgagaaggaagaac

cctcaggaaggcctgtacaatgaactgcagaaagataagatggcggaggcctacagtgagattgggatgaaaggcgagcgcc

ggaggggcaaggggcacgatggcctttaccaggggtctcagtacagccaccaaggacacctacgacgcccttcacatgcagge

20

cctgccccctcgc

SEQ ID NO: 118 (CD3 zeta signaling domain)

LRVKFSRSADAPAYQQGQNQLYNELNLGRREEYDVLDKRRGRDPPEMGGKPRRK

NPQEGLYNELQKDKMAEAYSEIGMKGERRRGKGHDGLYQGLSTATKDTYDAL

25

HMQALPPR

Example 14 – LBD-ECD reduces background localization of the CAR to the cell surface in the absence of ligand

Primary human T cells were transduced with lentiviral vectors encoding the CC.v2 or LBD ECD.v1 construct as indicated. Cells were left un-treated or treated with 500 ng/mL of 4-OHT. Duration of treatment was as shown in Figure 14. Cells were

30

subsequently stained for surface expression of the chimeric receptor using anti-Myc AlexaFluor 647 antibody.

Placement of the LBD to the extracellular portion of the CAR reduces the background levels of CAR surface expression when the ligand has not been added, relative to when the LBD is placed in the intracellular portion of the CAR (Figure 14). Both v2 CAR and ECD.v1 were expressed on the surface of cells when 500 ng/ml of 4-OHT was added.

Example 15 – LBD-ECD CAR kills cells in a drug dependent manner

Primary human T cells were transduced with lentiviral vectors encoding the LBD ECD.v1 or control CAR construct as indicated. T cells were allowed to rest after expansion and subsequently co-cultured with luciferase expressing Nalm6 tumor cells at an effector:target ratio shown in Figure 15. After 24 hours of co-culture the cells were lysed and luciferase substrate added to quantify the number of surviving tumor cells.

LBD ECD.v1 CAR kills cells in a drug dependent manner. The addition of increasing amounts of 4-OHT leads to greater levels of cell lysis (approximately 50% lysis at 500 ng/mL 4-OHT) (Figure 15).

Example 16 – LBD-ECD CAR is localized intracellularly in activated T cells

Primary human T cells were transduced with lentiviral vectors encoding the LBD_ECD, CC.v2, or constitutive control CAR construct as indicated. After cells had rested, cells were re-stimulated with aCD3/aCD28 dynabeads for 48 hours. Cells were subsequently stained with anti-Myc antibody to detect surface expression of the CAR, and analyzed via flow cytometry.

CARs with an extracellular LBD (LBD ECD v1) are localized intracellularly in T cells that are activated when exposed to a CD3/CD28 beads. CARs with an intracellular LBD (v2 CAR) show some localization to the cell surface in activated T cells (Figure 16).

Example 17 – ECD.v1 CAR (LBD_ECD) produces cytokine IL-2

IL-2 production from the ECD.v1 CAR T cells was compared to the conventional CAR+ control after overnight co-culture of CAR-bearing T cells with NALM-6 targets in

the presence (500 ng/mL) or absence of 4-hydroxytamoxifen (Figure 16). IL-2 production from the ECD.v1 CAR receptor (Figure 13) was comparable to the conventional CAR control, dependent upon 4-hydroxytamoxifen, and undetectable in the absence of drug.

5

OTHER EMBODIMENTS

It is to be understood that while the invention has been described in conjunction with the detailed description thereof, the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the following claims.

10

WHAT IS CLAIMED IS:

1. A single-chain chimeric polypeptide, wherein the single-chain chimeric polypeptide comprises:
 - a transmembrane domain; and
 - a hormone receptor ligand binding domain,wherein:
 - the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to 500 amino acids; and
 - the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal.
2. The single-chain chimeric polypeptide of claim 1, wherein the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154.
3. The single-chain chimeric polypeptide of claim 1, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor.
4. The single-chain chimeric polypeptide of claim 3, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.
5. The single-chain chimeric polypeptide of any one of claims 1-4, wherein the transmembrane domain and the hormone receptor ligand binding domain directly abut each other.

6. The single-chain chimeric polypeptide of any one of claims 1-4, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 500 amino acids.

7. The single-chain chimeric polypeptide of claim 6, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 250 amino acids.

8. The single-chain chimeric polypeptide of claim 7, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 50 amino acids.

9. A nucleic acid comprising a nucleotide sequence encoding the single-chain chimeric polypeptide of any one of claims 1-8.

