

CA2-IL15 FUSION PROTEINS FOR TUNABLE REGULATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of priority to U.S. Provisional Application No. 62/898,520, filed September 10, 2019. The entire contents of the aforementioned application are incorporated herein by reference in their entireties.

REFERENCE TO THE SEQUENCE LISTING

[0002] The instant application contains a Sequence Listing which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on September 10, 2020, is named 268052_473951_SL.txt and is 178,693 bytes in size.

FIELD

[0003] The present disclosure relates to drug responsive domains (DRDs) derived from human carbonic anhydrase 2 (CA2) which can modulate protein stability for at least one payload comprising human interleukin 15 (IL15), compositions and methods of use thereof. Provided in the present disclosure are polypeptides of CA2 biocircuit systems, CA2 effector modules, stimulus response elements (SREs), polynucleotides encoding the same, vectors and cells containing the polypeptides and/or polynucleotides for use in augmenting responses from immune cells.

BACKGROUND

[0004] Utilization of the DRD technology described herein with methods of regulating cytokine function and/or expression represent a significant improvement on existing immunotherapy strategies, and can expand the universe of protein therapeutics that can be safely and effectively incorporated into gene transfer and adoptive T cell transfer (ACT) therapies, including applications that have previously been considered unsuitable for therapeutic use. Improved Natural Killer cells (NK cells), Tumor Infiltrating Lymphocytes (TIL) and T cell-based immunotherapies are needed to enhance and improve the functionality of the treatments, for example, by improving the persistence and/or survival of engineered immune cells, for use in various immunotherapies upon administration to subjects. Provided are CA2 DRDs linked to human IL15, modified cells comprising such DRDs, compositions, and methods that meet such needs.

SUMMARY

[0005] The present disclosure provides novel protein domains derived from human carbonic anhydrase 2 (CA2) displaying small molecule-dependent stability. Such protein domains are called drug responsive domains (DRDs). In the absence of its binding (i.e., stabilizing) ligand, the DRD is destabilizing and causes degradation of a payload operably linked to the DRD (e.g., a protein of interest (POI)), while in the presence of its binding ligand, the DRD and its operably linked payload are stabilized. The stability of the DRD and its operably linked payload is dependent on the dose of the binding ligand.

[0006] In some embodiments, the present disclosure provides a stimulus response element (SRE), which may comprise a drug responsive domain (DRD) derived from human carbonic anhydrase 2 (CA2, having the amino acid sequence of SEQ ID NO: 1) in whole or in part. In one embodiment, the DRD may be derived from the full-length CA2 polypeptide (SEQ ID NO: 1). In some embodiments, the DRD may be derived from a portion or region of the human carbonic anhydrase. The portion or region of CA2 may be selected from amino acids 2-260 of CA2 (SEQ ID NO: 2).

[0007] In some embodiments, the SRE may include a DRD comprising one, two, three, four or more mutations in CA2 relative to SEQ ID NO:1 or SEQ ID NO: 2. In some embodiments, the SRE may include a DRD comprising one, two, three, four or more amino acid substitutions in CA2 relative to SEQ ID NO:1 or SEQ ID NO: 2.

[0008] In some embodiments, the SRE may include a DRD comprising one, two, three, four or more mutations in a portion of CA2. In some embodiments, the SRE may include a DRD comprising one, two, three, four or more mutations in CA2 or portion thereof, and may further comprise additional amino acids. In some embodiments, the SRE may include a DRD comprising one, two, three, four or more amino acid substitutions in a portion of CA2. In some embodiments, the SRE may include a DRD comprising one, two, three, four or more amino acid substitutions in CA2 or portion thereof, and may further comprise additional amino acids.

[0009] Also provided herein are isolated polypeptide variants comprising at least one mutation relative to SEQ ID NO: 1. Non-limiting examples of CA2 mutations relative to SEQ ID NO: 1 include M1del and L156H. In another aspect, a DRD is a polypeptide comprising or consisting of the amino acid sequence of SEQ ID NO:4, wherein the CA2 mutation comprises Mdel1 and L156H relative to SEQ ID NO: 1. In another aspect, the DRD is a polypeptide

containing the amino acid deletion M1del and amino acid substitution L156H relative to SEQ ID NO: 1 and may further comprise additional amino acids. In another aspect, the DRD is a polypeptide consisting of the amino acid sequence of SEQ ID NO:4.

[0010] Also provided herein are biocircuit systems that include at least one effector module. The effector module of the biocircuit may include a stimulus response element (SRE), and the SRE may include a DRD derived from a human carbonic anhydrase 2 (CA2; SEQ ID NO: 1) or a mutant thereof comprising one, two, three, four or more mutations of CA2 relative to the amino acid sequence of SEQ ID NO: 1 or SEQ ID NO: 2. In some embodiments, the effector module of the biocircuit includes an SRE including a DRD comprising one, two, three, four or more amino acid substitutions in CA2 relative to SEQ ID NO:1 or SEQ ID NO: 2. The biocircuits may also include at least one payload, which may be attached, appended or associated with the SRE. The payload may include but is not limited to (i) a human IL15 comprising the amino acid sequence of SEQ ID NO: 8.

[0011] The SRE of the biocircuit system may include one, two, three or more mutations of CA2 (SEQ ID NO: 1 or SEQ ID NO: 2) such as, but not limited to, Mdel1 and L156H. The SRE of the biocircuit system may include one, two, three or more amino acid substitutions in CA2 (SEQ ID NO: 1 or SEQ ID NO: 2), such as, but not limited to L156H.

[0012] In some embodiments, the SRE in the CA2 biocircuit system may be CA2 having the mutations M1del and L156H, wherein the numbering is relative to the amino acid sequence of SEQ ID NO:1 (SEQ ID NO: 4). In some embodiments, the SRE is a polypeptide comprising or consisting of the amino acid sequence of SEQ ID NO:4. In some embodiments, the SRE is a polypeptide consisting of the amino acid sequence of SEQ ID NO:4.

[0013] The biocircuit system described herein may include SREs that are responsive to one or more stimuli.

[0014] In some embodiments, the stimulus may be a small molecule, wherein the small molecule is acetazolamide (ACZ).

[0015] In another aspect, the present disclosure provides an effector module comprising at least one payload. In some embodiments, the effector module comprises an SRE comprising a CA2 DRD operably linked to an IL15 payload. In some embodiments, the IL15 payload comprises the amino acid sequence of SEQ ID NO: 8. In some embodiments, the IL15 payload may be encoded in part by a nucleic acid sequence comprising the nucleotide sequence of SEQ

ID NO: 9. In some embodiments, the IL15 payload is a membrane-bound form of IL15. In some embodiments, the IL15 payload is a membrane-bound form of IL15 comprising a functional IL15 component or domain, a transmembrane domain and an intracellular tail. In some embodiments, the IL15 payload is a membrane-bound form of IL15 comprising a functional IL15 component or domain, a transmembrane domain, an intracellular tail and a leader sequence. In some embodiments, the present disclosure provides an SRE comprising a CA2 DRD operably linked to a membrane-bound IL15 polypeptide. In some embodiments, the present disclosure provides an SRE comprising a CA2 DRD operably linked to a membrane-bound IL15 polypeptide, wherein the membrane-bound IL15 polypeptide comprises, from N-terminal to C-terminal, a leader sequence, an IL15 polypeptide comprising the amino acid sequence of SEQ ID NO: 8, a peptide linker, a transmembrane domain, and an intracellular tail.

[0016] In another aspect, the present disclosure provides a method of making a modified or genetically engineered cell comprising introducing a polynucleotide encoding an effector module into the cell. In some embodiments, the modified or engineered cell is an immune cell. In some embodiments, the immune cell is a T cell, a natural killer (NK) cell or a tumor infiltrating lymphocyte (TIL). In some embodiments, the polynucleotide encodes a CA2 DRD operably linked to an IL15 payload. In some embodiments, the polynucleotide encodes a CA2 DRD operably linked to a membrane-bound IL15 payload. In some embodiments, the polynucleotide is introduced into the cell by a non-viral vector delivery method. In some embodiments, the polynucleotide is introduced into the cell by viral transduction. In some embodiments, the polynucleotide is introduced into the cell by lentiviral transduction. In some embodiments, the polynucleotide is introduced into the cell by lentiviral transduction into a T cell, an NK cell or a TIL. In some embodiments, the present disclosure provides a method of making a modified or genetically engineered T cell, NK cell or TIL comprising introducing a polynucleotide encoding a CA2 DRD operably linked to a membrane-bound IL15 payload into the T cell, NK cell or TIL by a viral vector, such as a lentiviral vector.

[0017] In another aspect, the present disclosure provides a method of treatment, comprising (a) administering a modified cell comprising a recombinant construct comprising an SRE linked to a payload of the present disclosure or a composition comprising a plurality of such modified cells to a subject having a disease or condition, and (b) administering to the subject a therapeutically effective amount of a stimulus to which the SRE responds. In some embodiments

of this aspect, the disease or condition is a cancer, a neoplasm or a tumor. In some embodiments, the SRE is a CA2 DRD. In some embodiments, the payload is IL15 or membrane-bound IL15. In some embodiments, the modified cells comprise a CA2 SRE operably linked to an IL15 payload. In some embodiments, the modified cells comprise a CA2 SRE operably linked to a membrane-bound IL15 payload. In some embodiments, the stimulus is acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide. In some embodiments, the modified cells comprise a CA2 SRE operably linked to a membrane-bound IL15 payload and the stimulus is acetazolamide. In some related aspects, the modified cells are engineered or modified immune cells, for example, CA2-IL15 biocircuits and systems may be used with immune cells including T cells such as CD8⁺ T cells and CD4⁺ T cells, natural killer (NK) cells, NK T cells, cytotoxic T lymphocytes (CTLs), tumor infiltrating lymphocytes (TIL), lymphokine-activated killer (LAK) cells, memory T cells, regulatory T cells (Tregs), helper T cells, cytokine-induced killer (CIK) cells, and any combination thereof. In other embodiments, immune stimulatory cells for ACT may be generated from embryonic stem cell (ESC) and induced pluripotent stem cell (iPSC). In some embodiments, autologous or allogeneic immune cells are used for ACT. In some embodiments, the immune cells are T cells, TIL or NK cells. In some embodiments, the immune cells are NK cells derived from iPSCs, cord blood, or peripheral blood mononuclear cells, wherein the modified immune cells exhibit increased or longer expansion and/or persistence in the subject than in a subject administered the same or about the same dosage amount of a reference cell composition lacking the SRE linked to a payload.

[0018] In another aspect, the present disclosure provides a method of treating a malignant tumor in a subject, comprising (a) administering a modified T cell, modified NK cell or a modified TIL, wherein the T cell, NK cell or TIL comprises a recombinant construct comprising an SRE linked to a payload of the present disclosure or a composition comprising a plurality of such modified cells to the subject, and (b) administering to the subject a therapeutically effective amount of a stimulus to which the SRE responds. In some embodiments, the tumor expresses a tumor-associated antigen. In some embodiments, the modified T cell or modified NK cell further comprises a chimeric antigen receptor (CAR) or T cell receptor (TCR) that comprises an antigen-binding domain specific to the tumor-associated antigen. In some embodiments, the modified T cell or modified NK cell comprises a CAR comprising an antigen-binding domain

specific to the tumor-associated antigen. In some embodiments, the modified T cell, modified NK cell or modified TIL comprise an SRE that is a CA2 DRD. In some embodiments, the modified T cell, modified NK cell or modified TIL comprise a payload that is IL15 or membrane-bound IL15. In some embodiments, the modified the modified T cell, modified NK cell or modified TIL comprise a CA2 SRE operably linked to an IL15 payload. In some embodiments, the modified the modified T cell, modified NK cell or modified TIL comprise a CA2 SRE operably linked to a membrane-bound IL15 payload. In some embodiments, the stimulus is acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide. In some embodiments, the modified cells comprise a CA2 SRE operably linked to a membrane-bound IL15 payload and the stimulus is acetazolamide.

[0019] In another aspect, the present disclosure provides polynucleotides and vectors encoding the biocircuit system, and a pharmaceutical composition that includes the biocircuit system and a pharmaceutically acceptable excipient.

[0020] In another aspect, the present disclosure provides recombinant proteins encoded by the polynucleotides of the disclosure. In some embodiments, the recombinant proteins comprise an effector module comprising a CA2 DRD operably linked to an IL15 payload.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The foregoing and other objects, features, and advantages will be apparent from the following description of particular embodiments of the present disclosure, as illustrated in the accompanying drawings. The drawings are not necessarily to scale; emphasis instead being placed upon illustrating the principles of various embodiments of the present disclosure.

[0022] FIG. 1 depicts a representative procedure for in vitro characterization and/or validation of ACZ-regulated membrane-bound IL15 (mbIL15) expression in T cells.

[0023] FIG. 2 depicts a representative procedure for in vivo characterization and/or validation of ACZ-regulated mbIL15 expression in T cells.

[0024] FIG. 3A-FIG. 3C shows in vitro expansion of T cells expressing constitutive IL15-292 and IL15-294 (FIG. 3A), and regulated IL15-293 (FIG. 3B) and IL15-295 (FIG. 3C) constructs in the presence of different concentrations of ACZ. Empty vector (EV) transduced cells cultured in the absence or presence of exogenous IL15 (2 ng/mL) were used as controls.

[0025] FIG. 4A-FIG. 4B shows acetazolamide dose response and IL15 expression on T cells. Cells were treated with different concentrations of ACZ (ligand) starting at 100 μ M for 24 hrs. Graphs show %IL15+ T Cells (FIG. 4A) and mean fluorescence intensity (MFI) of IL15 (FIG. 4B).

[0026] FIG. 5A-FIG. 5C shows in vivo analyses of T cells expressing constitutive and regulated IL15 constructs and their effects on NK cells. FIG. 5A shows in vivo expansion of T cells expressing constitutive IL15 (IL15-292 and IL15-294) and regulated IL15 (IL15-293 and IL15-295) constructs. FIG. 5B shows in vivo expansion of bystander NK cells under the same conditions. T cell and NK cell frequencies in blood was determined by flow cytometry. FIG. 5C shows expression of IL15 on T cells on day 25, analyzed by flow cytometry. Empty vector (EV) transduced cells were used as controls.

[0027] FIG. 6 depicts schematic representations of tandem CD19 CAR and mbIL15 constructs encoding a constitutively expressed mbIL15 (CD19-IL15-057) or a regulated mbIL15 (CD19-IL15-058). Each construct comprises polynucleotide sequences encoding a regulated or constitutive mbIL15 that comprises an IgKv leader sequence (IgKv LS), an IL15 polypeptide component, a GS linker, a B7-1 hinge, a transmembrane domain (TM), and a tail. The constitutive construct encodes the mbIL15 operably linked to a CA2 wildtype sequence (CA2 (WT)). The regulated construct encodes the mbIL15 operably linked to a CA2(L156H) DRD. Each construct also comprises a P2A sequence and polynucleotide sequences encoding an anti-CD19 CAR that comprises a CD8 α leader sequence (CD8 α LS), a CD19 scFv, a CD8 α transmembrane domain and hinge, a costimulatory domain derived from 4-1BB and a CD3 ζ signaling domain.

[0028] FIG 7A-FIG. 7E show T cells transduced with tandem CD19 CAR and mbIL15 constructs evaluated for regulated mbIL15 expression and anti-tumor effects *in vivo*. FIG. 7A shows flow cytometry analyses for expression of mbIL15 and CAR in peripheral blood T cells. FIG. 7B shows tumor growth curves of individual mice implanted with CD19+ Nalm6-Luc tumors and infused with T cells that were transduced with lentiviral vectors expressing CD19 CAR with or without constitutive or regulated mbIL15. FIG. 7C shows tumor growth curves with group averages and standard error. FIG. 7D shows frequency of T cells in blood collected from animals on days 7, 14 and 21 post T cell infusion. FIG. 7E shows frequency of T cells in bone marrow harvested from animals on day 14 post T cell infusion.

[0029] FIG. 8 shows analyses of TILs from patient tumor samples after a culturing process and after transduction with mbIL15-expressing constructs. FIG. 8A shows frequency of CD45⁺ cells (top) and CD3⁺ T cells within CD45⁺ cells (bottom) in fresh tumor digest and after 3 weeks of pre-REP TIL culture. FIG. 8B shows mbIL15 expression determined by flow cytometry for TILs transduced with constitutive or regulated mbIL15 constructs. TILs transduced with the regulated mbIL15 construct were treated with 10 μ M ACZ or DMSO for 24 hrs. Untransduced cells were evaluated as a negative control.

[0030] FIG. 9 shows expression of constitutive and regulated mbIL15 in NK cells. Each symbol on the graph (squares and triangles) represents one of three donors. Error bars represent standard deviation for the three donors for each indicated transduction/treatment group.

DETAILED DESCRIPTION

[0031] The details of one or more embodiments of the present disclosure are set forth in the accompanying description below. Although any materials and methods similar or equivalent to those described herein can be used in the practice or testing of the present disclosure, the preferred materials and methods are now described. Other features, objects and advantages of the present disclosure will be apparent from the description. In the description, the singular forms also include the plural unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the present disclosure belongs. In the case of conflict, the present description will control.

[0032] Cancer immunotherapy aims to induce or restore the reactivity of the immune system towards cancer. Significant advances in immunotherapy research have led to the development of various strategies which may broadly be classified into active immunotherapy and passive immunotherapy. In general, these strategies may be utilized to directly kill cancer cells or to counter the immunosuppressive tumor microenvironment. Active immunotherapy aims at induction of an endogenous, long-lasting tumor-antigen specific immune response. The response can further be enhanced by non-specific stimulation of immune response modifiers such as cytokines. In contrast, passive immunotherapy includes approaches where immune effector molecules such as tumor-antigen specific cytotoxic T cells or antibodies are administered to the host. This approach is short lived and requires multiple applications.

[0033] Efficient T cell activation requires three signals, T cell receptor (TCR) signaling (Signal 1), activation by co-stimulatory molecules (Signal 2), and immune-stimulatory cytokines (Signal 3). So far, the majority of the CAR-based immunotherapies designed and discussed possess Signal 1 and Signal 2; however, Signal 3, generally provided by homeostatic cytokines, is typically absent in conventional CAR T cells and is also less abundant in the tumor microenvironment.

[0034] Therefore, there exists a need to engineer T cells (including for example, CAR T cells) that are capable of supplying additional cytokine signaling to satisfy the need for Signal 3 for optimal T cell activation. The major cytokines involved in T cell activation, which encompass Signal 3 cytokines, belong to γ c class like IL-2, IL-7, IL-15, IL-21, and IL-9. These cytokines control T cell survival and proliferation, which ultimately has significant roles in T cell persistence and efficacy. These cytokines are currently employed in ex vivo expansion of CAR T cells prior to therapy in combinations or alone.

[0035] Supporting T cell longevity via continuous exposure to IL15 however may have risk, because chronic high exposure to IL-15 may cause aberrant T cell proliferation or toxicities. In humans, dysregulated IL15 production, elevated serum levels, or abnormal IL15 signaling has been associated with autoimmune disease and may be involved in the pathogenesis of large granular lymphocytic leukemia and cutaneous T cell lymphoma.