10. A vector comprising the nucleic acid of claim 9.

11. A mammalian cell comprising the vector of claim 10.

12. A method of inducing the membrane localization of a single-chain chimeric polypeptide in a mammalian cell, the method comprising:

contacting a mammalian cell expressing a single-chain chimeric polypeptide of any one of claims 1-8 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell.

13. A method of reversibly altering the membrane localization of a single-chain chimeric polypeptide in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a single-chain chimeric polypeptide of any one of claims 1-8 with an amount of a hormone or a hormone analogue sufficient

to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell; and

(b) contacting the mammalian cell with a reduced amount of the hormone or the hormone analogue that results in a decreased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the mammalian cell.

14. The method of claim 13, further comprising:

(c) contacting the mammalian cell with an increased amount of the hormone or the hormone analogue that results in an increased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the cell as compared to the level of in step (b).

15. The method of any one of claims 12-14, further comprising:

introducing a nucleic acid encoding the single-chain chimeric polypeptide into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric polypeptide.

16. The method of any one of claims 12-15, wherein the mammalian cell is a T cell.

17. The method of claim 16, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

18. The method of any one of claims 12-17, wherein the mammalian cell is a mammalian cell previously obtained from a subject.

19. The method of claim 18, wherein the subject has been identified or diagnosed as having a cancer.

20. The method of claim 18 or 19, further comprising:
obtaining the mammalian cell from the subject.

21. The method of any one of claims 12-20, wherein the contacting step is performed *in vitro*.

22. The method of any one of claims 12-20, wherein the contacting step is performed in a mammal.

23. A single-chain chimeric antigen receptor, wherein the single-chain chimeric antigen receptor comprises:

an extracellular antigen-binding domain;
a transmembrane domain;
a hormone receptor ligand binding domain;
a costimulatory domain; and
an immunoreceptor tyrosine-based activation motif (ITAM);
wherein:

the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to 500 amino acids; and

the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal.

24. The single-chain chimeric antigen receptor of claim 23, wherein the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_{HH} domain, and a V_{NAR} domain.

25. The single-chain chimeric antigen receptor of claim 24, wherein the extracellular antigen-binding domain is a scFv.

26. The single-chain chimeric antigen receptor of any one of claims 23-25, wherein the extracellular antigen-binding domain binds specifically to a single antigen.

27. The single-chain chimeric antigen receptor of claim 26, wherein the single antigen is a tumor antigen.

28. The single-chain chimeric antigen receptor of claim 27, wherein the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16.

29. The single-chain chimeric antigen receptor of claim 28, wherein the tumor antigen is CD19.

30. The single-chain chimeric antigen receptor of claim 23, wherein the extracellular antigen-binding domain binds specifically to two different antigens.

31. The single-chain chimeric antigen receptor of any one of claims 23-30, wherein the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154.

32. The single-chain chimeric antigen receptor of any one of claims 23-31, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor.

33. The single-chain chimeric antigen receptor of claim 32, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

34. The single-chain chimeric antigen receptor of any one of claims 23-33, wherein the costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, and B7-H3.

35. The single-chain chimeric antigen receptor of claim 34, wherein the costimulatory domain is 4-1BB or CD28.

36. The single-chain chimeric antigen receptor of any one of claims 23-35, wherein the ITAM comprises a cytoplasmic signaling sequence from CD3 ζ .

37. The single-chain chimeric antigen receptor of any one of claims 23-36, wherein the transmembrane domain and the hormone receptor ligand binding domain directly abut each other.

38. The single-chain chimeric antigen receptor of any one of claims 23-36, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 500 amino acids.

39. The single-chain chimeric antigen receptor of claim 38, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 250 amino acids.

40. The single-chain chimeric antigen receptor of claim 39, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 50 amino acids.

41. A nucleic acid comprising a nucleotide sequence encoding the single chain-chimeric antigen receptor of any one of claims 23-40.

42. A vector comprising the nucleic acid of claim 41.

43. A mammalian cell comprising the vector of claim 42.

44. A method of inducing the membrane localization of a single-chain chimeric antigen receptor in a mammalian cell, the method comprising:

contacting a mammalian cell expressing a single-chain chimeric antigen receptor of any one of claims 23-40 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

45. A method of altering the membrane localization of a single-chain chimeric antigen receptor in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a single-chain chimeric antigen receptor of any one of claims 23-40 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and

(b) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in a reduced level of the single-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell.

46. The method of claim 45, further comprising:

(c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increased level of single-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell as compared to the level in (b).

47. The method of any one of claims 44-46, further comprising:

introducing a nucleic acid encoding the single-chain chimeric antigen receptor into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric antigen receptor.

48. The method of claim 47, wherein the mammalian cell is a T cell.

49. The method of claim 48, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell.

50. The method of any one of claims 44-49, wherein the mammalian cell is a mammalian cell previously obtained from a subject.

51. The method of claim 50, wherein the subject has been identified or diagnosed as having a cancer.

52. The method of claim 50 or 51, further comprising:
obtaining the mammalian cell from the subject.

53. The method of any one of claims 44-52, wherein the contacting step is performed in vitro.

54. The method of any one of claims 44-52, wherein the contacting step is performed in a mammal.

55. The method of claim 54, wherein the mammal has a cancer.

56. The method of claim 55, wherein the contacting step results in the treatment of the cancer in the mammal.

57. A multi-chain chimeric antigen receptor, wherein the multi-chain chimeric antigen receptor comprises at least one first polypeptide comprising:

an extracellular antigen-binding domain;
a transmembrane domain; and
a hormone receptor ligand binding domain;
wherein:

the transmembrane domain and the hormone receptor ligand binding domain directly abut each other or are separated by 1 to 500 amino acids; and

the transmembrane domain and the hormone receptor ligand binding domain are not both present in the same endogenous single-chain polypeptide in a mammal.

58. The multi-chain chimeric antigen receptor of claim 57, wherein the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_HH domain, and a V_{NAR} domain.

59. The multi-chain chimeric antigen receptor of claim 58, wherein the extracellular antigen-binding domain is a scFv.

60. The multi-chain chimeric antigen receptor of any one of claims 57-59, wherein the extracellular antigen-binding domain binds specifically to a single antigen.

61. The multi-chain chimeric antigen receptor of claim 60, wherein the single antigen is a tumor antigen.

62. The multi-chain chimeric antigen receptor of claim 61, wherein the tumor antigen is selected from the group of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16.

63. The multi-chain chimeric antigen receptor of claim 62, wherein the tumor antigen is CD19.

64. The multi-chain chimeric antigen receptor of claim 57, wherein the extracellular antigen-binding domain binds specifically to two different antigens.

65. The multi-chain chimeric antigen receptor of any one of claims 57-64, wherein the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154.

66. The multi-chain chimeric antigen receptor of any one of claims 57-65, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor.

67. The multi-chain chimeric antigen receptor of claim 66, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

68. The multi-chain chimeric antigen receptor of any one of claims 57-67, wherein the transmembrane domain and the hormone receptor ligand binding domain directly abut each other.

69. The multi-chain chimeric antigen receptor of any one of claims 57-67, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 500 amino acids.

70. The multi-chain chimeric antigen receptor of claim 69, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 250 amino acids.

71. The multi-chain chimeric antigen receptor of claim 70, wherein the transmembrane domain and the hormone receptor ligand binding domain are separated by 1 to 50 amino acids.

72. The multi-chain chimeric antigen receptor of any one of claims 57-71, wherein the at least one polypeptide further comprises a costimulatory domain.

73. The multi-chain chimeric antigen receptor of claim 72, wherein the costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, and B7-H3.

74. The multi-chain chimeric antigen receptor of claim 33, wherein the costimulatory domain is 4-1BB or CD28.

75. A method of inducing the membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell, the method comprising:

contacting a mammalian cell expressing a multi-chain chimeric antigen receptor of any one of claims 57-74 with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

76. A method of altering the membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a multi-chain chimeric antigen receptor of any one of claims 57-74 with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and

(b) contacting the mammalian cell with an amount of the hormone or the hormone analogue with an amount of the hormone or the hormone analogue that results in a decreased level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell.

77. The method of claim 76, further comprising:

(c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increase in the level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell.

78. The method of any one of claims 75-77, further comprising:

introducing a nucleic acid encoding the single-chain chimeric antigen receptor into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric antigen receptor.

79. The method of claim 78, wherein the mammalian cell is a T cell.

80. The method of claim 79, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell.

81. The method of any one of claims 75-80, wherein the mammalian cell is a mammalian cell previously obtained from a subject.