[0036] Natural killer (NK) cells are members of the innate lymphoid cell family and characterized in humans by expression of the phenotypic marker CD56 (neural cell adhesion molecule) in the absence of CD3 (T cell co-receptor). NK cells are potent effector cells of the innate immune system which mediate cytotoxic attack without the requirement of prior antigen priming, forming the first line of defense against diseases including cancer malignancies and viral infection.

[0037] Several pre-clinical and clinical trials have demonstrated that adoptive transfer of NK cells is a promising treatment approach against cancers such as acute myeloid leukemia (Ruggeri et al., *Science*; 2002, 295: 2097–2100; and Geller et al., *Immunotherapy*, 2011, 3: 1445-1459). Adoptive transfer of NK cells expressing CAR such as DAP12-Based Activating CAR revealed improved eradication of tumor cells (Topfer et al., *J Immunol.* 2015; 194:3201–3212). NK cell engineered to express a CS-1 specific CAR also displayed enhanced cytotoxicity and interferon- γ (IFN- γ) production in multiple myeloma (Chu et al., *Leukemia*, 2014, 28(4): 917-927).

[0038] NK cell activation is characterized by an array of receptors with activating and inhibitory functions. The important activation receptors on NK cells include CD94/NKG2C and NKG2D (the C-type lectin-like receptors), and the natural cytotoxicity receptors (NCR) NKp30, NKp44 and NKp46, which recognize ligands on tumor cells or virally infected cells. NK cell inhibition is essentially mediated by interactions of the polymorphic inhibitory killer cell immunoglobulin-like receptors (KIRs) with their cognate human-leukocyte-antigen (HLA) ligands via the alpha-1 helix of the HLA molecule. The balance between signals that are generated from activating receptors and inhibitory receptors mainly determines the immediate cytotoxic activation.

[0039] NK cells may be isolated from peripheral blood mononuclear cells (PBMCs) and cord blood, or derived from human embryonic stem (ES) cells and induced pluripotent stem cells (iPSCs). NK cells may be further expanded for adoptive immunotherapy. Strategies and protocols useful for the expansion of NK cells may include interleukin 2 (IL2) stimulation and the use of autologous feeder cells, or the use of genetically modified allogeneic feeder cells. In some aspects, NK cells can be selectively expanded with a combination of stimulating ligands including IL15, IL21, IL2, 41BBL, IL12, IL18, MICA, 2B4, LFA-1, and BCM1/SLAMF2 (e.g., US patent publication NO. US20150190471).

[0040] NK cell-based immunotherapy is rapidly evolving due to the ability of NK cells to directly lyse tumor targets, the emergence of antibodies and molecules that mediate NK cell-driven antibody-dependent cell-mediated cytotoxicity (ADCC), and the ability of NK cells to induce inflammatory responses. NK cells are being exploited in clinical trials using autologous and allogeneic NK cell infusion strategies alone or with hematopoietic stem cell transplantation. In addition, other modalities of NK cell therapy, such as use of NK cell line products and NK cells transduced with chimeric antigen receptors (CARs) are on the horizon. Others have shown that in vivo persistence and expansion of NK cells correlate with antitumor efficacy in patients with advanced AML. Among the strategies being evaluated preclinically to address this issue, utilization of cytokines to induce NK cell persistence and expansion seems to dominate current clinical trials. IL15 has a known physiologic role on NK cell development and homeostasis without stimulating regulatory T cells but experimental findings indicate that continuous treatment with IL-15 results in a functional NK cell changes consistent with exhaustion. For example, continuously IL15-treated NK cells have been experimentally shown in at least one

study to initially display better proliferation and expansion during a 9-day experimental continuous treatment with IL15 but were more susceptible to cell death. In addition, cell cycle gene expression data show that NK cells continuously dosed with IL15 are enriched for expression of cell cycle checkpoint and arrest genes, indicating that at day 9 of culture these cells transition to an arrested state due to cellular stress.

[0041] Tumor infiltrating lymphocytes (TIL) consist of all lymphocytic cell populations that have invaded the tumor tissue. The cellular constituents of tumors include TIL, NK cells, macrophages, dendritic cells, and myeloid lineage cells, suggesting a productive immune response. However, most of the immune cells residing in the tumor microenvironment are functionally impaired in some manner because many of the immune cell populations are converted to phenotypes that further impair immune system responses. Tumors are able to recruit Treg lymphocytes, TAMs, myeloid-derived suppressor cells (MDSCs), and cancer-associated fibroblasts (CAFs) to aid them in escape from immune recognition. Tregs and MDSCs have both been shown to immunosuppressing functions, limiting response by TIL and other cells. Depletion of CD4⁺ Tregs improves clinical responses in patients during immune reconstitution treated with autologous TIL during TIL therapy. In mouse models, even small numbers of Tregs can abrogate effective CD8⁺ T cell-mediated adoptive cell therapy.

[0042] TIL have been described in a number of solid tumors, including breast cancer and melanoma, and are emerging as an important biomarker in predicting the efficacy and outcome of treatment. In breast cancer, TIL are comprised primarily of cytotoxic (CD8⁺) and helper (CD4⁺) T cells, and a smaller proportion of B- and NK cells. Breast cancer patients who had advanced tumors with higher CD8⁺ T cell infiltrates or a high density of TIL have more favorable outcomes. In melanoma, TIL therapy is improved by including lymphodepleting preparative regimens prior to cell infusion. Investigations in humans and murine models of melanoma suggest that lymphodepletion depletes negative regulatory cells including regulatory T cells (Tregs) and peripheral myeloid-derived suppressor cells, which can suppress T cell proliferation in melanoma patients, both of which aid in the proliferation of adoptively transferred T lymphocytes.

[0043] Adoptive cell therapy (ACT) using TIL is a personalized cancer treatment based on the infusion of autologous CD4⁺ and CD8⁺ T lymphocytes expanded from tumors in the presence of interleukin-2 (IL-2) alone or in combination with IL-7, IL-15, and/or IL-21. TIL are

polyclonal populations enriched for lymphocytes recognizing tumor-specific antigens, including shared tumor-associated antigens as well as individual tumor neoantigens. Studies at the National Cancer Institute (NCI) initiated in 1980 demonstrated tumor regression in selected patients receiving adoptive transfer of lymphokine-activated killer cells in combination with recombinant IL-2. Subsequent methods for large-scale expansion of human TIL, simplified and shortened TIL production processes, and improved patient preconditioning and treatment protocols have resulted in enhanced response rates for patients. However, complete response rates for TIL therapy are still quite low and need improvement.

[0044] The present disclosure provides systems, compositions, immunotherapeutic agents and methods that avoid the issues of continuously dosed or expressed IL15 by providing tunable regulation of IL15 gene expression and function for cancer immunotherapy. The present invention also provides biocircuit systems, effector modules, stimulus response elements (SREs) and IL15 payloads, as well as polynucleotides encoding any of the foregoing. In one aspect, the systems, compositions, immunotherapeutic agents and other components of the invention can be controlled by a separately added stimulus, which provides a significant flexibility to regulate cancer immunotherapy.

[0045] The tunable nature of the systems and compositions of the invention has the potential to improve the potency and duration of the efficacy of immunotherapies. The ability to reversibly increase, decrease or silence the biological activity of adoptively transferred cells using compositions of the present invention allows maximizing the potential of cell therapy, which is not available using a “kill switch” that will terminate the therapy. Without being bound by any particular theory, it is believed that the long-term engraftment of T cells can be achieved through temporal, intermittent exposure of IL15 in NK cells, TIL and T cell groups used in various therapies, including cancer immunotherapies, without dysregulated proliferation or activation and no phenotypic, functional, or chromosomal anomalies.

[0046] The present invention provides methods for fine tuning of immunotherapy after administration to patients. This in turn improves the safety and efficacy of immunotherapy and increases the subject population that may benefit from immunotherapy. Effector module(s) as described and disclosed in the present disclosure are independently associated, or integral therewith, one or more stimulus response elements (SREs), which may be operably linked to an IL15, to form an effector module comprising mbIL15. The biocircuits, SRE, DRDs of the

present disclosure can be employed with immune cells and may provide a desired signaling enabling adoptively transferred NK cells and T cells, including TIL, to prolong persistence, thereby providing durable immune surveillance and therapeutic potential.

[0047] As used herein, a “biocircuit” or “biocircuit system” is defined as a circuit within or useful in biologic systems comprising a stimulus and at least one effector module responsive to a stimulus, where the response to the stimulus produces at least one signal or outcome within, between, as an indicator of, or on a biologic system. Biologic systems are generally understood to be any cell, tissue, organ, organ system or organism, whether animal, plant, fungi, bacterial, or viral. It is also understood that biocircuits may be artificial circuits which employ the stimuli or effector modules taught by the present disclosure and effect signals or outcomes in acellular environments such as with diagnostic, reporter systems, devices, assays or kits.

[0048] The biocircuits of the present disclosure include at least one effector module. As used herein, an “effector module” is a single or multi-component construct or complex comprising at least (a) one or more stimulus response elements (SREs) and (b) one or more payloads (e.g., proteins of interest (POIs)). In some embodiments, the effector module comprises one SRE and one payload.

[0049] Effector modules may be designed to include one or more payloads, one or more SREs, one or more cleavage sites, one or more signal sequences and one or more additional features including the presence or absence of one or more linkers.

[0050] In one embodiment, the effector module comprises at least one immunotherapeutic agent, for example, IL15.

[0051] Effector modules, including their SREs and payloads, may be nucleic acid-based, protein-based or a combination thereof. They may be in the form of DNA, RNA, mRNA, proteins, fusion proteins, or any combination of the foregoing. In one embodiment, the effector module is a fusion protein. In one embodiment, the effector module is encoded by nucleic acid, such as DNA.

[0052] Effector modules, including their SREs and payloads may individually, collectively or independently comprise peptides, polypeptides or proteins. At the protein level, such payload may be any natural or artificial peptide or polypeptide or fragment thereof. Natural peptides or polypeptide components of the payload may be derived from any known protein of any species.

[0053] Effector modules may be designed to operate in groups of one, two, three, four or more modules. When more than one effector module is utilized in a biocircuit, it is known as an effector module system of that biocircuit.

[0054] As used herein a “stimulus response element” (SRE) is a component of an effector module which is joined, attached, linked to or associated with one or more payloads and in some instances, is responsible for the responsive nature of the effector module to one or more stimuli. As used herein, the “responsive” nature of an SRE to a stimulus may be characterized by a covalent or non-covalent interaction, a direct or indirect association or a structural or chemical reaction to the stimulus. Further, the response of any SRE to a stimulus may be a matter of degree or kind. The response may be a partial response. The response may be a reversible response. The response may ultimately lead to a regulated signal or output. Such output signal may be of a relative nature to the stimulus, e.g., producing a modulatory effect of between 1% and 100% or a factored increase or decrease such as 2-fold, 3-fold, 4-fold, 5-fold, 10-fold or more. In some embodiments, the SRE is a polypeptide operably linked to a polypeptide payload. In some embodiments, the SRE is a polypeptide fused to a polypeptide payload.

[0055] In some embodiments, the present disclosure provides methods for modulating protein expression, function or level. In some aspects, the modulation of protein expression, function or level refers to modulation of expression, function or level by at least about 20%, such as by at least about 30%, 40%, 50%, 60%, 70%, 80%, 85%, 90%, 95% and 100%, or at least 20-30%, 20-40%, 20-50%, 20-60%, 20-70%, 20-80%, 20-90%, 20-95%, 20-100%, 30-40%, 30-50%, 30-60%, 30-70%, 30-80%, 30-90%, 30-95%, 30-100%, 40-50%, 40-60%, 40-70%, 40-80%, 40-90%, 40-95%, 40-100%, 50-60%, 50-70%, 50-80%, 50-90%, 50-95%, 50-100%, 60-70%, 60-80%, 60-90%, 60-95%, 60-100%, 70-80%, 70-90%, 70-95%, 70-100%, 80-90%, 80-95%, 80-100%, 90-95%, 90-100% or 95-100%.

[0056] Drug responsive domains (DRDs) are small protein domains that can be appended to a target protein of interest. In some embodiments, a DRD is operably linked to a target protein of interest. DRDs render the attached protein of interest unstable in the absence of a DRD-binding ligand. However, when a specific small molecule ligand binds its intended DRD as a ligand binding partner, the instability is reversed, and protein function is restored. The conditional nature of DRD stability allows a rapid and non-perturbing switch from stable protein to unstable substrate for degradation. Moreover, its dependency on the concentration of its ligand further

provides tunable control of degradation rates. The term drug responsive domain (DRD) is interchangeable with the term destabilizing domain (DD).

[0057] In one embodiment, the SRE is a drug responsive domain (DRD). In some embodiments, the CA2 drug responsive domains described herein may be used as SREs in the biocircuit systems of the present disclosure in association with any of the IL15 payloads taught herein.

[0058] Regions or portions or domains of wild type proteins (e.g., CA2) may be utilized as SREs/DRDs in whole or in part. In one embodiment, the SRE is derived from parent protein CA2 or from a mutant CA2 protein. In various embodiments, the DRD comprises one, two, three, or four or more mutations compared to the parent CA2 protein, for example, a human CA2 SEQ ID NO: 1 having the amino acid sequence:

MSHHWGYGKH NGPEHWHKDF PIAKGERQSP VDIDHTAKY DPSLKPLSVS
YDQATSLRIL NNGHAFNVEF DDSQDKAVLK GGPLDGTYRL IQFHFHWGSL
DGQGSEHTVD KKKYAAELHL VHWNTKYGDF GKAVQQPDGL AVLGLFLKVG
SAKPGLQKVV DVLDSIKTKG KSADFTNFDG RGLLPESLDY WTYPGSLTTP
PLLECVTWIV LKEPISVSSE QVLKFRKLN NGEGEPEELM VDNWRPAQPL
KNRQIKASFK or SEQ ID NO: 2 having the amino acid sequence:

SHHWGYGKH NGPEHWHKDF PIAKGERQSP VDIDHTAKY DPSLKPLSVS
YDQATSLRIL NNGHAFNVEF DDSQDKAVLK GGPLDGTYRL IQFHFHWGSL
DGQGSEHTVD KKKYAAELHL VHWNTKYGDF GKAVQQPDGL AVLGLFLKVG
SAKPGLQKVV DVLDSIKTKG KSADFTNFDG RGLLPESLDY WTYPGSLTTP
PLLECVTWIV LKEPISVSSE QVLKFRKLN NGEGEPEELM VDNWRPAQPL
KNRQIKASFK.

[0059] Human CA2 having the amino acid sequence of SEQ ID NO: 1 is encoded by the polynucleotide having a nucleic acid sequence of SEQ ID NO: 3:

atgtcccatcactgggggtacggcaaacacaacggacctgagcactggcataaggacttccccattgccaaggagagcgccagtcacct
gttgacatcgacactcatacagccaagtatgaccttccctgaagcccctgtctgttctctatgatcaagcaacttccctgaggatcctcaaca
atggatcatgttcaacgtggagttgatgactctcaggacaaagcagtgctcaaggaggaccctggatggcacttacagattgattcagt
ttcactttcactgggggtcacttgatggacaaggttcagagcactgtggataaaaagaaatgctgcagaacttcacttggtcactggaac
accaaatattggggttttgggaaagctgtgcagcaacctgatggactggccgttctaggtatttttgaaggttgccagcgctaaaccgggc
cttcagaaagtgtgatgtgctggattccattaaaacaaagggaagagtgctgacttcactaacttcgatcctcgtggcctcctcctgaatc

cctggattactggacctaccaggtcactgaccacccctcctcttctggaatgtgtgacctggattgtgctcaaggaaacccatcagcgtcag
cagcgagcaggtgttgaaattccgtaaacttaactcaatggggagggtgaacccgaagaactgatggaggacaactggcgcccagctca
gccactgaagaacaggcaaatcaaagcttccttcaaa

[0060] As used herein, the phrase “derived from” as it relates to effector modules, SREs or payloads means that the effector module, SRE or payload originates at least in part from the stated parent molecule or sequence. For example, in designing an SRE, such SRE may be derived from an epitope or region of a naturally occurring protein but then have been modified in any of the ways taught herein to optimize the SRE function.

[0061] In some embodiments, the DRDs of the present disclosure may be derived from CA2 (SEQ ID NO: 1; Uniprot ID: P00918) which may be stabilized by ligands such as small molecule inhibitors of CA2. As used herein, the term “CA2 WT”, refers to the human wildtype CA2 protein sequence, which is defined as SEQ ID NO: 1, with the GenBank Access NO. P00918. In some aspects, the DRDs may be derived from CA2 of SEQ ID NO: 2.

[0062] In some embodiments, DRDs may be derived from CA2 having amino acids 2-260 of the parent CA2 sequence. This is referred to herein as an M1del mutation. The M1del mutation may also be referred herein as an amino acid deletion. In some embodiments, human DRD constructs disclosed herein may not comprise an N-terminal methionine corresponding to the N-terminal methionine of SEQ ID NO: 1. Regardless of the presence or absence of the N-terminal methionine in a disclosed CA2 DRD, the present disclosure identifies positions of the CA2 DRD relative to the wildtype human CA2 (Uniprot ID: P00918) of SEQ ID NO: 1, wherein reference position 1 is the N-terminal methionine of SEQ ID NO: 1. For example, a hypothetical CA2 DRD comprising a G12A mutation, refers herein to a CA2 DRD construct wherein glycine (G) is mutated to alanine (A) at a position in the CA2 DRD construct that corresponds to the twelfth amino acid of SEQ ID NO: 1, regardless of whether the CA2 DRD construct itself comprises an N-terminal methionine corresponding to the N-terminal methionine of SEQ ID NO: 1. In this hypothetical CA2 DRD comprising a G12A mutation example, the glycine (G) to alanine (A) change may also be referred to as an amino acid substitution.

[0063] In some embodiments, DRDs may be derived from human CA2 having amino acids 2-260 of the wild type human CA2 sequence of SEQ ID NO: 1. This may be referred to as an M1del mutation and has an amino acid sequence of SEQ ID NO: 2. In some embodiments, the DRD of the present disclosure has an amino acid sequence as set forth in SEQ ID NO: 4.

[0064] Table 1 provides a CA2 DRD. The position of the mutated amino acids listed in Table 1 is relative to the full length CA2 of SEQ ID NO: 1.

Table 1: CA2 DRD amino acid and nucleotide sequences.