82. The method of claim 81, wherein the subject has been identified or diagnosed as having a cancer.

83. The method of claim 81 or 82, further comprising:
obtaining the mammalian cell from the subject.

84. The method of any one of claims 75-83, wherein the contacting step is performed in vitro.

85. The method of any one of claims 75-83, wherein the contacting step is performed in a mammal.

86. The method of claim 85, wherein the mammal has a cancer.

87. The method of claim 86, wherein the contacting step results in the treatment of the cancer in the mammal.

88. A method of treating a cancer in a subject, comprising:

(a) administering to the subject a mammalian cell expressing a single chain chimeric antigen receptor of any one of claims 23-40 or a multi-chain chimeric antigen receptor of any one of claims 57-74, wherein the antigen binding domain binds specifically to an antigen expressed by the cancer in the subject;

(b) administering to the subject an amount of a hormone or hormone sufficient to induce localization of the single-chain or multi-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell;

(c) determining the presence or severity of one or more symptoms associated with toxicity, the level of one or more cytokines associated with a cytokine storm, or both, in the subject following (b);

(d) comparing the determined presence or severity of one or more symptoms associated with toxicity, the determined level of one or more cytokines associated with the cytokine storm, or both, to a control(s); and

(e) administering to the subject an amount of the hormone or hormone analogue sufficient to reduce the level of the single-chain or multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell, such that the presence or severity of one or more symptoms associated with toxicity, the level of one or more cytokines associated with a cytokine storm, or both, is reduced in the subject after (e).

89. The method of claim 88, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 25% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b).

90. The method of claim 89, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 50% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b).

91. The method of claim 90, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 75% as compared to the level of the hormone or hormone analogue administered to the subject in step (b).

92. The method of claim 91, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by 100% as compared to the level of the hormone or hormone analogue administered to the subject in step (b).

93. The method of claim 88, wherein the one or more symptoms associated with toxicity are selected from the group consisting of: high fever, swelling, chills, hypotension, tachycardia, asthenia, headache, rash, scratchy throat, dyspnea, redness, extreme fatigue, nausea, and cerebral edema.

94. The method of claim 88, wherein the one or more cytokines associated with a cytokine storm are selected from the group consisting of: include tumor necrosis factor- α , IFN γ , IL-10, IL-1 β , IL-2, IL-6, IL-8, and IL-10, granulocyte macrophage-colony-stimulating factor (GM-CSF), and IL-5.

95. A single-chain chimeric polypeptide, wherein the single-chain chimeric polypeptide comprises:

an extracellular hormone receptor ligand binding domain; and
a transmembrane domain,

wherein:

the hormone receptor ligand binding domain and the extracellular transmembrane domain directly abut each other or are separated by 1 to 700 amino acids; and

the transmembrane domain and the extracellular hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal.

96. The single-chain chimeric polypeptide of claim 95, wherein the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154.

97. The single-chain chimeric polypeptide of claim 95, wherein the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor.

98. The single-chain chimeric polypeptide of claim 97, wherein the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

99. The single-chain chimeric polypeptide of claim 98, wherein extracellular hormone receptor ligand binding domain is a ligand binding domain from a human estrogen receptor.

100. The single-chain chimeric polypeptide of claim 99, wherein the ligand binding domain of the human estrogen receptor has a wildtype sequence, except that it comprises one or both of a substitution at amino acid position 521 and a substitution at amino acid position 537, each numbered relative to the full-length wildtype sequence of human hormone receptor.

101. The single-chain chimeric polypeptide of any one of claims 95-100, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain directly abut each other.

102. The single-chain chimeric polypeptide of any one of claims 95-100, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 700 amino acids.

103. The single-chain chimeric polypeptide of claim 102, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 500 amino acids.

104. The single-chain chimeric polypeptide of claim 103, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 250 amino acids.

105. The single-chain chimeric polypeptide of claim 104, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 100 amino acids.

106. The single-chain chimeric polypeptide of claim 105, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 50 amino acids.

107. The single-chain chimeric polypeptide of claim 106, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 25 amino acids.

108. The single-chain chimeric polypeptide of any one of claims 95-100, wherein, when going in the N-terminal to C-terminal direction, the single-chain chimeric polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

109. The single-chain chimeric polypeptide of any one of claims 95-100, wherein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

110. The single-chain chimeric polypeptide of any one of claims 95-100, wherein, when going in the N-terminal to the C-terminal direction, the single-chain chimeric polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

111. The single-chain chimeric polypeptide of any one of claims 95-100, wherein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

112. A nucleic acid comprising a nucleotide sequence encoding the single-chain chimeric polypeptide of any one of claims 95-111.