Description	AA SEQUENCE	Nucleic Acid Sequence	AA SEQ ID NO	NA SEQ ID NO
CA2 mutant (M1del, L156H) relative to SEQ ID NO:1	SHHWGYGKHNGPEHWHKDFPI AKGERQSPVDIDHTAKYDPS LKPLSVSYDQATSLRILNNGH AFNVEFDDSQDKAVLKGGPLD GTYRLIQFHFHWGSLDGQGSE HTVDKKKYAAELHLVHWNTKY GDFGKAVQQPDGLAVLGIFLK VGSAPGHQKVVDVLDSEIKTK GKSADFTNFDPRGLLPESLDY WTYPGSLTTPPILLECVTWIVL KEPISVSSEQVLKFRKLNENG EGEPEELMVDNWRPAQPLKNR QIKASFK	TCCCATCACTGGGGGTACGGCAAACACAACGG ACCTGAGCACTGGCATAAGGACTTCCCCATTG CCAAGGGAGAGCGCCAGTCCCCTGTTGACATC GACACTCATAAGCCAAAGTATGACCCTTCCCT GAAGCCCCTGTCTGTTTCCCTATGATCAAGCAA CTTCCCCTGAGAATCCTCAACAATGGTCATGCT TTCAACGTGGAGTTTGATGACTCTCAGGACAA AGCAGTGCTCAAGGGAGGACCCCTGGATGGCA CTTACAGATTGATTGAGTTTCACTTTCACTGG GGTTCACTTGATGGACAAGGTTCAAGACATAC TGTGGATAAAAAGAAATATGCTGCAGAACTTC ACTTGGTTCACTGGAACACCAAATATGGGGAT TTTGGGAAAGCTGTGCAGCAACCTGATGGACT GGCCGTTCTAGGTATTTTTTTGAAGGTTGGCA GCGCTAAACCGGGCCATCAGAAAGTTGTTGAT GTGCTGGATTCCATTAAACAAAGGGCAAGAG TGCTGACTTCACTAACTTCGATCCTCGTGGCC TCCTTCCTGAATCCCTGGATTACTGGACCTAC CCAGGCTCACTGACCACCCCTCCTCTTCTGGA ATGTGTGACCTGGATTGTGCTCAAGGAACCCA TCAGCGTCAGCAGCGAGCAGGTGTTGAAATTC CGTAACTTAACTTCAATGGGGAGGGTGAACC CGAAGAACTGATGGTGGACAACCTGGCGCCAG CTCAGCCACTGAAGAACAGGCAAATCAAAGCT TCCTTCAA	4	5

[0065] In some embodiments, an exemplary DRD derived from CA2 that regulates an operably linked IL15 payload comprises or consists of the amino acid sequence of SEQ ID NO: 4 or is encoded by the nucleotide sequence of SEQ ID NO: 5.

[0066] In some embodiments, the CA2 DRD useful for the regulated and tunable expression of IL15 as described herein may include one or more mutations that are relative to Uniprot ID: P00918 (SEQ ID NO: 1) and include but are not limited to (M1del, L156H) relative to the amino acid sequence of SEQ ID NO: 1. In some embodiments, the CA2 DRD useful for the regulated and tunable expression of IL15 as described herein may include one mutation relative to (SEQ ID NO: 2) (L156H). In some embodiments, the CA2 DRD useful for the regulated and tunable expression of IL15 as described herein may include one amino acid substitution relative to (SEQ ID NO: 2) (L156H). In some embodiments, the CA2 DRD comprises the amino acid sequence of SEQ ID NO: 4. In some embodiments, the CA2 DRD consists of the amino acid sequence of SEQ ID NO: 4.

[0067] The SRE described herein may include CA2 DRDs which include but are not limited to one or two mutations such as, but not limited to, M1del, and L156H relative to the CA2 WT of SEQ ID NO: 1. In some embodiments, the CA2 DRD comprises the L156H mutation relative to SEQ ID NO: 1 and further comprises one or more additional mutations. In some embodiments, the CA2 DRD comprises the M1del and L156H mutation relative to SEQ ID NO: 1 and further comprises one or more additional mutations. In some embodiments, the CA2 DRD comprises the M1del amino acid deletion and L156H amino acid substitution relative to SEQ ID NO: 1 and further comprises one or more additional amino acid substitutions.

[0068] Also provided herein are biocircuit systems that include at least one effector module. The effector module of the biocircuit may include a stimulus response element (SRE) derived from CA2 (SEQ ID NO: 1 or SEQ ID NO: 2). In one embodiment, the SRE comprises or consists of the amino acid sequence of SEQ ID NO: 4. The biocircuits may also include at least one payload, which may be attached, appended or associated with the SRE. The payload may include a human IL15, comprising the amino acid sequence of SEQ ID NO: 8; the payload may be encoded by a nucleic acid sequence comprising the nucleotide sequence of SEQ ID NO: 9.

Table 2. An IL15 payload of the present disclosure.

Description	AA SEQUENCE	Nucleic Acid Sequence	AA SEQ ID NO	NA SEQ ID NO
IL15	NWVNVISDLKKIEDLIQSMHIDA TLYTESDVHPSCKVTAMKCFLL	AATTGGGTAAATGTTATCAGTGATCTCA AGAAGATAGAGGATCTCATCCAGTCCAT	8	9

Description	AA SEQUENCE	Nucleic Acid Sequence	AA SEQ ID NO	NA SEQ ID NO
	LQVISLES GDASIHDTVENLIIL ANNSLSSNGNVTESGCKECEELE EKNIKEFLQSFVHIVQMFINTS	GCATATTGATGCCACGCTGTACACAGAA AGCGATGTGCATCCTAGCTGTAAGGTGA CAGCGATGAAGTGTTTTCTTTGGAGCT GCAGGTAATTAGTCTTGAGTCCGGCGAT GCCAGCATTCATGATACCGTAGAAACT TGATTATCCTGGCCAACAATTCTCTGTC CTCAAACGGAAACGTAACCGAGAGCGGT TGTAAGAATGTGAAGAACTGGAAGAAA AGAACATCAAGGAGTTTCTGCAATCATT CGTTCACATCGTACAAATGTTCATAAAT ACGTCA		

[0069] In some embodiments, the present disclosure provides methods for modulating protein, expression, function or level by measuring the stabilization ratio and destabilization ratio. As used herein, the stabilization ratio may be defined as the ratio of expression, function or level of a protein of interest in response to the stimulus to the expression, function or level of the protein of interest in the absence of the stimulus specific to the SRE. As used herein, the destabilization ratio may be defined as the ratio of expression, function or level of a protein of interest in the absence of the stimulus specific to the effector module to the expression, function or level of the protein of interest, that is expressed constitutively and in the absence of the stimulus specific to the SRE. As used herein “constitutively” refers to the expression, function or level of a protein of interest that is not linked to an SRE and is therefore expressed both in the presence and absence of the stimulus.

[0070] As used herein a “payload” or “target payload” or “payload of interest (POI)” is defined as any protein whose function is to be altered. Payloads may include any protein or fragment thereof.

[0071] In some embodiments, payloads of the present disclosure include IL15. It is understood in the art that certain gene and/or protein nomenclature for the same gene or protein may be inclusive or exclusive of punctuation such as a dash “-” or symbolic such as Greek letters. Whether these are included or excluded herein, the meaning is not meant to be changed as would be understood by one of skill in the art. For example, IL15, IL 15 and IL-15 refer to the

same interleukin. In some embodiments, payloads of the present disclosure may be an IL15 interleukin cytokine that stimulate certain immune responses.

[0072] Payloads of the present disclosure may comprise amino acid sequences similar to the amino acid sequence of human IL15, for example, UniProtKB - P40933 (IL15_HUMAN). In one embodiment, the IL15 payload comprises the amino acid sequence provided in Table 2 (SEQ ID NO. 8).

[0073]

[0074] In some embodiments, payloads of the present disclosure may be utilized to improve expansion, survival, persistence, and potency of immune cells such as CD8+TEM, natural killer (NK) cells and tumor infiltrating lymphocytes (TIL), and CAR T cells used for immunotherapy. In one aspect, the present disclosure provides biocircuits and compositions to minimize toxicity related to cytokine therapy.

[0075] In some embodiments, the effector module may be a CA2 DRD-IL15 fusion polypeptide. In some embodiments, the IL15-containing constructs of the disclosure may be placed under the transcriptional control of the human cytomegalovirus (CMV) promoter, an Elongation Factor 1 α (EF1 α) promoter, HIV LTR promoter, 3-phosphoglycerate kinase (PGK) promoter, Rous sarcoma virus long terminal repeat (RSV) promoter, spleen focus forming virus (SFFV) promoter, synthetic MND promoter, murine stem cell virus (MSCV) promoter, synthetic RPBSA promoter or a ubiquitin promoter.

[0076] A unique feature of IL15 mediated activation is the mechanism of trans-presentation in which IL15 is presented as a complex with the alpha subunit of IL15 receptor (IL15Ra) that binds to and activates membrane bound IL15 beta/gamma receptor, either on the same cell or a different cell. In various embodiments, the payload of the present disclosure is a membrane bound IL15, wherein the amino acid sequence of said membrane bound IL15 comprises the amino acid sequence of SEQ ID NO: 8.

[0077] Payloads of the present disclosure may comprise nucleic acid sequences as disclosed herein but the payload may comprise additional or fewer nucleotides than those listed. Such nucleic acid sequences may comprise about 1 more or fewer nucleotides, about 2 more or fewer nucleotides, about 3 more or fewer nucleotides, about 4 more or nucleotides acids, about 5 more or fewer nucleotides, about 6 more or fewer nucleotides, about 7 more or fewer nucleotides,

about 8 more or fewer nucleotides, about 9 more or fewer nucleotides, about 10 more or fewer nucleotides or greater than 10 nucleotides.

[0078] Biocircuit components including effector modules, their SREs and payloads, may be nucleic acid-based. The term “nucleic acid,” in its broadest sense, includes any compound and/or substance that comprise a polymer of nucleotides, e.g., linked nucleosides. These polymers are often referred to as polynucleotides. Exemplary nucleic acids or polynucleotides of the disclosure include, but are not limited to, ribonucleic acids (RNAs), deoxyribonucleic acids (DNAs), threose nucleic acids (TNAs), glycol nucleic acids (GNAs), peptide nucleic acids (PNAs), locked nucleic acids (LNAs, including LNA having a β -D-ribo configuration, α -LNA having an α -L-ribo configuration (a diastereomer of LNA), 2'-amino-LNA having a 2'-amino functionalization, and 2'-amino- α -LNA having a 2'-amino functionalization) or hybrids thereof.

[0079] In some embodiments, the nucleic acid molecule is DNA. In some embodiments, the nucleic acid molecule is a messenger RNA (mRNA). As used herein, the term “messenger RNA” (mRNA) refers to any polynucleotide which encodes a polypeptide of interest and which is capable of being translated to produce the encoded polypeptide of interest in vitro, in vivo, in situ or ex vivo. Polynucleotides of the disclosure may be mRNA or any nucleic acid molecule and may or may not be chemically modified.

[0080] In some embodiments, polynucleotides of the present disclosure may harbor 5'UTR sequences which play a role in translation initiation. 5'UTR sequences may include features such as Kozak sequences which are commonly known to be involved in the process by which the ribosome initiates translation of genes, Kozak sequences have the consensus XCCR(A/G)CCAUG, where R is a purine (adenine or guanine) three bases upstream of the start codon (AUG) and X is any nucleotide. In one embodiment, the Kozak sequence is ACCGCC. By engineering the features that are typically found in abundantly expressed genes of target cells or tissues, the stability and protein production of the polynucleotides of the disclosure can be enhanced.

[0081] In one embodiment, polynucleotides of the present disclosure may encode variant polypeptides which have a certain identity with a reference polypeptide sequence. As used herein, a “reference polypeptide sequence” refers to a starting polypeptide sequence. Reference sequences may be wild type sequences or any sequence to which reference is made in the design of another sequence.

[0082] The term “identity” as known in the art, refers to a relationship between two or more sequences, as determined by comparing the sequences. In the art, identity also means the degree of sequence relatedness between sequences, as determined by the number of matches between strings of two or more residues (amino acid or nucleic acid). Identity measures the percent of identical matches between two or more sequences with gap alignments (if any) addressed by a particular mathematical model or computer program (i.e., “algorithms”). Identity of related sequences can be readily calculated by known methods. Such methods include, but are not limited to, those described in Computational Molecular Biology, Lesk, A. M., ed., Oxford University Press, New York, 1988; Biocomputing: Informatics and Genome Projects, Smith, D. W., ed., Academic Press, New York, 1993; Computer Analysis of Sequence Data, Part 1, Griffin, A. M., and Griffin, H. G., eds., Humana Press, New Jersey, 1994; Sequence Analysis in Molecular Biology, von Heinje, G., Academic Press, 1987; Sequence Analysis Primer, Gribskov, M. and Devereux, J., eds., M. Stockton Press, New York, 1991; and Carillo et al., SIAM J. Applied Math. 48, 1073 (1988).

[0083] In some embodiments, the variant sequence may have the same or a similar activity as the reference sequence. Alternatively, the variant may have an altered activity (e.g., increased or decreased) relative to a reference sequence. Generally, variants of a particular polynucleotide or polypeptide of the disclosure will have at least about 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% but less than 100% sequence identity to that particular reference polynucleotide or polypeptide as determined by sequence alignment programs and parameters described herein and known to those skilled in the art. Such tools for alignment include those of the BLAST suite (Stephen F. Altschul, Thomas L. Madden, Alejandro A. Schäffer, Jinghui Zhang, Zheng Zhang, Webb Miller, and David J. Lipman (1997), "Gapped BLAST and PSI-BLAST: a new generation of protein database search programs", Nucleic Acids Res. 25:3389-3402.)

[0084] The effector module of the present disclosure may further comprise a signal sequence which regulates the distribution of the payload of interest, a cleavage and/or processing feature which facilitate cleavage of the payload from the effector module construct, a targeting and/or penetrating signal which can regulate the cellular localization of the effector module, a tag, and/or one or more linker sequences which link different components of the effector module.

[0085] In addition to the SRE and payload region, effector modules of the disclosure may further comprise one or more additional features such as one or more signal sequences.

[0086] Signal sequences (sometimes referred to as signal peptides, targeting signals, target peptides, localization sequences, transit peptides, leader sequences or leader peptides) direct proteins (e.g., the effector module of the present disclosure) to their designated cellular and/or extracellular locations. Protein signal sequences play a central role in the targeting and translocation of nearly all secreted proteins and many integral membrane proteins.

[0087] A signal sequence is a short (5-30 amino acids long) peptide present at the N-terminus of the majority of newly synthesized proteins that are destined towards a particular location. Signal sequences can be recognized by signal recognition particles (SRPs) and cleaved using type I and type II signal peptide peptidases. Signal sequences derived from human proteins can be incorporated as a regulatory module of the effector module to direct the effector module to a particular cellular and/or extracellular location.

[0088] In some embodiments, a signal sequence may be, although not necessarily, located at the N-terminus or C-terminus of the effector module, and may be, although not necessarily, cleaved off the desired effector module to yield a “mature” payload.

[0089] In some embodiments, the signal sequence used herein may exclude the methionine at the position 1 of amino acid sequence of the signal sequence. This may be referred to as an M1del mutation.

[0090] In addition to signal sequences naturally occurring such as from a secreted protein, a signal sequence may be a variant modified from a known signal sequence of a protein.

[0091] In some instances, signal sequences directing the payload of interest to the surface membrane of the target cell may be used. Expression of the payload on the surface of the target cell may be useful to limit the diffusion of the payload to non-target in vivo environments, thereby potentially improving the safety profile of the payloads. Additionally, the membrane presentation of the payload may allow for physiologically and qualitative signaling as well as stabilization and recycling of the payload for a longer half-life. Membrane sequences may be the endogenous signal sequence of the N terminal component of the payload of interest. Optionally, it may be desirable to exchange this sequence for a different signal sequence. Signal sequences may be selected based on their compatibility with the secretory pathway of the cell type of interest so that the payload is presented on the surface of the T cell. In some embodiments, the

signal sequence may be IgE signal sequence, CD8a signal sequence (also referred to as CD8a leader), or IL15Ra signal sequence (also referred to as IL15Ra leader) or M1del CD8a signal sequence (also referred to as M1del CD8 leader sequence).

[0092] In some embodiments, the effector module comprises a cleavage and/or processing feature. In some embodiments, the effector module of the present disclosure may include at least one protein cleavage signal/site. The protein cleavage signal/site may be located at the N-terminus, the C-terminus, at any space between the N-and the C-termini such as, but not limited to, half-way between the N-and C-termini, between the N-terminus and the half-way point, between the half-way point and the C-terminus, and combinations thereof.

[0093] In some embodiments, the effector module comprises a linker.

[0094] In some embodiments, the effector module of the disclosure may further comprise a linker sequence. The linker region serves primarily as a spacer between two or more polypeptides within the effector module. The "linker" or "spacer", as used herein, refers to a molecule or group of molecules that connects two molecules, or two parts of a molecule such as two domains of a recombinant protein.

[0095] In some embodiments, "Linker" (L) or "linker domain" or "linker region" or "linker module" or "peptide linker" as used herein refers to an oligo-or polypeptide region of from about 1 to 100 amino acids in length, which links together any of the domains/regions of the effector module (also called peptide linker).

[0096] In some embodiments, an artificially designed peptide linker may be composed of a polymer of flexible residues such as Glycine (G) and Serine (S) so that the adjacent protein domains are free to move relative to one another. Longer linkers may be used when it is desirable to ensure that two adjacent domains do not interfere with one another. The choice of a particular linker sequence may be of concern if it affects biological activity, stability, folding, targeting and/or pharmacokinetic features of the fusion construct.

[0097] A linker sequence may be a natural linker derived from a multi-domain protein. A natural linker is a short peptide sequence that separates two different domains or motifs within a protein.

[0098] In one embodiment, the linker may be a BamHI site. As a non-limiting example, the BamHI site has the amino acid sequence GS and/or the DNA sequence GGATCC.

[0099] Biocircuits of the present disclosure are triggered by one or more stimuli. In some embodiments, the stimulus is a small molecule. In some embodiments, the small molecules are cell permeable. In some embodiments, the small molecules are FDA-approved, safe and orally administered.

[00100] In some embodiments, the ligands bind to carbonic anhydrases. In some embodiments, the ligand binds to and inhibits carbonic anhydrase function and is herein referred to as carbonic anhydrase inhibitor.

[00101] In some embodiments, the ligand is a small molecule that binds to carbonic anhydrase 2. In one embodiment, the small molecule is CA2 inhibitor. In some embodiments, the ligand is a small molecule selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, and dichlorphenamide. In some embodiments, the ligand is a small molecule selected from acetazolamide, brinzolamide, dorzolamide hydrochloride, dichlorphenamide, chlorthalidone, methazolamide, topiramate, indapamide, ambroxol hydrochloride, glimepiride, tetracaine hydrochloride and celecoxib. In some embodiments, the ligand is a small molecule selected from acetazolamide, brinzolamide, dorzolamide hydrochloride, dichlorphenamide, chlorthalidone, methazolamide or topiramate. In some embodiments, the ligand is a CA2 inhibitor selected from acetazolamide, brinzolamide, dorzolamide hydrochloride, dichlorphenamide or methazolamide. In some embodiments, the ligand is acetazolamide (ACZ).

[00102] In some embodiments, ligands that do not affect the activity of the immune cell, and/or the chimeric antigen receptor, in the absence of the SREs may be preferably selected.

[00103] In some embodiments, compositions of the disclosure comprise a promoter.

[00104] As used herein a promoter is defined as a DNA sequence recognized by transcription machinery of the cell, required to initiate specific transcription of the polynucleotide sequence of the present disclosure. Vectors can comprise native or non-native promoters operably linked to the polynucleotides of the disclosure. The promoters selected may be strong, weak, constitutive, inducible, tissue specific, development stage-specific, and/or organism specific. . A strong constitutive promoter sequence is capable of driving high levels of expression of polynucleotide sequence that is operatively linked to it. Examples of strong constitutive promoters include, without limitation, immediate early cytomegalovirus (CMV) promoter and Elongation Growth Factor-1 Alpha (EF-1 alpha). Other constitutive promoters that may be used, include, but are not

limited to, simian virus 40 (SV40), mouse mammary tumor virus (MMTV) promoter, human immunodeficiency virus (HIV) long terminal repeat (LTR) promoter, an avian leukemia virus promoter, a spleen focus forming virus (SFFV) promoter, a murine stem cell virus (MSCV) promoter, an Epstein-Barr virus immediate early promoter, a Rous sarcoma virus promoter, human gene promoters including, but not limited to, the phosphoglycerate kinase (PGK) promoter, an actin promoter, a myosin promoter, the hemoglobin promoter, the Ubiquitin C (Ubc) promoter, the human U6 small nuclear protein promoter and a creatine kinase promoter. Synthetic promoters include a MND promoter and a RPBSA promoter. In some instances, inducible promoters such as, but not limited to, metallothionine promoter, glucocorticoid promoter, a progesterone promoter, and a tetracycline promoter may be used.

[00105] In some embodiments, the optimal promoter may be selected based on its ability to achieve minimal expression of the SREs and payloads of the disclosure in the absence of the ligand and detectable expression in the presence of the ligand.

[00106] Additional promoter elements, e.g., enhancers may be used to regulate the frequency of transcriptional initiation. Such regions may be located 10-100 base pairs upstream or downstream of the start site. In some instances, two or more promoter elements may be used to cooperatively or independently activate transcription.

[00107] Biocircuits of the present disclosure may comprise at least one effector module which may comprise at least one SRE derived from CA2 (referred to as “CA2 SREs”) which may be operably linked to at least one payload of interest. These types of biocircuits and effector modules are referred to as “CA2 biocircuits” and “CA2 effector modules”. Additionally, the CA2 effector module may comprise additional features including, but not limited to, signal sequences, linker, spacers, tags, flags, cleavage sites, and IRES. Any of the exemplary SREs (e.g., DRDs), payloads of interest, signal sequences, linker, spacers, hinges, tags, flags, cleavage sites, and IRES taught herein or known in the art may be combined to create the CA2 effector modules of the present disclosure.

[00108] In one embodiment, the CA2 effector module comprises a payload of interest. The payload of interest may be a wild-type sequence, a fragment of a wild-type sequence and/or comprise one or more mutations. In one embodiment, the CA2 effector module produces regulated interleukin-15 (IL15). In some embodiments, an IL15 payload is N-terminal to the DRD. The CA2 effector module may include or be derived from any of the IL15-related

sequences in Table 3. In some embodiments, at least one payload in the CA2 effector module is an IL15 (e.g. an IL15 payload) comprising an amino acid sequence that is at least 95%, or at least 96%, or at least 97%, or at least 98%, or at least 99%, or 100% identical to the amino acid sequence of SEQ ID NO: 8; the payload may be encoded by a nucleic acid sequence comprising the nucleotide sequence of SEQ ID NO: 9). In some embodiments, the payload is a membrane-bound form of IL15. In some embodiments, the payload is a membrane-bound form of IL15 comprising a transmembrane domain and an intracellular tail. In some embodiments, the payload is a membrane-bound form of IL15 comprising an IL15 polypeptide component comprising the amino acid sequence of SEQ ID NO: 8, a transmembrane domain and an intracellular tail, wherein the transmembrane domain is C-terminal to the IL15 polypeptide component and the intracellular tail is C-terminal to the transmembrane domain. In some embodiments, the payload is a membrane-bound form of IL15 comprising a transmembrane domain, intracellular tail and one or more linkers. In some embodiments, linkers are peptide domains that may be placed between the SRE or DRD and the payload, or between different domains within the payload. In some embodiments, linkers are peptide domains comprising glycine and serine amino acid residues. In some embodiments, peptide linkers comprising glycine and serine amino acid residues may be from 2-36 amino acids in length. In one embodiment, at least one payload in the CA2 effector module is a membrane-bound form of IL15 which further includes a linker (GS)15, a B7.1 Hinge, a B7.1 transmembrane domain, a B7.1 intracellular tail, and a linker (GS). The CA2 effector module may include a payload component of a transmembrane domain and/or cytoplasmic domain from another parent protein as well as the IL15 payload component. In one embodiment, at least one payload in the CA2 effector module includes at least one mutation as compared to the wild-type sequence. In one embodiment, at least one payload in the CA2 effector module includes at least one amino acid substitution as compared to the wild-type sequence.

[00109] Non-limiting examples of constructs and construct components are shown in Table 3. Table 3. Constructs and construct components of interest.

Description	Amino Acid Sequence (AA)	Nucleic Acid Sequence (NA)	Amino Acid SEQ ID NO	Nucleic Acid SEQ ID NO
Leader sequence	MDMRVPAQLLGLLLWL SGARC	ATGGACATGCGGGTGCCTGCACAACTTCTGGGCCTG CTGTTGTTGTGGCTGTCTGGAGCCCCGGTGT	6	7
Interleukin-15 (IL15)	NWVNVISDLKKIEDLIQ SMHIDATLYTESDVHPS CKVTAMKCFLELQVIS LESGDASIHDTVENLII LANNLSNNGNVTESGC KECEELEEKNIKEFLQS FVHIVQMFINTS	AATTGGGTAAATGTTATCAGTGATCTCAAGAAGATA GAGGATCTCATCCAGTCCATGCATATTGATGCCACG CTGTACACAGAAAGCGATGTGCATCCTAGCTGTAAG GTGACAGCGATGAAGTGTTCCTTTGGAGCTGCAG GTAATTAGTCTTGAGTCCGGCGATGCCAGCATTCAT GATACCGTAGAAAACCTTGATTATCCTGGCCAACAAT TCTCTGTCTCAAACGGAACGTAACCGAGAGCGGT TGTAAGAAGTGTGAAGAACTGGAAGAAAAGAACATC AAGGAGTTTCTGCAATCATTCGTTACATCGTACAA ATGTTCATAAATACGTCA	8	9
Linker (GS)15	SGSGSGSGSGSGSGSG SGSGSGSGSGSGS	GGATCTGGTTCTGGTCCGGAAGTGGATCTGGTTCA GGGTCCGGTAGTGGATCTGGGTGAGGAAGTGAAGC GGTAGTGGGTCTGGATCT	10	11
Hinge	KQEHFPDN	AAACAAGAGCACTTTCCTGATAAC	12	13
Transmembrane	LLPSWAITLISVNGIFV ICCL	CTGTTGCCGAGCTGGGCGATTACGCTTATCAGTGTA AACGGCATCTTTGTAATATGCTGTCTG	14	15
Intracellular tail	TYCFAPRCRERRRNERL RRESVRPV	ACCTACTGCTTCGCACCAAGGTGCCGGGAGAGAAGG AGAAATGAAAGACTGAGAAGGGAGAGCGTGAGACCT GTG	16	17
Intracellular tail	TYCFAPRCRERARNERL RRETVRPV	ACCTACTGCTTCGCACCAAGGTGCCGGGAGAGAGCA AGAAATGAAAGACTGAGAAGGGAGACCGTGAGACCT GTG	18	19
Linker (GS)	GS	GGATCC	20	21
CA2 (M1del, L156H)	SHHWGYGKHNGPEHWHK DFPIAKGERQSPVDIDT HTAKYDPSLKPLSVSYD QATSLRILNNGHAFNVE FDDSQDKAVLKGGPLDG TYRLIQFHFHWGSLDGQ GSEHTVDKKKYAAELHL VHWNTKYGDFGKAVQQP DGLAVLGIFLKVGSAPK GHQKVVVDVLDISKTKGK	TCCCATCACTGGGGGTACGGCAAACACAACGGACCT GAGCACTGGCATAAGGACTTCCCCATTGCCAAGGGA GAGCGCCAGTCCCCTGTTGACATCGACACTCATACA GCCAAGTATGACCCTTCCCTGAAGCCCCTGTCTGTT TCCTATGATCAAGCAACTTCCCTGAGAATCCTCAAC AATGGTCATGCTTCAACGTGGAGTTTGATGACTCT CAGGACAAAGCAGTGCTCAAGGGAGGACCCCTGGAT GGCACTTACAGATTGATTGAGTTTCACTTTCACTGG GGTTCACTTGATGGACAAGGTTGAGAGCATACTGTG GATAAAAAGAAATATGCTGCAGAACTTCACTTGTT	4	5

Description	Amino Acid Sequence (AA)	Nucleic Acid Sequence (NA)	Amino Acid SEQ ID NO	Nucleic Acid SEQ ID NO
	SADFTNFDPRGLLPESL DYWTYPGSLTTPPLEC VTWIVLKEPISVSSEQV LKFRKLNENGEPEEL MVDNWRPAQPLKNRQIK ASFK	CACTGGAACACCAAATATGGGGATTTTGGGAAAGCT GTGCAGCAACCTGATGGACTGGCCGTTCTAGGTATT TTTTTGAAGGTTGGCAGCGCTAAACCGGGCCATCAG AAAGTTGTTGATGTGCTGGATTCCATTAAACAAAG GGCAAGAGTGCTGACTTCACTAACTTCGATCCTCGT GGCCTCCTTCCTGAATCCCTGGATTACTGGACCTAC CCAGGCTCACTGACCACCCCTCCTCTTCTGGAATGT GTGACCTGGATTGTGCTCAAGGAACCCATCAGCGTC AGCAGCGAGCAGGTGTTGAAATTCGGTAAACTTAAC TTCAATGGGGAGGGTGAACCCGAAGAACTGATGGTG GACAACTGGCGCCAGCTCAGCCACTGAAGAACAGG CAAATCAAAGCTTCCTTCAA		
IL15-292	MDMRVPAQLLGLLLLWL SGARCNWVNVISDLKKI EDLIQSMHIDATLYTES DVHPSCKVTAMKCFLE LQVISLESGDASIHDTV ENLIILANNSLSSNGNV TESGCKECELEEKNIK EFLQSFVHIVQMFINTS GSGSGSGSGSGSGSGSG SGSGSGSGSGSGSKQEH FPDNLPSWAITLISVN GIFVICCLTYCFAPRCR ERRRNERLRRESVRPVG S	ATGGACATGCGGGTGCCTGCACAACTTCTGGGCCTG CTGTTGTTGTGGCTGTCTGGAGCCCGGTGTAATTGG GTAAATGTTATCAGTGATCTCAAGAAGATAGAGGAT CTCATCCAGTCCATGCATATTGATGCCACGCTGTAC ACAGAAAGCGATGTGCATCCTAGCTGTAAGGTGACA GCGATGAAGTGTTCCTTTTGGAGCTGCAGGTAATT AGTCTTGAGTCCGGCGATGCCAGCATTATGATACC GTAGAAAACCTTGATTATCCTGGCCAACAATTCTCTG TCCTCAAACGGAACGTAACCGAGAGCGGTTGTAAA GAATGTGAAGAACTGGAAGAAAAGAACATCAAGGAG TTTCTGCAATCATTCGTTACATCGTACAAATGTTT ATAAATACGTCAGGATCTGGTTCTGGTTCCGGAAGT GGATCTGGTTGAGGTCGGTAGTGGATCTGGGTCA GGAAGTGAAGCGGTAGTGGGTCTGGATCTAAACAA GAGCACTTTCCTGATAACCTGTTGCCGAGCTGGGCG ATTACGCTTATCAGTGTAACGGCATCTTTGTAATA TGCTGTCTGACCTACTGCTTCGCACCAAGGTGCCGG GAGAGAAGGAGAAATGAAAGACTGAGAAGGGAGAGC GTGAGACCTGTGGGATCC	22	23
OT-IL15-293	MDMRVPAQLLGLLLLWL SGARCNWVNVISDLKKI	ATGGACATGCGGGTGCCTGCACAACTTCTGGGCCTG CTGTTGTTGTGGCTGTCTGGAGCCCGGTGTAATTGG	24	25

Description	Amino Acid Sequence (AA)	Nucleic Acid Sequence (NA)	Amino Acid SEQ ID NO	Nucleic Acid SEQ ID NO
	EDLIQSMHIDATLYTES DVHPSCKVTAMKCFLE LQVISLESGDASIHDTV ENLIILANNSLSSNGNV TESGCKECELEEKNIK EFLQSFVHIVQMFINTS SGSGSGSGSGSGSGSG SGSGSGSGSGSGSKQEH FPDNLPSWAITLISVN GIFVICCLTYCFAPRCR ERRRNERLRRESVRPVG SSHHWGYCKHNGPEHWH KDFPIAKGERQSPVDID THTAKYDFSLKPLSVSY DQATSLRILNNGHAFNV EFDDSQDKAVLKGGLD GTYRLIQFHFHWGSLDG QGSEHTVDKKKYAAELH LVHWNTKYGDFGKAVQQ PDGLAVLGI FLKVGSAK PGHQKVVDVLDISKTKG KSADFTNFDPRGLLPES LDYWTPGSLTTPPLLE CVTWIVLKEPISVSSEQ VLKFRKLNFNGEPEPEE LMVDNWRPAQPLKNRQI KASFK	GTAAATGTTATCAGTGATCTCAAGAAGATAGAGGAT CTCATCCAGTCCATGCATATTGATGCCACGCTGTAC ACAGAAAGCGATGTGCATCCTAGCTGTAAGGTGACA GCGATGAAGTGTCTTTCTTTGGAGCTGCAGGTAATT AGTCTTGAGTCCGGCGATGCCAGCATTCATGATACC GTAGAAAACCTTGATTATCCTGGCCAACAATTCTCTG TCCTCAAACGGAACGTAACCGAGAGCGGTTGTAAA GAATGTGAAGAACTGGAAGAAAAGAACATCAAGGAG TTTCTGCAATCATTCGTTTACATCGTACAAATGTTT ATAAATACGTCAGGATCTGGTTCTGGTTCCGGAAGT GGATCTGGTTTCCGGTCCGGTAGTGGATCTGGGTCA GGAAGTGAAGCGGTAGTGGGTCTGGATCTAAACAA GAGCACTTTCCTGATAACCTGTTGCCGAGCTGGGCG ATTACGCTTATCAGTGTAACCGGCATCTTTGTAATA TGCTGTCTGACCTACTGCTTCGCACCAAGGTGCCGG GAGAGAAGGAGAAATGAAAGACTGAGAAGGGAGAGC GTGAGACCTGTGGGATCCTCCCATCACTGGGGGTAC GGCAAACACAACGGACCTGAGCACTGGCATAAGGAC TTCCCCATTGCCAAGGGAGAGCGCCAGTCCCCTGTT GACATCGACACTCATAACGCAAGTATGACCCTTCC CTGAAGCCCCTGTCTGTTTCTATGATCAAGCAACT TCCCTGAGAATCCTCAACAATGGTCATGCTTTCAAC GTGGAGTTTGATGACTCTCAGGACAAAGCAGTGCTC AAGGGAGGACCCCTGGATGGCACTTACAGATTGATT CAGTTTCACTTTCACTGGGGTTCACTTGATGGACAA GGTTCAGAGCATACTGTGGATAAAAAGAAATATGCT GCAGAACTTCACCTGGTTCACTGGAACACCAAATAT GGGGATTTTGGGAAAGCTGTGCAGCAACCTGATGGA CTGGCCGTCTAGGTATTTTTTTGAAGGTTGGCAGC GCTAAACCGGGCCATCAGAAAGTTGTTGATGTGCTG GATTCCATTAAACAAAGGGCAAGAGTGCTGACTTC ACTAACTTCGATCCTCGTGGCCTCCTTCTGAATCC CTGGATTACTGGACCTACCCAGGCTCACTGACCACC		

Description	Amino Acid Sequence (AA)	Nucleic Acid Sequence (NA)	Amino Acid SEQ ID NO	Nucleic Acid SEQ ID NO
		CCTCCTCTTCTGGAATGTGTGACCTGGATTGTGCTC AAGGAACCCATCAGCGTCAGCAGCGAGCAGGTGTTG AAATTCGTAACCTTAACCTCAATGGGGAGGGTGAA CCCGAAGAACTGATGGTGGACAACCTGGCGCCAGCT CAGCCACTGAAGAACAGGCAATCAAAGCTTCCTTC AAA		
OT-IL15-294	MDMRVPAQLLGLLLLWL SGARCNWVNVISDLKKI EDLIQSMHIDATLYTES DVHPSCKVTAMKCFLE LQVISLES GDASIHDTV ENLIILANNSLSSNGNV TESGCKECELEEKNIK EFLQSFVHIVQMFINTS SGSGSGSGSGSGSGSG SGSGSGSGSGSGSKQEH FPDNLLPSWAITLISVN GIFVICCLTYCFAPRCR ERARNERLRRETVRPVG S	ATGGACATGCGGGTGCCTGCACAACTTCTGGGCCTG CTGTTGTTGTGGCTGTCTGGAGCCCGGTGTAATTGG GTAAATGTTATCAGTGATCTCAAGAAGATAGAGGAT CTCATCCAGTCCATGCATATTGATGCCACGCTGTAC ACAGAAAGCGATGTGCATCCTAGCTGTAAGGTGACA GCGATGAAGTGTCTTTCTTTGGAGCTGCAGGTAATT AGTCTTGAGTCCGGCGATGCCAGCATTCTATGATACC GTAGAAAACCTTGATTATCCTGGCCAACAATTCTCTG TCCTCAAACGGAACGTAACCGAGAGCGGTTGTAAA GAATGTGAAGAACTGGAAGAAAAGAACATCAAGGAG TTTCTGCAATCATTCGTTACATCGTACAAATGTTTC ATAAATACGTCAGGATCTGGTTCTGGTTCCGGAAGT GGATCTGGTTGAGGTCGGGTAGTGGATCTGGGTCA GGAAGTGAAGCGGTAGTGGGTCTGGATCTAAACAA GAGCACTTTCCTGATAACCTGTTGCCGAGCTGGGCG ATTACGCTTATCAGTGTAACGGCATCTTTGTAATA TGCTGTCTGACCTACTGCTTCGCACCAAGGTGCCGG GAGAGAGCAAGAAATGAAAGACTGAGAAGGGAGACC GTGAGACCTGTGGGATCC	26	27
OT-IL15-295	MDMRVPAQLLGLLLLWL SGARCNWVNVISDLKKI EDLIQSMHIDATLYTES DVHPSCKVTAMKCFLE LQVISLES GDASIHDTV ENLIILANNSLSSNGNV TESGCKECELEEKNIK EFLQSFVHIVQMFINTS	ATGGACATGCGGGTGCCTGCACAACTTCTGGGCCTG CTGTTGTTGTGGCTGTCTGGAGCCCGGTGTAATTGG GTAAATGTTATCAGTGATCTCAAGAAGATAGAGGAT CTCATCCAGTCCATGCATATTGATGCCACGCTGTAC ACAGAAAGCGATGTGCATCCTAGCTGTAAGGTGACA GCGATGAAGTGTCTTTCTTTGGAGCTGCAGGTAATT AGTCTTGAGTCCGGCGATGCCAGCATTCTATGATACC GTAGAAAACCTTGATTATCCTGGCCAACAATTCTCTG	28	29