113. A vector comprising the nucleic acid of claim 112.

114. A mammalian cell comprising the vector of claim 113.

115. The mammalian cell of claim 114, wherein the mammalian cell is a T cell.

116. The mammalian cell of claim 115, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

117. A method of inducing the plasma membrane localization of a single-chain chimeric polypeptide in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a single-chain chimeric polypeptide of any one of claims 95-111 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell.

118. A method of reversibly altering the plasma membrane localization of a single-chain chimeric polypeptide in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a single-chain chimeric polypeptide of any one of claims 95-111 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric polypeptide to the extracellular side of the plasma membrane of the cell; and

(b) contacting the mammalian cell with a reduced amount of the hormone or the hormone analogue that results in a decreased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the mammalian cell.

119. The method of claim 118, further comprising:

(c) contacting the mammalian cell with an increased amount of the hormone or the hormone analogue that results in an increased level of the single-chain chimeric polypeptide on the extracellular side of the plasma membrane of the cell as compared to the level of in step (b).

120. The method of any one of claims 117-119, further comprising, before step (a):

introducing a nucleic acid encoding the single-chain chimeric polypeptide into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric polypeptide.

121. The method of any one of claims 117-120, wherein the mammalian cell is a T cell.

122. The method of claim 121, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

123. The method of any one of claims 117-122, wherein the mammalian cell is a mammalian cell previously obtained from a subject.

124. The method of claim 123, wherein the subject has been identified or diagnosed as having a cancer.

125. The method of claim 123 or 124, further comprising:
obtaining the mammalian cell from the subject.

126. The method of any one of claims 117-125, wherein the contacting step(s) is performed *in vitro*.

127. The method of any one of claims 117-125, wherein the contacting step(s) is performed in a mammal.

128. A single-chain chimeric antigen receptor, wherein the single-chain chimeric antigen receptor comprises:

an extracellular antigen-binding domain;

an extracellular hormone receptor ligand binding domain;

a transmembrane domain;

an intracellular costimulatory domain; and

an intracellular immunoreceptor tyrosine-based activation motif (ITAM);

wherein:

the transmembrane domain and the extracellular hormone receptor ligand binding domain directly abut each other or are separated by 1 to 700 amino acids; and

the transmembrane domain and the extracellular hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal.

129. The single-chain chimeric antigen receptor of claim 128, wherein the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_HH domain, and a V_{NAR} domain.

130. The single-chain chimeric antigen receptor of claim 129, wherein the extracellular antigen-binding domain is a scFv.

131. The single-chain chimeric antigen receptor of any one of claims 128-130, wherein the extracellular antigen-binding domain binds specifically to a single antigen.

132. The single-chain chimeric antigen receptor of claim 131, wherein the single antigen is a tumor antigen.

133. The single-chain chimeric antigen receptor of claim 132, wherein the tumor antigen is selected from the group consisting of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16.

134. The single-chain chimeric antigen receptor of claim 133, wherein the tumor antigen is CD19.

135. The single-chain chimeric antigen receptor of claim 128, wherein the extracellular antigen-binding domain binds specifically to two different antigens.

136. The single-chain chimeric antigen receptor of claim 135, wherein at least one of the two different antigens is a tumor antigen.

137. The single-chain chimeric antigen receptor of claim 136, wherein the tumor antigen is selected from the group consisting of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16.

138. The single-chain chimeric antigen receptor of claim 137, wherein the tumor antigen is CD19.

139. The single-chain chimeric antigen receptor of any one of claims 128-138, wherein the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154.

140. The single-chain chimeric antigen receptor of any one of claims 128-139, wherein the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor.

141. The single-chain chimeric antigen receptor of claim 140, wherein the extracellular hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

142. The single-chain chimeric antigen receptor of claim 141, wherein extracellular hormone receptor ligand binding domain is a ligand binding domain from a human estrogen receptor.

143. The single-chain chimeric antigen receptor of claim 142, wherein the ligand binding domain of the human estrogen receptor has a wildtype sequence, except that it comprises one or both of a substitution at amino acid position 521 and a substitution at amino acid position 537, each numbered relative to the full-length wildtype sequence of human hormone receptor.

144. The single-chain chimeric antigen receptor of any one of claims 128-143, wherein the intracellular costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, and B7-H3.

145. The single-chain chimeric antigen receptor of claim 144, wherein the intracellular costimulatory domain is the cytoplasmic costimulatory domain from 4-1BB or CD28.