Description	Amino Acid Sequence (AA)	Nucleic Acid Sequence (NA)	Amino Acid SEQ ID NO	Nucleic Acid SEQ ID NO
	GSGSGSGSGSGSGSGSG SSGSGSGSGSGSGSKQEH FPDNLLPSWAITLISVN GIFVICCLTYCFAPRCR ERARNERLRRETVRPVG SSHHWGYCKHNGPEHWH KDFPIAKGERQSPVDID THTAKYDFSLKPLSVSY DQATSLRILNNGHAFNV EFDDSQDKAVLKGGPLD GTYRLIQFHFHWGSLDG QGSEHTVDKKKYAAELH LVHWNTKYGDFGKAVQQ PDGLAVLGI FLKVGSAK PGHQKVVDVLDSEIKTKG KSADFTNFDPRGLLPES LDYWTYPGSLTTPPLLE CVTWIVLKEPISVSSEQ VLKFRKLNFNGEPEPEE LMVDNWREAPQLKNRQI KASFK	TCCTCAAACGGAACGTAACCGAGAGCGGTTGTAAA GAATGTGAAGAACTGGAAGAAAAGAACATCAAGGAG TTTCTGCAATCATTCGTTACATCGTACAAATGTTT ATAAATACGTGAGGATCTGGTTCTGGTTCCGGAAGT GGATCTGGTTGAGGTCGGGTAGTGGATCTGGGTCA GGAAGTGAAGCGGTAGTGGGTCTGGATCTAAACAA GAGCACTTTCCTGATAACCTGTTGCCGAGCTGGGCG ATTACGCTTATCAGTGTAACGGCATCTTTGTAATA TGCTGTCTGACCTACTGCTTCGCACCAAGGTGCCGG GAGAGAGCAAGAAATGAAAGACTGAGAAGGGAGACC GTGAGACCTGTGGGATCCTCCCATCACTGGGGGTAC GGCAAAACACAACGGACCTGAGCACTGGCATAAGGAC TTCCCCATTGCCAAGGGAGAGCGCCAGTCCCCTGTT GACATCGACACTCATAACAGCAAGTATGACCCCTCC CTGAAGCCCTGTCTGTTTCTTATGATCAAGCAACT TCCCTGAGAATCCTCAACAATGGTCATGCTTCAAC GTGGAGTTTGATGACTCTCAGGACAAAGCAGTGCTC AAGGGAGGACCCCTGGATGGCACTTACAGATTGATT CAGTTTCACTTTCACTGGGGTCACTTGATGGACAA GGTTCAGAGCATACTGTGGATAAAAAGAAATATGCT GCAGAACTTCACTTGGTTCACTGGAACACCAATAT GGGGATTTTGGGAAAGCTGTGCAGCAACCTGATGGA CTGGCCGTTCTAGGTATTTTTTTGAAGGTTGGCAGC GCTAAACCGGGCCATCAGAAAGTTGTTGATGTGCTG GATTCCATTAAACAAAGGGCAAGAGTGCTGACTTC ACTAACTTCGATCCTCGTGGCCTCCTTCTGAATCC CTGGATTACTGGACCTACCCAGGCTCACTGACCACC CCTCCTCTTCTGGAATGTGTGACCTGGATTGTGCTC AAGGAACCCATCAGCGTCAGCAGCGAGCAGGTGTTG AAATTCGTAACTTAACTTCAATGGGGAGGGTGAA CCCGAAGAACTGATGGTGGACAACTGGCGCCAGCT CAGCCACTGAAGAACAGGCAATCAAAGCTTCCTTC AAA		

[00110] In various embodiments, the effector module produces regulated membrane-bound interleukin-15 (IL15). In some embodiments, the effector module is IL15-293 or IL15-295 as described in Table 3. In various embodiments, the IL15 payload is expressed as a CA2 DRD fusion protein comprising a membrane-bound form of IL15.

[00111] The CA2 biocircuits and/or CA2 effector modules of the present disclosure may be monocistronic or multicistronic meaning one (monocistronic) or more than one (multicistronic) message (e.g., payload of interest) is produced. If two messages are produced, the CA2 biocircuit or CA2 effector module is considered bicistronic. In one embodiment, at least one CA2 effector module of the present disclosure is monocistronic.

[00112] Various embodiments of the present disclosure provide nucleic acid molecules comprising one or more of the polynucleotides described. In some embodiments, the nucleic acid molecule comprises a polynucleotide encoding a recombinant protein comprising a drug responsive domain (DRD) operably linked to an IL15 payload, wherein said DRD is derived from human carbonic anhydrase II (CA2) and comprises one, two, three, four or more mutations relative to SEQ ID NO:1 or SEQ ID NO:2. In some embodiments, the nucleic acid molecule further comprises a second polynucleotide encoding a chimeric antigen receptor (CAR) or T cell receptor (TCR), wherein the CAR or TCR comprises an antigen-binding domain specific to an antigen of interest. In some embodiments, the CAR or TCR comprises an antigen-binding domain specific to an antigen of interest for example, the CAR comprises an antigen-binding domain specific to CD19.

[00113] The present teachings further comprise pharmaceutical compositions comprising one or more of CA2 biocircuits, CA2 effector modules or systems of the present disclosure, and optionally at least one pharmaceutically acceptable excipient or inert ingredient.

[00114] As used herein the term “pharmaceutical composition” refers to a preparation of one or more of the CA2 biocircuits or components described herein, or pharmaceutically acceptable salts thereof, optionally with other chemical components such as physiologically suitable carriers and excipients.

[00115] The term “excipient” or “inactive ingredient” refers to an inert or inactive substance added to a pharmaceutical composition to further facilitate administration of a compound. Non-limiting examples of such inert ingredients are disclosed herein.

[00116] In some embodiments, compositions are administered to humans, such as human patients or subjects. For the purposes of the present disclosure, the phrase “active ingredient” generally refers to any one or more CA2 biocircuit components to be delivered as described herein.

[00117] Although the descriptions of pharmaceutical compositions provided herein are principally directed to pharmaceutical compositions which are suitable for administration to humans, it will be understood by the skilled artisan that such compositions are generally suitable for administration to any other animal, e.g., to non-human animals, e.g. non-human mammals. Subjects to which administration of the pharmaceutical compositions is contemplated include, but are not limited to, non-human mammals, including agricultural animals such as cattle, horses, chickens and pigs, domestic animals such as cats, dogs, or research animals such as mice, rats, rabbits, dogs and non-human primates.

[00118] A pharmaceutical composition in accordance with the disclosure may be prepared, packaged, and/or sold in bulk, as a single unit dose, and/or as a plurality of single unit doses. As used herein, a “unit dose” is discrete amount of the pharmaceutical composition comprising a predetermined amount of the active ingredient. The amount of the active ingredient is generally equal to the dosage of the active ingredient which would be administered to a subject and/or a convenient fraction of such a dosage such as, for example, one-half or one-third of such a dosage.

[00119] Relative amounts of the active ingredient, the pharmaceutically acceptable excipient or inert ingredient, and/or any additional ingredients in a pharmaceutical composition in accordance with the disclosure will vary, depending upon the identity, size, and/or condition of the subject treated and further depending upon the route by which the composition is to be administered. By way of example, the composition may comprise between 0.1% and 100%, e.g., between 0.5 and 50%, between 1-30%, between 5-80%, at least 80% (w/w) active ingredient.

[00120] Efficacy of treatment or amelioration of disease can be assessed, for example by measuring disease progression, disease remission, symptom severity, reduction in pain, quality of life, dose of a medication required to sustain a treatment effect, level of a disease marker or

any other measurable parameter appropriate for a given disease being treated or targeted for prevention. It is well within the ability of one skilled in the art to monitor efficacy of treatment or prevention by measuring any one of such parameters, or any combination of parameters. In connection with the administration of compositions of the present disclosure, "effective against" for example a cancer, indicates that administration in a clinically appropriate manner results in a beneficial effect for at least a statistically significant fraction of patients, such as an improvement of symptoms, a cure, a reduction in disease load, reduction in tumor mass or cell numbers, extension of life, improvement in quality of life, or other effect generally recognized as positive by medical doctors familiar with treating the particular type of cancer.

[00121] A treatment or preventive effect is evident when there is a statistically significant improvement in one or more parameters of disease status, or by a failure to worsen or to develop symptoms where they would otherwise be anticipated. As an example, a favorable change of at least 10% in a measurable parameter of disease, and preferably at least 20%, 30%, 40%, 50% or more can be indicative of effective treatment. Efficacy for a given composition or formulation of the present disclosure can also be judged using an experimental animal model for the given disease as known in the art. When using an experimental animal model, efficacy of treatment is evidenced when a statistically significant change is observed.

[00122] The compositions of the present disclosure may be formulated in any manner suitable for delivery. The formulation may be, but is not limited to, nanoparticles, poly (lactic-co-glycolic acid) (PLGA) microspheres, lipidoids, lipoplex, liposome, polymers, carbohydrates (including simple sugars), cationic lipids and combinations thereof.

[00123] In some embodiments, pharmaceutical or other formulations may comprise at least one excipient which is an inactive ingredient. As used herein, the term "inactive ingredient" refers to one or more inactive agents included in formulations. In some embodiments, all, none or some of the inactive ingredients which may be used in the formulations of the present disclosure may be approved by the US Food and Drug Administration (FDA). The compositions of the disclosure may be delivered to a cell or a subject through one or more routes and modalities. The viral vectors containing one or more CA2 biocircuits, CA2 effector modules, SREs, payloads and other components described herein may be used to deliver them to a cell and/or a subject. Other modalities may also be used such as mRNAs, plasmids, and as recombinant proteins.

[00124] Pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure may be delivered to cells, tissues, organs and/or organisms in naked form. As used herein in, the term “naked” refers to pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads delivered free from agents or modifications which promote transfection or permeability. The naked pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads may be delivered to the cells, tissues, organs and/or organisms using routes of administration known in the art and described herein. In some embodiments, naked delivery may include formulation in a simple buffer such as saline or PBS.

[00125] In some embodiments, pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure may be formulated, using methods described herein. Formulations may comprise pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads which may be modified and/or unmodified. Formulations may further include, but are not limited to, cell penetration agents, pharmaceutically acceptable carriers, delivery agents, bioerodible or biocompatible polymers, solvents, and/or sustained-release delivery depots. Formulations of the present disclosure may be delivered to cells using routes of administration known in the art and described herein.

[00126] Pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads may also be formulated for direct delivery to organs or tissues in any of several ways in the art including, but not limited to, direct soaking or bathing, via a catheter, by gels, powder, ointments, creams, gels, lotions, and/or drops, by using substrates such as fabric or biodegradable materials coated or impregnated with compositions, and the like.

[00127] In another aspect of the disclosure, polynucleotides encoding CA2 biocircuits, CA2 effector modules, SREs (e.g., CA2 DRDs), payloads of interest (e.g., IL15) and compositions of the disclosure and vectors comprising said polynucleotides may be introduced into cells. As a non-limiting example, the cells may be effector immune cells.

[00128] In various embodiments, the present disclosure provides a cell comprising one or more nucleic acid molecules, one or more vectors or one or more recombinant proteins of the

disclosure. In some embodiments, a method of modulating the expression, function, and/or level of an IL15 payload in the cell are provided, said method comprising administering to the cell a stimulus to which the DRD is responsive, wherein the stimulus is administered in an amount sufficient to modulate the expression, function and/or level of the IL15 payload. In some embodiments, the cell is isolated. In some embodiments, the cell is a bacterial cell. In some embodiments, the cell is a mammalian cell. The mammalian cell may be a human cell. The human cell may be a T cell, natural killer (NK) cell, or tumor infiltrating lymphocyte (TIL). In some embodiments, the cell is a CD4⁺ or CD8⁺ T cell. In some embodiments, the human T cell or the human NK cell further comprises a polynucleotide encoding a chimeric antigen receptor (CAR) or T cell receptor (TCR), wherein the CAR or TCR comprises an antigen-binding domain specific to an antigen of interest. In some embodiments, the CAR comprises antigen-binding domain specific to CD19.

[00129] In one aspect of the disclosure, polynucleotides encoding CA2 biocircuits, CA2 effector modules, SREs (e.g., CA2 DRDs), payloads of interest (e.g., IL15) and compositions of the disclosure, may be packaged into viral vectors or integrated into viral genomes allowing transient or stable expression of the polynucleotides. Preferable viral vectors are retroviral vectors including lentiviral vectors and gamma retroviral vectors. In order to construct a retroviral vector, a polynucleotide molecule encoding a CA2 biocircuit, a CA2 effector module, a CA2 DRD or a payload of interest (e.g., an immunotherapeutic agent) is inserted into the viral genome in the place of certain viral sequences to produce a virus that is replication-defective. The recombinant viral vector is then introduced into a packaging cell line containing the gag, pol, and env genes, but without the LTR (for lentiviral vectors) and packaging components. The recombinant retroviral particles are secreted into the culture media, then collected, optionally concentrated, and used for gene transfer. Lentiviral vectors are especially preferred as they are capable of infecting both dividing and non-dividing cells.

[00130] Vectors may also be transferred to cells by non-viral methods by physical methods such as needles, electroporation, sonoporation, hyrdoporation; chemical carriers such as inorganic particles (e.g. calcium phosphate, silica, gold) and/or chemical methods. In some embodiments, synthetic or natural biodegradable agents may be used for delivery such as cationic lipids, lipid nano emulsions, nanoparticles, peptide-based vectors, or polymer-based vectors.

[00131] The CA2 biocircuit systems, CA2 effector modules, SREs and/or payloads of the present disclosure may be delivered using one or more modalities. The present disclosure also provides vectors that package polynucleotides of the disclosure encoding CA2 biocircuits, CA2 effector modules, SREs (e.g., CA2 DRDs) and IL15 payloads of interest, and combinations thereof. Vectors of the present disclosure may also be used to deliver the packaged polynucleotides to a cell, a local tissue site or a subject. These vectors may be of any kind, including DNA vectors, RNA vectors, plasmids, viral vectors and particles. Viral vector technology is well known and described in Sambrook et al. (2001, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, New York). Viruses, which are useful as vectors include, but are not limited to lentiviral vectors, adenoviral vectors, adeno-associated viral (AAV) vectors, herpes simplex viral vectors, retroviral vectors, oncolytic viruses, and the like. In some embodiments, a viral vector useful for introducing one or more nucleic acid molecules encoding a DRD and IL15 payload exemplified herein into a cell may be derived from an adenovirus, adeno-associated virus (AAV), alphavirus, flavivirus, herpes virus, measles virus, rhabdovirus, retrovirus, lentivirus, Newcastle disease virus (NDV), poxvirus, or picornavirus.

[00132] In general, vectors contain an origin of replication functional in at least one organism, a promoter sequence and convenient restriction endonuclease site, and one or more selectable markers e.g. a drug resistance gene.

[00133] In some embodiments, the recombinant expression vector may comprise regulatory sequences, such as transcription and translation initiation and termination codons, which are specific to the type of host cell into which the vector is to be introduced.

[00134] In some embodiments, the vector of the disclosure may comprise one or more payloads taught herein, wherein the two or more payloads may be included in one CA2 effector module. In this case, the two or more payloads are tuned by the same stimulus simultaneously. In other embodiments, the vector of the disclosure may comprise two or more CA2 effector modules, wherein each CA2 effector module comprises a different payload. In this case, the two or more CA2 effector modules and payloads are tuned by different stimuli, providing separately independent regulation of the two or more components. In other embodiments, the vector of the disclosure may comprise one or more CA2 effector modules and one or more non-CA2 effector modules, wherein each CA2 effector module comprises a different payload. In this case, the CA2

effector modules and payloads are tuned by different stimuli, providing separately independent regulation of the two or more components.

[00135] In some embodiments, lentiviral vehicles/particles may be used as delivery modalities. Lentiviruses are subgroup of the Retroviridae family of viruses, named because reverse transcription of viral RNA genomes to DNA is required before integration into the host genome. As such, the most important features of lentiviral vehicles/particles are the integration of their genetic material into the genome of a target/host cell. Some examples of lentivirus include the Human Immunodeficiency Viruses: HIV-1 and HIV-2, the Simian Immunodeficiency Virus (SIV), feline immunodeficiency virus (FIV), bovine immunodeficiency virus (BIV), Jembrana Disease Virus (JDV), equine infectious anemia virus (EIAV), equine infectious anemia virus, visna-maedi and caprine arthritis encephalitis virus (CAEV).

[00136] Typically, lentiviral particles making up the gene delivery vehicle are replication defective on their own (also referred to as “self-inactivating”). Lentiviruses are able to infect both dividing and non-dividing cells by virtue of the entry mechanism through the intact host nuclear envelope (Naldini L et al., Curr. Opin. Biotechnol, 1998, 9: 457-463). Recombinant lentiviral vehicles/particles have been generated by multiply attenuating the HIV virulence genes, for example, the genes Env, Vif, Vpr, Vpu, Nef and Tat are deleted making the vector biologically safe. Correspondingly, lentiviral vehicles, for example, derived from HIV-1/HIV-2 can mediate the efficient delivery, integration and long-term expression of transgenes into non-dividing cells. As used herein, the term “recombinant” refers to a vector or other nucleic acid containing both lentiviral sequences and non-lentiviral retroviral sequences.

[00137] Lentiviral particles may be generated by co-expressing the virus packaging elements and the vector genome itself in a producer cell such as human HEK293T cells. These elements are usually provided in three or four separate plasmids. The producer cells are co-transfected with plasmids that encode lentiviral components including the core (i.e. structural proteins) and enzymatic components of the virus, and the envelope protein(s) (referred to as the packaging systems), and a plasmid that encodes the genome including a foreign transgene, to be transferred to the target cell, the vehicle itself (also referred to as the transfer vector). In general, the plasmids or vectors are included in a producer cell line. The plasmids/vectors are introduced via transfection, transduction or infection into the producer cell line. Methods for transfection, transduction or infection are well known by those of skill in the art. As non-limiting example, the

packaging and transfer constructs can be introduced into producer cell lines by calcium phosphate transfection, lipofection or electroporation, generally together with a dominant selectable marker, such as neo, DHFR, Gln synthetase or ADA, followed by selection in the presence of the appropriate drug and isolation of clones.

[00138] The producer cell produces recombinant viral particles that contain the foreign gene, for example, the CA2 effector module of the present disclosure. The recombinant viral particles are recovered from the culture media and titrated by standard methods used by those of skill in the art. The recombinant lentiviral vehicles can be used to infect target cells.

[00139] Cells that can be used to produce high-titer lentiviral particles may include, but are not limited to, HEK293T cells, 293G cells, STAR cells (Relander et al., *Mol. Ther.*, 2005, 11: 452-459), FreeStyle™ 293 Expression System (ThermoFisher, Waltham, MA), and other HEK293T-based producer cell lines (e.g., Stewart et al., *Hum Gene Ther.* 2011, 22(3):357-369; Lee et al., *Biotechnol Bioeng.* 2012, 10996): 1551-1560; Throm et al., *Blood.* 2009, 113(21): 5104-5110; the contents of each of which are incorporated herein by reference in their entirety).

[00140] In some aspects, the envelope proteins may be heterologous envelop proteins from other viruses, such as the G protein of vesicular stomatitis virus (VSV G) or baculoviral gp64 envelop proteins. The VSV-G glycoprotein may especially be chosen among species classified in the vesiculovirus genus: Carajas virus (CJSV), Chandipura virus (CHPV), Cocal virus (COCV), Isfahan virus (ISFV), Maraba virus (MARAV), Piry virus (PIRYV), Vesicular stomatitis Alagoas virus (VSAV), Vesicular stomatitis Indiana virus (VSIV) and Vesicular stomatitis New Jersey virus (VSNJV) and/or stains provisionally classified in the vesiculovirus genus as Grass carp rhabdovirus, BeAn 157575 virus (BeAn 157575), Boteke virus (BTKV), Calchaqui virus (CQIV), Eel virus American (EVA), Gray Lodge virus (GLOV), Jurona virus (JURY), Klamath virus (KLAV), Kwatta virus (KWAV), La Joya virus (LJV), Malpais Spring virus (MSPV), Mount Elgon bat virus (MEBV), Perinet virus (PERV), Pike fry rhabdovirus (PFRV), Porton virus (PORV), Radi virus (RADIV), Spring viremia of carp virus (SVCV), Tupaia virus (TUPV), Ulcerative disease rhabdovirus (UDRV) and Yug Bogdanovac virus (YBV). The gp64 or other baculoviral env protein can be derived from Autographa californica nucleopolyhedrovirus (AcMNPV), Anagrapha falcifera nuclear polyhedrosis virus, Bombyx mori nuclear polyhedrosis virus, Choristoneura fumiferana nucleopolyhedrovirus, Orgyia pseudotsugata single capsid nuclear polyhedrosis virus, Epiphyas postvittana nucleopolyhedrovirus, Hyphantria cunea

nucleopolyhedrovirus, Galleria mellonella nuclear polyhedrosis virus, Dhori virus, Thogoto virus, Antheraea pernyi nucleopolyhedrovirus or Batken virus.

[00141] Other elements provided in lentiviral particles may comprise retroviral LTR (long-terminal repeat) at either 5' or 3' terminus, a retroviral export element, optionally a lentiviral reverse response element (RRE), a promoter or active portion thereof, and a locus control region (LCR) or active portion thereof. The CA2 effector module is linked to the vector.

[00142] Methods for generating recombinant lentiviral particles are discussed in the art, for example, U.S. Pat. NOs.: 8, 846, 385; 7,745, 179; 7,629,153; 7,575,924; 7,179, 903; and 6, 808, 905; the contents of each of which are incorporated herein by reference in their entirety.

[00143] Lentivirus vectors used may be selected from, but are not limited to pLVX, pLenti, pLenti6, pLJM1, FUGW, pWPXL, pWPI, pLenti CMV puro DEST, pLJM1-EGFP, pULTRA, pInducer20, pHIV-EGFP, pCW57.1, pTRPE, pELPS, pRRL, and pLionII.

[00144] Lentiviral vectors are used for introducing transgenes into T cells (e.g., primary human T cells or Jurkat cells) for preclinical research and clinical applications, including recently approved products such as Tisagenlecleucel (KYMRIA[®]) for relapsed/refractory B-cell lymphoma. VSV-G pseudotyped 3rd generation lentiviral vectors offer high titers, high transduction efficiency and safety, and have become the vectors of choice for T cell engineering. While not wishing to be bound by theory, T cell engineering usually involves T cell activation by CD3/CD28 antibodies, followed by lentivirus transduction, and then cell expansion which can last from 5 to 30 days (e.g., 9 to 14 days or 9 to 15 days). In general, lentivirus transgene integration may take over 7 days to fully stabilize in T cells (e.g., primary human T cells or Jurkat cells).

[00145] In some embodiments, to determine the transgene expression kinetics CD3/CD28 activated primary human T cells can be transduced with lentivirus carrying a transgene (e.g., IL15). The cells may be analyzed by methods described herein and/or known in the art for viability, viral genomic integration (e.g., by using quantitative PCR), transcript levels (e.g., by using quantitative RT-PCR), and cell surface expression of the transgene. The cells may be analyzed prior to transduction and/or after transduction such as 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11 days, 12 days, 13 days, 14 days, 15 days, 16 days, 17 days, 18 days, 19 days, 20 days, 21 days, 22 days, 23 days, 24 days, 25 days, 26 days, 27 days, 28 days, 29 days, 30 or more than 30 days after transduction. As a non-limiting

example, the cells may be analyzed at various time points between 3 to 14 days after transduction (e.g., 3 days, 4 days, 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11 days, 12 days, 13 days, and/or 14 days). As a non-limiting example, the cells may be analyzed 3 to 15 days after transduction. As a non-limiting example, the cells may be analyzed 9 to 15 days after transduction.

[00146] In some embodiments, the CD3/CD28 activated primary human T cells can be reactivated with CD3/CD28 beads after transduction. The cells may be reactivated 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11 days, 12 days, 13 days, 14 days, 15 days, 16 days, 17 days, 18 days, 19 days, 20 days, 21 days, 22 days, 23 days, 24 days, 25 days, 26 days, 27 days, 28 days, 29 days, 30 or more than 30 days after transduction. The cells may be analyzed by methods described herein and/or known in the art for viability, viral genomic integration (e.g., by using quantitative PCR), transcript levels (e.g., by using quantitative RT-PCR), cell surface expression of the transgene, copy number, and/or mRNA levels.

[00147] In some embodiments, the cell viability of activated primary human T cells transduced with lentivirus carrying a transgene is greater than 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, or 99%. As a non-limiting example, the cell viability is greater than 90%. As a non-limiting example, the cell viability is greater than 85%.

[00148] In some embodiments, the cell viability of Jurkat cells transduced with lentivirus carrying a transgene is greater than 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, or 99%. As a non-limiting example, the cell viability is greater than 90%. As a non-limiting example, the cell viability is greater than 85%.

[00149] In some embodiments, the integration of the transgene into the genome of the cell may be at or above the saturation point. As a non-limiting example, the saturation point may be 3 copies per cell.

[00150] In some embodiments, the integration of the transgene into the genome may be high in the initial timepoints evaluated and then decline to a lower integration value before becoming stable for the remainder of the culture. As a non-limiting example, the integration may be up to 20 copies per cell of the transgene into the genome during the early timepoints before declining to 2 copies per cell and being stable throughout the remainder of the culture.

[00151] In some embodiments, the transduction of ability of T cells may be evaluated. T cells from at least one donor may be transduced with a lentivirus containing a transgene at a dose that

is predicted to reach the saturating levels (e.g., enough virus that each cell should contain a copy if a Poisson distribution is expected) and a higher lentivirus dose that exceeds saturation 5 times. Copies per cell, percentage and MFI of cells (or concentration in media of transgene) may be detected in order to determine if all cells are expressing transgene. As a non-limiting example, T cells from two distinct donors may be transduced with lentivirus which includes a transgene. The transduction may be at two doses, saturation and 5x saturation, and show that 5-10 days after transduction that all groups may reach or exceed a predicted saturating level of integrated transgene and similar expression intensity across groups but not all cells are expressing the transgene. Not all T cells may have equal transduction susceptibility, even when sourced from the same donor. The fraction of total cells that express GFP (above the detection threshold) may vary between donors, lots and/or viral dose.

[00152] In some embodiments, a percentage of the cultured T cells (e.g., primary human T cells and/or Jurkat cells) may express the transgene. The percentage of culture T cells expressing the transgene may be, but is not limited to, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, 99% or greater than 99%. As a non-limiting example, the percentage may be greater than 70%. As a non-limiting example, the percentage may be greater than 75%. As a non-limiting example, the percentage may be greater than 80%. As a non-limiting example, the percentage may be greater than 85%. As a non-limiting example, the percentage may be greater than 90%. As a non-limiting example, the percentage may be greater than 95%.

[00153] In some embodiments, the mRNA levels from the culture may decline over the duration of the study. The decline may not be limited to a specific transgene and the trend may be seen across multiple classes of expressed proteins. In order to increase the mRNA levels, the cells may be reactivated after the mRNA levels decrease from the initial levels. The cells may be reactivated 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11 days, 12 days, 13 days, 14 days, 15 days, 16 days, 17 days, 18 days, 19 days, 20 days, 21 days, 22 days, 23 days, 24 days, 25 days, 26 days, 27 days, 28 days, 29 days, 30 or more than 30 days after transduction. As a non-limiting example, in order to increase mRNA levels in the culture, the cells may be reactivated with CD3/CD28 beads 13 days after transduction. As a non-limiting example, in order to increase mRNA levels in the culture, the cells may be reactivated with CD3/CD28 beads 14 days after

transduction. As a non-limiting example, in order to increase mRNA levels in the culture, the cells may be reactivated with CD3/CD28 beads 15 days after transduction

[00154] In some embodiments, the surface expression from the culture may decline over the duration of the study. For example, the surface expression may decline between days 3 to 13 days, 3 to 14 days, or 3 to 15 days after transduction. In order to increase the surface expression, the cells may be reactivated after the surface expression decrease from the initial levels. The cells may be reactivated 5 days, 6 days, 7 days, 8 days, 9 days, 10 days, 11 days, 12 days, 13 days, 14 days, 15 days, 16 days, 17 days, 18 days, 19 days, 20 days, 21 days, 22 days, 23 days, 24 days, 25 days, 26 days, 27 days, 28 days, 29 days, 30 or more than 30 days after transduction. As a non-limiting example, in order to increase surface expression in the culture, the cells may be reactivated with CD3/CD28 beads 13 days after transduction. As a non-limiting example, in order to increase surface expression in the culture, the cells may be reactivated with CD3/CD28 beads 14 days after transduction. As a non-limiting example, in order to increase surface expression in the culture, the cells may be reactivated with CD3/CD28 beads 15 days after transduction.

[00155] In some embodiments, the transgene is IL15 (e.g., a membrane bound IL15 payload when combined with the other effector module components described in Table 3). The cell viability may be greater than 90% in cells transduced with IL15. The cell viability may be greater than 85% in cells transduced with IL15. If the cells are primary T cells transduced with IL15, the number of viable cells may increase over the initial timepoints before decreasing. If the cells are Jurkat cells transduced with IL15, the number of viable cells may increase for at least 10 days. The number of copies per cell for IL15 transduced cells may be higher for the initial timepoints before decreasing by 50% or more for the later timepoints. For IL15 transduced primary human T cells, the level of soluble IL15 in the media may drop steadily over the time course of the study with a slight increase visible in the restimulated group. For IL15 transduced Jurkat cells, the level of soluble IL15 in the media may have a drop in IL15 secretion in the first half of the culture with the levels remaining low through the second half of the culture time.

[00156] In some embodiments, lentivirally engineered cells described herein have genomic DNA integration that stabilizes after an initial decline of copy number, decreasing RNA and surface expression levels over time, and an increase in RNA and surface expression after re-stimulation.

[00157] In some embodiments, lentivirally engineering cells may be evaluated using the following 14-day method where samples are collected 5 times throughout the culture. On day -1 the T cells (e.g., primary human T cells or Jurkat cells) may be thawed and the CD3/CD28 beads are added. On day 0, the lentivirus for each of the conditions is added (e.g., 4 mL of cells at 0.5×10^6 /mL) and there is a control of non-transduced cells. Double media to 8 mL on day 1 and then double the media to 16 mL on day 2. On day 3, harvest 4 mL and then double media to 24 mL on day 4. Harvest 4 mL on day 6 before doubling media to 40 mL. The cells can be split (e.g., 14 mL 0.5×10^6 cells/mL) on day 8 and then on day 6 harvest 4 mL before doubling media to 40 mL. 4mL may be harvested on day 10 before the media is doubled to 20 mL. On day 13, 4 mL are harvested before doubling the media to 32 mL. The culture is split in half and half of the culture is activated (CD3/CD28 activation beads 1:1) and stimulated overnight. On day 14, 4 mL of each stimulated and non-stimulated cells are harvested and the culture is ended. Transgene copy number per cell are assayed by harvesting cells and extracting genomic DNA then quantifying with standard curve qPCR against the endogenous genome and against the transgene sequence, then converting the detected quantities to a ratio. Mean Fluorescence Intensity (MFI) is assayed by FLO on an Attune with appropriate staining for each group. Percent expressing may also be assayed by FLO on an attune quantifying the percent of cells fluorescing above threshold. Soluble payloads can be quantified by harvesting culture supernatant at each marked timepoint and running MesoScale Discovery plate assay (MSD) then normalizing for cell density.

[00158] In some embodiments, the CA2 effector modules of the disclosure may be designed as a messenger RNA (mRNA). As used herein, the term “messenger RNA” (mRNA) refers to any polynucleotide which encodes a polypeptide of interest and which is capable of being translated to produce the encoded polypeptide of interest in vitro, in vivo, in situ or ex vivo.

[00159] The present disclosure provides methods comprising administering any one or more or components of a CA2 biocircuit system to a subject in need thereof. These may be administered to a subject using any amount and any route of administration effective for preventing or treating or imaging a disease, disorder, and/or condition (e.g., a disease, disorder, and/or condition relating to working memory deficits). The exact amount required will vary from subject to subject, depending on the species, age, and general condition of the subject, the severity of the disease, the particular composition, its mode of administration, its mode of activity, and the like.

[00160] In some embodiments, the present disclosure provides a method of treating a disease or disorder responsive to regulated IL15 in a subject in need thereof, said method comprising: (a) administering to the subject a therapeutically effective amount of a nucleic acid molecule, vector, recombinant protein, cell, or pharmaceutical composition of the disclosure; and administering a therapeutically effective amount of a stimulus to the subject, wherein the DRD is responsive to the stimulus and wherein expression of the IL15 payload is modulated in response to the stimulus. In some embodiments, the stimulus is selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide. In some embodiments, the stimulus is acetazolamide.

[00161] In some embodiments, the present disclosure provides a method of treating a malignant tumor in a subject in need thereof, wherein said tumor expresses a tumor-associated antigen, said method comprising: (a) administering to the subject a therapeutically effective amount of a human T cell or a human NK cell of the disclosure, which further comprises a polynucleotide encoding a CAR or TCR, or a pharmaceutical composition thereof, wherein the CAR or TCR comprises an antigen-binding domain specific to the tumor-associated antigen; and (b) administering a therapeutically effective amount of a stimulus to the subject, wherein the CA2 DRD is responsive to the stimulus and wherein expression of the IL15 payload is modulated in response to the stimulus. In some embodiments, the stimulus is selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide. In some embodiments, the stimulus administered to the subject is acetazolamide.

[00162] In some embodiments, the present disclosure provides a method of treating a malignant tumor in a subject in need thereof, said method comprising: (a) administering to the subject a therapeutically effective amount of a human TIL of the disclosure; and (b) administering a therapeutically effective amount of a stimulus to the subject, wherein the CA2 DRD is responsive to the stimulus and wherein expression of the IL15 payload is modulated in response to the stimulus. In some embodiments, the stimulus is selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide. In some embodiments, the stimulus administered to the subject is acetazolamide.

[00163] Compositions in accordance with the disclosure are typically formulated in dosage unit form for ease of administration and uniformity of dosage. It will be understood, however, that the total daily usage of the compositions of the present disclosure may be decided by the attending physician within the scope of sound medical judgment. The specific therapeutically effective, prophylactically effective, or appropriate imaging dose level for any particular patient will depend upon a variety of factors including the disorder being treated and the severity of the disorder; the activity of the specific compound employed; the specific composition employed; the age, body weight, general health, sex and diet of the patient; the time of administration, route of administration, and rate of excretion of the specific compound employed; the duration of the treatment; drugs used in combination or coincidental with the specific compound employed; and like factors well known in the medical arts.

[00164] Compositions of the disclosure may be used in varying doses to avoid T cell anergy, prevent cytokine release syndrome and minimize toxicity associated with immunotherapy. For example, low doses of the compositions of the present disclosure may be used to initially treat patients with high tumor burden, while patients with low tumor burden may be treated with high and repeated doses of the compositions of the disclosure to ensure recognition of a minimal tumor antigen load. In another instance, the compositions of the present disclosure may be delivered in a pulsatile fashion to reduce tonic T cell signaling and enhance persistence in vivo. In some aspects, toxicity may be minimized by initially using low doses of the compositions of the disclosure, prior to administering high doses. Dosing may be modified if serum markers such as ferritin, serum C-reactive protein, IL6, IFN- γ , and TNF- α are elevated.

[00165] Also provided herein are methods of administering ligands in accordance with the disclosure to a subject in need thereof. The ligand may be administered to a subject or to cells, using any amount and any route of administration effective for tuning the CA2 biocircuits of the present disclosure. The exact amount required will vary from subject to subject, depending on the species, age, and general condition of the subject, the severity of the disease, the particular composition, its mode of administration, its mode of activity, and the like. The subject may be a human, a mammal, or an animal. Compositions in accordance with the present disclosure are typically formulated in unit dosage form for ease of administration and uniformity of dosage. It will be understood, however, that the total daily usage of the compositions of the present disclosure may be decided by the attending physician within the scope of sound medical

judgment. In certain embodiments, the ligands in accordance with the present disclosure may be administered at dosage levels sufficient to deliver from about 0.0001 mg/kg to about 100 mg/kg, from about 0.001 mg/kg to about 0.05 mg/kg, from about 0.005 mg/kg to about 0.05 mg/kg, from about 0.001 mg/kg to about 0.005 mg/kg, from about 0.05 mg/kg to about 0.5 mg/kg, from about 0.01 mg/kg to about 50 mg/kg, from about 0.1 mg/kg to about 40 mg/kg, from about 0.5 mg/kg to about 30 mg/kg, from about 0.01 mg/kg to about 10 mg/kg, from about 0.1 mg/kg to about 10 mg/kg, or from about 1 mg/kg to about 25 mg/kg, from about 10 mg/kg to about 100 mg/kg, from about 50 mg/kg to about 500 mg/kg, from about 100 mg/kg to about 1000 mg/kg, of subject body weight per day, one or more times a day, to obtain the desired effect. In some embodiments, the dosage levels may be 1mg/kg, 5 mg/kg, 10mg/kg, 20mg/kg, 30 mg/kg, 40 mg/kg, 50 mg/kg, 60 mg/kg, 70 mg/kg, 80 mg/kg, 90 mg/kg, 100 mg/kg, 100 mg/kg, 110 mg/kg, 120 mg/kg, 130 mg/kg, 140 mg/kg, 150 mg/kg, 160 mg/kg, 170 mg/kg, 180 mg/kg, 190 mg/kg or mg/kg of subject body weight per day, or more times a day, to obtain the desired effect.