146. The single-chain chimeric antigen receptor of any one of claims 128-145, wherein the intracellular ITAM comprises a cytoplasmic signaling sequence from CD3ζ.

147. The single-chain chimeric antigen receptor of any one of claims 128-146, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain directly abut each other.

148. The single-chain chimeric antigen receptor of any one of claims 128-146, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 700 amino acids.

149. The single-chain chimeric antigen receptor of claim 148, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 500 amino acids.

150. The single-chain chimeric antigen receptor of claim 149, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 250 amino acids.

151. The single-chain chimeric antigen receptor of claim 150, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 100 amino acids.

152. The single-chain chimeric antigen receptor of claim 151, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 50 amino acids.

153. The single-chain chimeric antigen receptor of claim 152, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 25 amino acids.

154. The single-chain chimeric antigen receptor of any one of claims 128-146 wherein, when going in the N-terminal to C-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM.

155. The single-chain chimeric antigen receptor any one of claims 128-146, wherein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM.

156. The single-chain chimeric antigen receptor of any one of claims 128-146, wherein, when going in the N-terminal to the C-terminal direction, the single-chain chimeric antigen receptor comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM.

157. The single-chain chimeric antigen receptor of any one of claims 128-146, wherein, when going in the C-terminal to the N-terminal direction, the single-chain chimeric polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, the transmembrane domain, the intracellular costimulatory domain, and the ITAM.

158. A nucleic acid comprising a nucleotide sequence encoding the single chain-chimeric antigen receptor of any one of claims 128-157.

159. A vector comprising the nucleic acid of claim 158.

160. A mammalian cell comprising the vector of claim 159.

161. The mammalian cell of claim 160, wherein the mammalian cell is a T cell.

162. The mammalian cell of claim 161, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

163. A method of inducing the plasma membrane localization of a single-chain chimeric antigen receptor in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a single-chain chimeric antigen receptor of any one of claims 128-157 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

164. A method of altering the plasma membrane localization of a single-chain chimeric antigen receptor in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a single-chain chimeric antigen receptor of any one of claims 128-157 with an amount of a hormone or a hormone analogue sufficient to induce localization of the single-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and

(b) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in a reduced level of the single-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell.

165. The method of claim 164, further comprising:

(c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increased level of single-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell as compared to the level in (b).

166. The method of any one of claims 163-165, further comprising before step (a):

introducing a nucleic acid encoding the single-chain chimeric antigen receptor into a mammalian cell to generate the mammalian cell expressing the single-chain chimeric antigen receptor.

167. The method of claim 166, wherein the mammalian cell is a T cell.

168. The method of claim 167, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell.

169. The method of any one of claims 163-168, wherein the mammalian cell is a mammalian cell previously obtained from a subject.

170. The method of claim 169, wherein the subject has been identified or diagnosed as having a cancer.

171. The method of claim 169 or 170, further comprising:
obtaining the mammalian cell from the subject.

172. The method of any one of claims 163-171, wherein the contacting step(s) is performed in vitro.

173. The method of any one of claims 163-171, wherein the contacting step(s) is performed in a mammal.

174. The method of claim 173, wherein the mammal has a cancer.

175. The method of claim 174, wherein the contacting step results in the treatment of the cancer in the mammal.

176. A multi-chain chimeric antigen receptor, wherein the multi-chain chimeric antigen receptor comprises at least one first polypeptide comprising:
an extracellular antigen-binding domain;
an extracellular hormone receptor ligand binding domain; and
a transmembrane domain;
wherein:

the transmembrane domain and the extracellular hormone receptor ligand binding domain directly abut each other or are separated by 1 to 700 amino acids; and

the transmembrane domain and the extracellular hormone receptor ligand binding domain are not both present in a single endogenous single-chain polypeptide in a mammal.

177. The multi-chain chimeric antigen receptor of claim 176, wherein the extracellular antigen-binding domain is selected from the group consisting of: a scFv, a (scFv)₂, a V_{HH} domain, and a V_{NAR} domain.

178. The multi-chain chimeric antigen receptor of claim 177, wherein the extracellular antigen-binding domain is a scFv.

179. The multi-chain chimeric antigen receptor of any one of claims 176-178, wherein the extracellular antigen-binding domain binds specifically to a single antigen.

180. The multi-chain chimeric antigen receptor of claim 179, wherein the single antigen is a tumor antigen.

181. The multi-chain chimeric antigen receptor of claim 180, wherein the tumor antigen is selected from the group consisting of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16.