[00166] The present disclosure provides methods for delivering to a cell or tissue any of the ligands described herein, comprising contacting the cell or tissue with said ligand and can be accomplished in vitro, ex vivo, or in vivo. In certain embodiments, the ligands in accordance with the present disclosure may be administered to cells at dosage levels sufficient to deliver from about 1 nM to about 10 nM, from about 5 nM to about 50 nM, from about 10 nM to about 100 nM, from about 50 nM to about 500 nM, from about 100 nM to about 1000 nM, from about 1 μ M to about 10 μ M from about 5 μ M to about 50 μ M from about 10 μ M to about 100 μ M from about 25 μ M to about 250 μ M from about 50 μ M to about 500 μ M. In some embodiments, the ligand may be administered to cells at doses selected from but not limited to 0.00064 μ M, 0.0032 μ M, 0.016 μ M, 0.08 μ M, 0.4 μ M, 1 μ M 2 μ M, 10 μ M, 50 μ M, 75, μ M, 100 μ M, 150 μ M, 175 μ M, 200 μ M, 250 μ M.

[00167] The desired dosage of the ligands of the present disclosure may be delivered only once, three times a day, two times a day, once a day, every other day, every third day, every week, every two weeks, every three weeks, or every four weeks. In certain embodiments, the desired dosage may be delivered using multiple administrations (e.g., two, three, four, five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, or more administrations). When multiple administrations are employed, split dosing regimens such as those described herein may

be used. As used herein, a “split dose” is the division of “single unit dose” or total daily dose into two or more doses, e.g., two or more administrations of the “single unit dose”. As used herein, a “single unit dose” is a dose of any therapeutic administered in one dose/at one time/single route/single point of contact, i.e., single administration event. The desired dosage of the ligand of the present disclosure may be administered as a “pulse dose” or as a “continuous flow”. As used herein, a “pulse dose” is a series of single unit doses of any therapeutic administered with a set frequency over a period of time. As used herein, a “continuous flow” is a dose of therapeutic administered continuously for a period of time in a single route/single point of contact, i.e., continuous administration event. A total daily dose, an amount given or prescribed in 24-hour period, may be administered by any of these methods, or as a combination of these methods, or by any other methods suitable for a pharmaceutical administration.

[00168] In some embodiments, the compositions for immunotherapy may be administered to cells ex vivo and subsequently administered to the subject. Immune cells can be isolated and expanded ex vivo using a variety of methods known in the art. For example, methods of isolating cytotoxic T cells are described in U.S. Pat. Nos. 6,805,861 and 6,531, 451; the contents of each of which are incorporated herein by reference in their entirety. Isolation of NK cells is described in U.S. Pat. NOs. 7,435, 596; the contents of which are incorporated by reference herein in its entirety.

[00169] In some embodiments, depending upon the nature of the cells, the cells may be introduced into a host organism e.g. a mammal, in a wide variety of ways including by injection, transfusion, infusion, local instillation or implantation. In some aspects, the cells described herein may be introduced at the site of the tumor. The number of cells that are employed will depend upon a number of circumstances, the purpose for the introduction, the lifetime of the cells, the protocol to be used, for example, the number of administrations, the ability of the cells to multiply, or the like. The cells may be in a physiologically-acceptable medium.

[00170] In some embodiments, the cells described herein may be administered in multiple doses to subjects having a disease or condition. The administrations generally effect an improvement in one or more symptoms of cancer or a clinical condition and/or treat or prevent cancer or clinical condition or symptom thereof.

[00171] In some embodiments, the compositions for immunotherapy may be administered in vivo. In some embodiments, polypeptides of the present disclosure comprising CA2 biocircuits,

CA2 effector molecules, SREs, payloads of interest (IL15) and compositions of the disclosure may be delivered in vivo to the subject. In vivo delivery of immunotherapeutic agents is well described in the art. For example, methods of delivery of cytokines are described in the EP Pat. No. EP0930892 A1, the contents of which are incorporated herein by reference.

[00172] The pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs (e.g., CA2 DRDs), payloads (e.g., IL15), vectors and cells of the present disclosure may be administered by any route to achieve a therapeutically effective outcome.

[00173] The pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure may be administered by any route to achieve a therapeutically effective outcome. These include, but are not limited to enteral (into the intestine), gastroenteral, epidural (into the dura matter), oral (by way of the mouth), transdermal, peridural, intracerebral (into the cerebrum), intracerebroventricular (into the cerebral ventricles), epicutaneous (application onto the skin), intradermal, (into the skin itself), subcutaneous (under the skin), nasal administration (through the nose), intravenous (into a vein), intravenous bolus, intravenous drip, intraarterial (into an artery), intramuscular (into a muscle), intracardiac (into the heart), intraosseous infusion (into the bone marrow), intrathecal (into the spinal canal), intraperitoneal, (infusion or injection into the peritoneum), intravesical infusion, intravitreal, (through the eye), intracavernous injection (into a pathologic cavity) intracavitary (into the base of the penis), intravaginal administration, intrauterine, extra-amniotic administration, transdermal (diffusion through the intact skin for systemic distribution), transmucosal (diffusion through a mucous membrane), transvaginal, insufflation (snorting), sublingual, sublabial, enema, eye drops (onto the conjunctiva), in ear drops, auricular (in or by way of the ear), buccal (directed toward the cheek), conjunctival, cutaneous, dental (to a tooth or teeth), electro-osmosis, endocervical, endosinusial, endotracheal, extracorporeal, hemodialysis, infiltration, interstitial, intra-abdominal, intra-amniotic, intra-articular, intrabiliary, intrabronchial, intrabursal, intracartilaginous (within a cartilage), intracaudal (within the cauda equine), intracisternal (within the cisterna magna cerebellomedularis), intracorneal (within the cornea), dental intracornal, intracoronary (within the coronary arteries), intracorporus cavernosum (within the dilatable spaces of the corporus cavernosa of the penis), intradiscal (within a disc), intraductal (within a duct of a gland), intraduodenal (within the duodenum),

intradural (within or beneath the dura), intraepidermal (to the epidermis), intraesophageal (to the esophagus), intragastric (within the stomach), intragingival (within the gingivae), intraileal (within the distal portion of the small intestine), intralesional (within or introduced directly to a localized lesion), intraluminal (within a lumen of a tube), intralymphatic (within the lymph), intramedullary (within the marrow cavity of a bone), intrameningeal (within the meninges), intramyocardial (within the myocardium), intraocular (within the eye), intraovarian (within the ovary), intrapericardial (within the pericardium), intrapleural (within the pleura), intraprostatic (within the prostate gland), intrapulmonary (within the lungs or its bronchi), intrasinal (within the nasal or periorbital sinuses), intraspinal (within the vertebral column), intrasynovial (within the synovial cavity of a joint), intratendinous (within a tendon), intratesticular (within the testicle), intrathecal (within the cerebrospinal fluid at any level of the cerebrospinal axis), intrathoracic (within the thorax), intratubular (within the tubules of an organ), intratumor (within a tumor), intratympanic (within the auras media), intravascular (within a vessel or vessels), intraventricular (within a ventricle), iontophoresis (by means of electric current where ions of soluble salts migrate into the tissues of the body), irrigation (to bathe or flush open wounds or body cavities), laryngeal (directly upon the larynx), nasogastric (through the nose and into the stomach), occlusive dressing technique (topical route administration which is then covered by a dressing which occludes the area), ophthalmic (to the external eye), oropharyngeal (directly to the mouth and pharynx), parenteral, percutaneous, periarticular, peridural, perineural, periodontal, rectal, respiratory (within the respiratory tract by inhaling orally or nasally for local or systemic effect), retrobulbar (behind the pons or behind the eyeball), intramyocardial (entering the myocardium), soft tissue, subarachnoid, subconjunctival, submucosal, topical, transplacental (through or across the placenta), transtracheal (through the wall of the trachea), transtympanic (across or through the tympanic cavity), ureteral (to the ureter), urethral (to the urethra), vaginal, caudal block, diagnostic, nerve block, biliary perfusion, cardiac perfusion, photophoresis or spinal.

[00174] In some embodiments, pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure may be administered parenterally. Liquid dosage forms for oral and parenteral administration include, but are not limited to, pharmaceutically acceptable emulsions, microemulsions, solutions, suspensions, syrups, and/or elixirs. In addition to active ingredients, liquid dosage

forms may comprise inert diluents commonly used in the art such as, for example, water or other solvents, solubilizing agents and emulsifiers such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, dimethylformamide, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor, and sesame oils), glycerol, tetrahydrofurfuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof. Besides inert diluents, oral compositions can include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, and/or perfuming agents. In certain embodiments for parenteral administration, compositions are mixed with solubilizing agents such as CREMOPHOR®, alcohols, oils, modified oils, glycols, polysorbates, cyclodextrins, polymers, and/or combinations thereof. In other embodiments, surfactants are included such as hydroxypropylcellulose.

[00175] Injectable preparations, for example, sterile intravenous preparations or injectable aqueous or oleaginous suspensions may be formulated according to the known art using suitable dispersing agents, wetting agents, and/or suspending agents. Sterile injectable preparations may be sterile injectable solutions, suspensions, and/or emulsions in nontoxic parenterally acceptable diluents and/or solvents, for example, as a solution in 1,3-butanediol. Among the acceptable vehicles and solvents that may be employed are water, Ringer's solution, U.S.P., and isotonic sodium chloride solution. Sterile, fixed oils are conventionally employed as a solvent or suspending medium. For this purpose, any bland fixed oil can be employed including synthetic mono- or diglycerides. Fatty acids such as oleic acid can be used in the preparation of injectables.

[00176] Injectable formulations may be sterilized, for example, by filtration through a bacterial-retaining filter, and/or by incorporating sterilizing agents in the form of sterile solid compositions which can be dissolved or dispersed in sterile water or other sterile injectable medium prior to use.

[00177] The CA2 biocircuits, CA2 effector modules, SREs, stimuli, compositions or systems comprising one or more of the stimuli, CA2 biocircuits, CA2 effector modules of the present disclosure may be utilized in a large variety of applications including, but not limited to, therapeutics, diagnosis and prognosis, bioengineers, bioprocessing, biofactory, research agents, metabolomics, gene expression, enzyme replacement, etc.

[00178] According to the present disclosure, the CA2-IL15 biocircuits and systems may be used in the development and implementation of cell therapies such as adoptive cell therapy. The

CA2-IL15 biocircuits and systems may be used to effect CAR T cell therapy, T cell receptor (TCR) cell therapy, CAR NK cell therapy, TCR NK cell therapy, TIL therapy, any of which may be used in combination therapy with other treatment lines (e.g. radiation, cytokines).

[00179] In some embodiments, CA2-IL15 biocircuits and systems may be used to engineer immune cells including T cells such as CD8⁺ T cells and CD4⁺ T cells, natural killer (NK) cells, NK T cells, Cytotoxic T lymphocytes (CTLs), tumor infiltrating lymphocytes (TIL), lymphokine activated killer (LAK) cells, memory T cells, regulatory T cells (Tregs), helper T cells, cytokine-induced killer (CIK) cells, and any combination thereof. In other embodiments, CA2-IL15 biocircuits and systems may be used to engineer immune stimulatory cells generated from embryonic stem cell (ESC) and induced pluripotent stem cell (iPSC) that may be used for ACT. In some embodiments, CA2-IL15 biocircuits and systems may be used to engineer autologous or allogeneic immune cells that may be used for ACT. In some embodiments, CA2-IL15 biocircuits and systems may be used to engineer T cells, TIL or NK cells. In some embodiments, the immune cells are NK cells derived from cord blood, iPSCs or peripheral blood mononuclear cells.

[00180] In some embodiments, CA2-IL15-engineered cells used for ACT may be T cells that also have been engineered to express a CAR or TCR comprising an antigen-binding domain specific to an antigen on tumor cells of interest. In other embodiments, CA2-IL15-engineered cells used for ACT may be NK cells engineered to express a CAR or TCR comprising an antigen-binding domain specific to an antigen on tumor cells of interest. In some embodiments, CA2-IL15-engineered cells used for ACT may be a mixture of T cells and NK cells, either or both of which may be expressing a CAR or TCR.

[00181] A chimeric antigen receptor (CAR), when transduced into immune cells (e.g., T cells and NK cells), can re-direct the immune cells against a target (e.g., a tumor cell) which expresses a molecule recognized by the extracellular target moiety of the CAR. As used herein, the term “chimeric antigen receptor (CAR)” refers to a synthetic receptor that mimics TCR on the surface of T cells. In general, a CAR is composed of an extracellular targeting domain, a transmembrane domain/region and an intracellular signaling/activation domain. In a standard CAR receptor, the extracellular targeting domain, transmembrane domain and intracellular signaling/activation domain, are linearly constructed as a single fusion protein. The extracellular region comprises a targeting domain/moiety (e.g., a scFv) that recognizes a specific tumor antigen (e.g., a tumor

neoantigen) or other tumor cell-surface molecules. The intracellular region may contain a intracellular signaling domain (the immunoreceptor tyrosine-based activation motifs) of TCR complex (e.g., the signaling region of CD3 ζ), and/or one or more costimulatory signaling domains, such as those from CD28, 4-1BB (CD137) and OX-40 (CD134). A CAR, when expressed by a T cell or NK cell, endows the T cell or NK cell with antigen specificity determined by the extracellular targeting moiety of the CAR.

[00182] In some embodiments, the extracellular targeting domain is joined through the hinge (also called space domain or spacer) and transmembrane regions to an intracellular signaling domain. The hinge connects the extracellular targeting domain to the transmembrane domain which transverse the cell membrane and connects to the intracellular signaling domain. The hinge may need to be varied to optimize the potency of CAR transformed cells toward cancer cells due to the size of the target protein where the targeting moiety binds, and the size and affinity of the targeting domain itself. Upon recognition and binding of the targeting moiety to the target cell, the intracellular signaling domain leads to an activation signal to the CAR T cell or CAR NK cell, which is further amplified by the “second signal” from one or more intracellular costimulatory domains. The CAR T cell or CAR NK cell, once activated, can destroy the target cell.

[00183] In some embodiments, the present disclosure provides an immune cell comprising a CA2-IL15 effector module and further comprising a chimeric antigen receptor (CAR). The CAR may be regulated by a DRD or may be constitutively expressed. In some embodiments, the CAR is constitutively expressed.

[00184] In some embodiments, the constitutively expressed or regulated CAR and the CA2-IL15 effector module are encoded on different vectors. In some embodiments, a single vector comprises both the CA2-IL15 effector module and the constitutively expressed or regulated CAR to form a tandem construct. The CA2-IL15 effector module and the CAR may be separated from one another by an internal ribosome entry site (IRES); a ribosomal skipping sequence 2A peptide selected from foot-and-mouth disease virus (FMDV) 2A (F2A), equine rhinitis A virus (ERAV) 2A (E2A), porcine teschovirus-1 2A (P2A) or Thosea asigna virus 2A (T2A); or other ribosomal skipping sequence or ribosomal entry sequence, giving rise to a bicistronic construct. In some embodiments, the 2A sequence is a P2A sequence. The IRES, 2A sequence, or other ribosomal skipping sequence or ribosomal entry sequence leads to the expression of the upstream and

downstream sequences expressed as two independent polypeptides. In some embodiments, a single vector comprises, in order, a sequence encoding a CAR, a P2A sequence, and a sequence encoding the CA2-IL15 effector module. The sequence encoding the CAR may be either 5' or 3' to the sequence encoding the CA2-IL15 effector module.

[00185] A T cell receptor (TCR) when transduced into immune cells (e.g., T cells and NK cells), can re-direct the immune cells against a target (e.g., a tumor cell) which expresses a molecule recognized by the TCR. A TCR is a molecule that contains a variable α and β chains (also known as TCR α and TCR β , respectively) or a variable γ and δ chains (also known as TCR γ and TCR δ , respectively), or antigen-binding portions or fragments thereof, which is capable of specifically binding to a peptide bound to an MHC molecule. In some embodiments, the TCR is TCR $\alpha\beta$. Generally, a TCR is found on the surface of T cells where it is generally responsible for recognizing antigens bound to major histocompatibility complex (MHC) molecules.

[00186] As used herein, the term TCR encompasses full TCRs as well as antigen-binding portions or antigen-binding fragments thereof. In some embodiments, the TCR is a full-length TCR comprising both the α chain and β chain. In some embodiments, the TCR is an antigen-binding portion or fragment of a TCR, for example a portion of each of the α chain and β chain, that binds to a specific peptide bound in an MHC molecule. In some embodiments, the antigen-binding portion or fragment comprises the variable domains of a TCR, such as the variable α (V α) chain and variable β (V β) chain, sufficient to bind to a specific MHC-peptide complex.

[00187] The variable domains of the TCR contain complementarity determining regions (CDRs), which primarily contribute to MHC-peptide antigen recognition, binding and specificity. The CDRs within a variable region of a TCR chain are separated by framework regions (FRs), which typically display less variability than the CDRs. In some embodiments, one or more CDRs of a TCR form all or substantially all of the antigen-binding site of a given TCR molecule. In some embodiments, CDR3 is the main CDR responsible for antigen binding or specificity and for interaction with the processed peptide portion of the peptide-MHC complex.

[00188] The α -chain and β -chain of a TCR also may contain a constant domain, a transmembrane domain and a short cytoplasmic tail. The cytoplasmic tail of a TCR, anchors the protein in the cell membrane, where it associates with invariant subunits of the CD3 complex, which are involved in the signaling capacity of the TCR complex.

[00189] In some embodiments, the present disclosure provides a CAR T cell or TCR T cell that is “armed” with a CA2-IL15 effector module to improve the engineered cells’ efficacy and persistence.

[00190] In some embodiments, the present disclosure provides CAR NK cell or TCR NK cell that is “armed” with a CA2-IL15 effector module to improve the engineered cells’ efficacy and persistence or prevent immune exhaustion and senescence.

[00191] In some embodiments, the present disclosure provides TIL engineered with a CA2-IL15 effector module to improve the engineered cells’ efficacy and persistence.

[00192] In some embodiments, cells of the present disclosure may be autologous, allogeneic, syngeneic, or xenogeneic in relation to a particular individual subject. In some embodiments, cells of the present disclosure may be mammalian cells, particularly human cells. Cells described herein may be primary cells or immortalized cell lines.

[00193] Cancer immunotherapy aims at the induction or restoration of the reactivity of the immune system towards cancer. Adoptive cell therapy is a form of active immunotherapy that aims at induction of an endogenous, long-lasting tumor-antigen specific immune response. The response may be enhanced by non-specific stimulation of immune response modifiers such as cytokines but cytokine stimulation can cause toxicity or immune exhaustion.

[00194] Despite significant advances, the efficacy of current immunotherapy strategies is limited by associated toxicities. These are often related to the narrow therapeutic window associated with immunotherapy, which in part, emerges from the need to push therapy dose to the edge of potentially fatal toxicity to get a clinically meaningful treatment effect. Further, dose expands in vivo since adoptively transferred immune cells continue to proliferate within the patient, often unpredictably.

[00195] A major risk involved in immunotherapy is the on-target but off tumor side effects resulting from T cell activation in response to normal tissue expression of the tumor associated antigen (TAA).

[00196] Immunotherapy may also produce on target, on-tumor toxicities that emerge when tumor cells are killed in response to the immunotherapy. The adverse effects include tumor lysis syndrome, cytokine release syndrome and the related macrophage activation syndrome.

Importantly, these adverse effects may occur during the destruction of tumors, and thus even a successful on-tumor immunotherapy might result in toxicity. Approaches to regulatably control

immunotherapy are thus highly desirable since they have the potential to reduce toxicity and maximize efficacy.