182. The multi-chain chimeric antigen receptor of claim 181, wherein the tumor antigen is CD19.

183. The multi-chain chimeric antigen receptor of claim 179, wherein the extracellular antigen-binding domain binds specifically to two different antigens.

184. The multi-chain chimeric antigen receptor of claim 183, wherein at least one of the two different antigens is a tumor antigen.

185. The multi-chain chimeric antigen receptor of claim 184, wherein the tumor antigen is selected from the group consisting of: CD19, WT-1, CD22, L1-CAM, ROR-1, CD30, CD125, AFP, CEA, ETA, MAGE, and MUC16.

186. The multi-chain chimeric antigen receptor of claim 185, wherein the tumor antigen is CD19.

187. The multi-chain chimeric antigen receptor of any one of claims 176-186, wherein the transmembrane domain is a transmembrane domain from: α chain of a T cell receptor, β chain of the T cell receptor, ζ chain of the T cell receptor, CD28, CD3 ϵ , CD3 δ , CD3 γ , CD33, CD37, CD64, CD80, CD45, CD4, CD5, CD8 α , CD9, CD16, CD22, CD86, CD134, CD137, or CD154.

188. The multi-chain chimeric antigen receptor of any one of claims 176-187, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor, a progesterone receptor, or an androgen receptor.

189. The multi-chain chimeric antigen receptor of claim 188, wherein the hormone receptor ligand binding domain is a ligand binding domain from an estrogen receptor.

190. The multi-chain chimeric antigen receptor of claim 189, wherein extracellular hormone receptor ligand binding domain is a ligand binding domain from a human estrogen receptor.

191. The multi-chain chimeric antigen receptor of claim 190, wherein the ligand binding domain of the human estrogen receptor has a wildtype sequence, except that it comprises one or both of a substitution at amino acid position 521 and a substitution at amino acid position 537, each numbered relative to the full-length wildtype sequence of human hormone receptor.

192. The multi-chain chimeric antigen receptor of any one of claims 176-191, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain directly abut each other.

193. The multi-chain chimeric antigen receptor of any one of claims 176-191, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 700 amino acids.

194. The multi-chain chimeric antigen receptor of claim 193, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 500 amino acids.

195. The multi-chain chimeric antigen receptor of claim 194, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 250 amino acids.

196. The multi-chain chimeric antigen receptor of claim 195, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 100 amino acids.

197. The multi-chain chimeric antigen receptor of claim 196, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 50 amino acids.

198. The multi-chain chimeric antigen receptor of claim 197, wherein the extracellular hormone receptor ligand binding domain and the transmembrane domain are separated by 1 to 25 amino acids.

199. The multi-chain chimeric antigen receptor of any one of claims 176-198, wherein the at least one polypeptide further comprises an intracellular costimulatory domain.

200. The multi-chain chimeric antigen receptor of claim 199, wherein the intracellular costimulatory domain is a cytoplasmic costimulatory domain from CD27, CD28, 4-1BB, OX40, CD30, CD40L, CD40, PD-1, PD-L1, ICOS, LFA-1, CD2, CD7, CD160, LIGHT, BTLA, TIM3, CD244, CD80, LAG3, NKG2C, and B7-H3.

201. The multi-chain chimeric antigen receptor of claim 200, wherein the intracellular costimulatory domain is the cytoplasmic costimulatory domain from 4-1BB or CD28.

202. The multi-chain chimeric antigen receptor of one of claims 176-191, wherein, when going in the N-terminal to C-terminal direction, the at least one first polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

203. The multi-chain chimeric antigen receptor of one of claims 176-191, wherein, when going in the C-terminal to N-terminal direction, the at least one first polypeptide comprises the extracellular antigen-binding domain, the extracellular hormone receptor ligand binding domain, and the transmembrane domain.

204. The multi-chain chimeric antigen receptor of one of claims 176-191 wherein, when going in the N-terminal to C-terminal direction, the at least one first polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

205. The multi-chain chimeric antigen receptor of one of claims 176-191, wherein, when going in the C-terminal to N-terminal direction, the at least one first polypeptide comprises the extracellular hormone receptor ligand binding domain, the extracellular antigen-binding domain, and the transmembrane domain.

206. A nucleic acid that encodes the multi-chain chimeric receptor of any one of claims 176-205.

207. A set of nucleic acids that together encode the multi-chain chimeric receptor of any one of claims 176-205.

208. A mammalian cell comprising the nucleic acid of claim 206.

209. A mammalian cell comprising the set of nucleic acids of claim 207.

210. The mammalian cell of claim 208 or 209, wherein the mammalian cell is a T cell.

211. The mammalian cell of claim 210, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and natural killer T cell.

212. A method of inducing the plasma membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a multi-chain chimeric antigen receptor of any one of claims 176-205 with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell.

213. A method of altering the plasma membrane localization of a multi-chain chimeric antigen receptor in a mammalian cell, the method comprising:

(a) contacting a mammalian cell expressing a multi-chain chimeric antigen receptor of any one of claims 176-205 with an amount of a hormone or a hormone analogue sufficient to induce localization of the multi-chain chimeric antigen-binding receptor to the extracellular side of the plasma membrane of the cell; and

(b) contacting the mammalian cell with an amount of the hormone or the hormone analogue with an amount of the hormone or the hormone analogue that results in a decreased level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell.

214. The method of claim 213, further comprising:

(c) contacting the mammalian cell with an amount of the hormone or the hormone analogue that results in an increase in the level of the multi-chain chimeric antigen-binding receptor on the extracellular side of the plasma membrane of the cell.

215. The method of any one of claims 212-214, further comprising before step (a):

introducing a nucleic acid encoding the multi-chain chimeric antigen receptor or a set of nucleic acids that together encode the multi-chain chimeric receptor, into a mammalian cell to generate the mammalian cell expressing the multi-chain chimeric antigen receptor.

216. The method of claim 215, wherein the mammalian cell is a T cell.

217. The method of claim 216, wherein the T cell is selected from the group consisting of: a CD8⁺ T cell, a CD4⁺ T cell, a memory T cell, a Treg cell, and a natural killer T cell.

218. The method of any one of claims 212-217, wherein the mammalian cell is a mammalian cell previously obtained from a subject.

219. The method of claim 218, wherein the subject has been identified or diagnosed as having a cancer.

220. The method of claim 218 or 219, further comprising:
obtaining the mammalian cell from the subject.

221. The method of any one of claims 212-220, wherein the contacting step is performed in vitro.

222. The method of any one of claims 212-220, wherein the contacting step is performed in a mammal.

223. The method of claim 222, wherein the mammal has a cancer.

224. The method of claim 223, wherein the contacting step results in the treatment of the cancer in the mammal.

225. A method of treating a cancer in a subject, comprising:

(a) administering to the subject a mammalian cell expressing a single-chain chimeric antigen receptor of any one of claims 128-157 or a multi-chain chimeric antigen receptor of any one of claims 176-205, wherein the antigen binding domain binds specifically to an antigen expressed by the cancer in the subject;

(b) administering to the subject an amount of a hormone or hormone sufficient to induce localization of the single-chain or multi-chain chimeric antigen receptor to the extracellular side of the plasma membrane of the cell;

(c) determining the presence or severity of one or more symptoms associated with toxicity or the level of one or more cytokines associated with a cytokine storm, or both, in the subject following (b);

(d) comparing the determined presence or severity of one or more symptoms associated with toxicity or the determined level of one or more cytokines associated with the cytokine storm, or both, to a control(s); and

(e) administering to the subject an amount of the hormone or hormone analogue sufficient to reduce the level of the single-chain or multi-chain chimeric antigen receptor on the extracellular side of the plasma membrane of the cell, such that the presence or severity of one or more symptoms associated with toxicity or the level of one or more cytokines associated with a cytokine storm, or both, is reduced in the subject after (e).

226. The method of claim 225, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 25% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b).

227. The method of claim 226, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 50% as compared to the amount of the hormone or hormone analogue administered to the subject in step (b).

228. The method of claim 227, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by at least 75% as compared to the level of the hormone or hormone analogue administered to the subject in step (b).

229. The method of claim 228, wherein the amount of the hormone or hormone analogue administered to the subject in step (e) is reduced by 100% as compared to the level of the hormone or hormone analogue administered to the subject in step (b).

230. The method of claim 225, wherein the one or more symptoms associated with toxicity are selected from the group consisting of: high fever, swelling, chills, hypotension, tachycardia, asthenia, headache, rash, scratchy throat, dyspnea, redness, extreme fatigue, nausea, and cerebral edema.

231. The method of claim 225, wherein the one or more cytokines associated with a cytokine storm are selected from the group consisting of: include tumor necrosis factor-alpha, IFN γ , IL-10, IL-1 β , IL-2, IL-6, IL-8, and IL-10, granulocyte macrophage-colony-stimulating factor (GM-CSF), and IL-5.