[00197] The present disclosure provides systems, compositions, immunotherapeutic agents and methods for cancer immunotherapy. These compositions provide tunable regulation of gene expression and function in immunotherapy. The present disclosure also provides CA2 biocircuits, CA2 effector modules, stimulus response elements (SREs) and payloads, as well as polynucleotides encoding any of the foregoing. In one aspect, the systems, compositions, immunotherapeutic agents and other components of the disclosure can be controlled by a separately added stimulus, which provides a significant flexibility to regulate cancer immunotherapy. Further, the systems, compositions and the methods of the present disclosure may also be combined with therapeutic agents such as chemotherapeutic agents, small molecules, gene therapy, and antibodies.

[00198] The tunable nature of the systems and compositions of the disclosure has the potential to improve the potency and duration of the efficacy of immunotherapies. Reversibly silencing the biological activity of adoptively transferred cells using compositions of the present disclosure allows maximizing the potential of cell therapy without irretrievably killing and terminating the therapy.

[00199] The present disclosure provides methods for fine tuning of immunotherapy after administration to patients. This in turn improves the safety and efficacy of immunotherapy and increases the subject population that may benefit from immunotherapy.

[00200] In one embodiment, the CA2 biocircuits, CA2 effector modules, SREs, and components that tune expression levels and activities of any agents may be used for immunotherapy. As non-limiting examples, the immunotherapeutic agent used in the constructs of the present disclosure is IL15 that induces an immune response in a cell and a subject.

[00201] In some embodiments, the composition for inducing an immune response may comprise a CA2 effector module. In some embodiments, the CA2 effector module may comprise a stimulus response element (SRE) operably linked to a human IL15 comprising the amino acid sequence of SEQ ID NO: 8.

[00202] In some embodiments, CA2 biocircuits, CA2 effector modules, and compositions of the present disclosure relate to post-translational regulation of protein (payload) function anti-tumor immune responses of immunotherapeutic agents.

[00203] In some embodiments, cells which are genetically modified to express at least one CA2 biocircuit, CA2 effector module, SRE (e.g., CA2 DRD), and/or payload of interest (immunotherapeutic agent) may be used for adoptive cell therapy (ACT). As used herein, adoptive cell transfer refers to the administration of immune cells (from autologous, allogenic or genetically modified hosts) with direct anticancer activity. ACT has shown promise in clinical application against malignant and infectious disease.

[00204] According to the present disclosure, the CA2 biocircuits and systems may be used in the development and implementation of cell therapies such as adoptive cell therapy. The CA2 biocircuits, CA2 effector modules and their SREs and payloads may be used in cell therapies to effect immune cell therapies alone or in combination with other treatment lines (e.g. radiation, cytokines).

[00205] Provided herein are methods for use in adoptive cell therapy. In one embodiment, the method involves preconditioning a subject in need thereof, removing a portion of the subject's T cells, engineering the subject's T cells with a CA2 effector module of the present disclosure, and administering to the subject the engineered T cells expressing the CA2 effector module, wherein the engineered cells successfully engraft within the subject.

[00206] In another embodiment, the method involves preconditioning a subject in need thereof and administering to the subject allogeneic engineered T cells expressing the CA2 effector module, wherein the engineered cells successfully engraft within the subject.

[00207] In some embodiments, the method involves removing a malignant tumor from a subject, isolating TIL from the tumor, engineering the TIL with the CA2 effector module of the present disclosure, and administering to the subject the engineered TIL, wherein the TIL successfully infiltrate any remaining tumor or metastases in the subject.

[00208] In some embodiments, SREs, CA2 biocircuits and compositions of the present disclosure may be used to minimize preconditioning regimens associated with adoptive cell therapy. As used herein "preconditioning" refers to any therapeutic regimen administered to a subject to improve the outcome of adoptive cell therapy. Preconditioning strategies include but are not limited to total body irradiation and/or lymphodepleting chemotherapy. Adoptive therapy clinical trials without preconditioning have failed to demonstrate any clinical benefit, indicating its importance in ACT. Yet, preconditioning is associated with significant toxicity and limits the subject cohort that is suitable for ACT. In some instances, immune cells for ACT may be

engineered to express cytokines such as IL15 as payload using SREs of the present disclosure to reduce the need for preconditioning.

[00209] In some embodiments, NK cells engineered to express the present compositions may be used for ACT. NK cell activation induces perforin/granzyme-dependent apoptosis in target cells. NK cell activation also induces cytokine secretion such as IFN γ , TNF- α and GM-CSF. These cytokines enhance the phagocytic function of macrophages and their antimicrobial activity and augment the adaptive immune response via up-regulation of antigen presentation by antigen presenting cells such as dendritic cells (DCs).

[00210] Immune cells can be isolated and expanded ex vivo using a variety of methods known in the art. For example, methods of isolating and expanding cytotoxic T cells are described in U.S. Pat. NOs. 6,805,861 and 6,531,451; US Patent Publication NO. US20160348072A1 and International Patent Publication NO. WO2016168595A1; the contents of each of which are incorporated herein by reference in their entirety. Isolation and expansion of NK cells is described in US Patent Publication NO. US20150152387A1, U.S. Patent NO. 7,435,596; and Oyer, J.L. (2016). *Cytotherapy*.18(5):653-63; the contents of each of which are incorporated by reference herein in its entirety. Specifically, human primary NK cells may be expanded in the presence of feeder cells e.g. a myeloid cell line that has been genetically modified to express membrane bound IL15 and 4-1BBL.

[00211] In some embodiments, activation and expansion of T cells for ACT is achieved by antigenic stimulation of a transiently expressed Chimeric Antigen Receptor (CAR) on the cell surface. Such activation methods are taught in International Patent NO. WO2017015427, the content of which are incorporated herein by reference in their entirety.

[00212] In some embodiments, immune cells may be activated by antigens associated with antigen presenting cells (APCs). In some embodiments, the APCs may be dendritic cells, macrophages or B cells that antigen specific or nonspecific. The APCs may autologous or homologous in their organ. In some embodiments, the APCs may be artificial antigen presenting cells (aAPCs) such as cell based aAPCs or acellular aAPCs. Cell based aAPCs are may be selected from either genetically modified allogeneic cells such as human erythroleukemia cells or xenogeneic cells such as murine fibroblasts and Drosophila cells. Alternatively, the APCs maybe be acellular wherein the antigens or costimulatory domains are presented on synthetic surfaces such as latex beads, polystyrene beads, lipid vesicles or exosomes.

[00213] In some embodiments, adoptive cell therapy is carried out by autologous transfer, wherein the cells are derived from a subject in need of a treatment and the cells, following isolation and processing are administered to the same subject. In other instances, ACT may involve allogenic transfer wherein the cells are isolated and/or prepared from a donor subject other than the recipient subject who ultimately receives cell therapy. The donor and recipient subject may be genetically identical, or similar or may express the same HLA class or subtype.

[00214] Following genetic modulation using SREs, CA2 biocircuits and compositions of the disclosure, cells are administered to the subject in need thereof. Methods for administration of cells for adoptive cell therapy are known and may be used in connection with the provided methods and compositions. For example, adoptive T cell therapy methods are described, e.g., in US Patent Application Publication No. 2003/0170238 to Gruenberg et al; US Patent No. 4,690,915 to Rosenberg; Rosenberg (2011) *Nat Rev Clin Oncol.* 8(10):577-85). See, e.g., Themeli et al. (2013) *Nat Biotechnol.* 31(10): 928-933; Tsukahara et al. (2013) *Biochem Biophys Res Commun* 438(1): 84-9; Davila et al. (2013) *PLoS ONE* 8(4): e61338; the contents of each of which are incorporated herein by reference in their entirety.

[00215] In some embodiments, immune cells engineered with CA2-IL15 for ACT may be further modified to express one or more immunotherapeutic agents which facilitate immune cells activation, infiltration, expansion, survival and anti-tumor functions. The immunotherapeutic agents may be a CAR or TCR specific to a target molecule on a tumor cell; a second cytokine or a cytokine receptor; a chimeric switch receptor that converts an inhibitory signal to a stimulatory signal; a homing receptor that guides adoptively transferred cells to a target site such as the tumor tissue; an agent that optimizes the metabolism of the immune cell; or a safety switch gene (e.g., a suicide gene) that kills activated T cells when a severe event is observed after adoptive cell transfer or when the transferred immune cells are no-longer needed.

[00216] In some embodiments, immune cells used for adoptive cell transfer can be genetically manipulated to improve their persistence, cytotoxicity, tumor targeting capacity, and ability to home to disease sites in vivo, with the overall aim of further improving upon their capacity to kill tumors in cancer patients. One example is to introduce CA2 effector modules of the disclosure comprising IL15 into immune cells to promote immune cell proliferation and survival. Transduction of IL15 into cells will permit immune cells to propagate without addition of exogenous cytokines and cytokine-expressing NK cells may have enhanced tumor cytotoxicity.

[00217] In some embodiments, CA2 biocircuits, SREs or CA2 effector modules may be utilized to prevent T cell exhaustion. As used herein, "T cell exhaustion" refers to the stepwise and progressive loss of T cell function caused by chronic T cell activation. T cell exhaustion is a major factor limiting the efficacy of antiviral and antitumor immunotherapies. Exhausted T cells have low proliferative and cytokine producing capabilities concurrent with high rates of apoptosis and high surface expression of multiple inhibitory receptors. T cell activation leading to exhaustion may occur either in the presence or absence of the antigen.

[00218] In some embodiments, the CA2 biocircuits and their components may be utilized to prevent T cell exhaustion in the context of Chimeric Antigen Receptor-T cell therapy (CAR-T). In this context, exhaustion in some instances, may be caused by the oligomerization of the scFvs of the CAR on the cell surface which leads to continuous activation of the intracellular domains of the CAR. As a non-limiting example, CARs of the present disclosure may include scFvs that are unable to oligomerize. As another non-limiting example, CARs that are rapidly internalized and re-expressed following antigen exposure may also be selected to prevent chronic scFv oligomerization on cell surface. In one embodiment, the framework region of the scFvs may be modified to prevent constitutive CAR signaling.

[00219] Tunable CA2 biocircuits of the present disclosure may also be used to regulate the surface expression of the CAR on the T cell surface to prevent chronic T cell activation. The CARs of the disclosure may also be engineered to minimize exhaustion. As a non-limiting example, the 4-1-BB signaling domain may be incorporated into CAR design together with membrane bound IL15 expression regulated by CA2 biocircuits, SREs or CA2 effector modules, exemplified in Table 3 of the present disclosure, to ameliorate T cell exhaustion.

[00220] In some embodiments, the tunable nature of the CA2-IL15 biocircuits of the present disclosure may be utilized to reverse human T cell exhaustion observed with tonic CAR signaling. Reversibly silencing the biological activity of adoptively transferred cells using compositions of the present disclosure may be used to reverse tonic signaling which, in turn, may reinvigorate the T cells. Reversal of exhaustion may be measured by the downregulation of multiple inhibitory receptors associated with exhaustion.

[00221] In some embodiments, the compositions of the present disclosure may be utilized to alter TIL (tumor infiltrating lymphocyte) populations in a subject. In one embodiment, any of the payloads described herein may be utilized to change the ratio of CD4 positive cells to CD8

positive populations. In some embodiments, TIL may be sorted ex vivo and engineered to express any of the cytokines described herein. Payloads of the disclosure may be used to expand CD4 and/or CD8 populations of TIL to enhance TIL mediated immune response.

[00222] Provided in the present disclosure is a method of reducing a tumor volume or burden in a subject in need, the method comprising introducing into the subject a composition of the disclosure.

[00223] The present disclosure also provides methods for treating a cancer in a subject, comprising administering to the subject an effective amount of an effector immune cell genetically modified to express at least one CA2 effector module of the disclosure.

[00224] Various cancers may be treated with pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs and IL15 payloads of the present disclosure. As used herein, the term “cancer” refers to any of various malignant neoplasms characterized by the proliferation of anaplastic cells that tend to invade surrounding tissue and metastasize to new body sites and also refers to the pathological condition characterized by such malignant neoplastic growths. Cancers may be tumors or hematological malignancies, and include but are not limited to, all types of lymphomas/leukemias, carcinomas and sarcomas, such as those cancers or tumors found in the anus, bladder, bile duct, bone, brain, breast, cervix, colon/rectum, endometrium, esophagus, eye, gallbladder, head and neck, liver, kidney, larynx, lung, mediastinum (chest), mouth, ovaries, pancreas, penis, prostate, skin, small intestine, stomach, spinal marrow, tailbone, testicles, thyroid and uterus.

[00225] Types of carcinomas which may be treated with the compositions of the present disclosure include, but are not limited to, papilloma/carcinoma, choriocarcinoma, endodermal sinus tumor, teratoma, adenoma/adenocarcinoma, melanoma, fibroma, lipoma, leiomyoma, rhabdomyoma, mesothelioma, angioma, osteoma, chondroma, glioma, lymphoma/leukemia, squamous cell carcinoma, small cell carcinoma, large cell undifferentiated carcinomas, basal cell carcinoma and sinonasal undifferentiated carcinoma.

[00226] Types of carcinomas which may be treated with the compositions of the present disclosure include, but are not limited to, soft tissue sarcoma such as alveolar soft part sarcoma, angiosarcoma, dermatofibrosarcoma, desmoid tumor, desmoplastic small round cell tumor, extraskelatal chondrosarcoma, extraskelatal osteosarcoma, fibrosarcoma, hemangiopericytoma, hemangiosarcoma, Kaposi's sarcoma, leiomyosarcoma, liposarcoma, lymphangiosarcoma,

lymphosarcoma, malignant fibrous histiocytoma, neurofibrosarcoma, rhabdomyosarcoma, synovial sarcoma, and Askin's tumor, Ewing's sarcoma (primitive neuroectodermal tumor), malignant hemangioendothelioma, malignant schwannoma, osteosarcoma, and chondrosarcoma.

[00227] As a non-limiting example, the carcinoma which may be treated may be Acute granulocytic leukemia, Acute lymphocytic leukemia, Acute myelogenous leukemia, Adenocarcinoma, Adenosarcoma, Adrenal cancer, Adrenocortical carcinoma, Anal cancer, Anaplastic astrocytoma, Angiosarcoma, Appendix cancer, Astrocytoma, Basal cell carcinoma, B-Cell lymphoma), Bile duct cancer, Bladder cancer, Bone cancer, Bowel cancer, Brain cancer, Brain stem glioma, Brain tumor, Breast cancer, Carcinoid tumors, Cervical cancer, Cholangiocarcinoma, Chondrosarcoma, Chronic lymphocytic leukemia, Chronic myelogenous leukemia, Colon cancer, Colorectal cancer, Craniopharyngioma, Cutaneous lymphoma, Cutaneous melanoma, Diffuse astrocytoma, Ductal carcinoma in situ, Endometrial cancer, Ependymoma, Epithelioid sarcoma, Esophageal cancer, Ewing sarcoma, Extrahepatic bile duct cancer, Eye cancer, Fallopian tube cancer, Fibrosarcoma, Gallbladder cancer, Gastric cancer, Gastrointestinal cancer, Gastrointestinal carcinoid cancer, Gastrointestinal stromal tumors, General, Germ cell tumor, Glioblastoma multiforme, Glioma, Hairy cell leukemia, Head and neck cancer, Hemangioendothelioma, Hodgkin lymphoma, Hodgkin's disease, Hodgkin's lymphoma, Hypopharyngeal cancer, Infiltrating ductal carcinoma, Infiltrating lobular carcinoma, Inflammatory breast cancer, Intestinal Cancer, Intrahepatic bile duct cancer, Invasive / infiltrating breast cancer, Islet cell cancer, Jaw cancer, Kaposi sarcoma, Kidney cancer, Laryngeal cancer, Leiomyosarcoma, Leptomeningeal metastases, Leukemia, Lip cancer, Liposarcoma, Liver cancer, Lobular carcinoma in situ, Low-grade astrocytoma, Lung cancer, Lymph node cancer, Lymphoma, Male breast cancer, Medullary carcinoma, Medulloblastoma, Melanoma, Meningioma, Merkel cell carcinoma, Mesenchymal chondrosarcoma, Mesenchymous, Mesothelioma, Metastatic breast cancer, Metastatic melanoma, Metastatic squamous neck cancer, Mixed gliomas, Mouth cancer, Mucinous carcinoma, Mucosal melanoma, Multiple myeloma, Nasal cavity cancer, Nasopharyngeal cancer, Neck cancer, Neuroblastoma, Neuroendocrine tumors, Non-Hodgkin lymphoma, Non-Hodgkin's lymphoma, Non-small cell lung cancer, Oat cell cancer, Ocular cancer, Ocular melanoma, Oligodendroglioma, Oral cancer, Oral cavity cancer, Oropharyngeal cancer, Osteogenic sarcoma, Osteosarcoma, Ovarian cancer, Ovarian epithelial cancer, Ovarian germ cell tumor, Ovarian

primary peritoneal carcinoma, Ovarian sex cord stromal tumor, Paget's disease, Pancreatic cancer, Papillary carcinoma, Paranasal sinus cancer, Parathyroid cancer, Pelvic cancer, Penile cancer, Peripheral nerve cancer, Peritoneal cancer, Pharyngeal cancer, Pheochromocytoma, Pilocytic astrocytoma, Pineal region tumor, Pineoblastoma, Pituitary gland cancer, Primary central nervous system lymphoma, Prostate cancer, Rectal cancer, Renal cell cancer, Renal pelvis cancer, Rhabdomyosarcoma, Salivary gland cancer, Sarcoma, Sarcoma, bone, Sarcoma, soft tissue, Sarcoma, uterine, Sinus cancer, Skin cancer, Small cell lung cancer, Small intestine cancer, Soft tissue sarcoma, Spinal cancer, Spinal column cancer, Spinal cord cancer, Spinal tumor, Squamous cell carcinoma, Stomach cancer, Synovial sarcoma, T cell lymphoma), Testicular cancer, Throat cancer, Thymoma / thymic carcinoma, Thyroid cancer, Tongue cancer, Tonsil cancer, Transitional cell cancer, Transitional cell cancer, Transitional cell cancer, Triple-negative breast cancer, Tubal cancer, Tubular carcinoma, Ureteral cancer, Ureteral cancer, Urethral cancer, Uterine adenocarcinoma, Uterine cancer, Uterine sarcoma, Vaginal cancer, and Vulvar cancer.

[00228] In some embodiments, pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure may be used in the modulation or alteration or exploitation of the immune system to target one or more cancers. This approach may also be considered with other such biological approaches, e.g., immune response modifying therapies such as the administration of interferons, interleukins, colony-stimulating factors, other monoclonal antibodies, vaccines, gene therapy, and nonspecific immunomodulating agents are also envisioned as anti-cancer therapies to be combined with the pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure.

[00229] Cancer immunotherapy refers to a diverse set of therapeutic strategies designed to induce the patient's own immune system to fight the cancer. In some embodiments, pharmaceutical compositions, CA2 biocircuits, CA2 biocircuit components, CA2 effector modules including their SREs or payloads of the present disclosure are designed as immune-oncology therapeutics.

[00230] There are several types of cellular immunotherapies, including NK cells, tumor infiltrating lymphocyte (TIL) therapy, and genetically engineered T cells bearing chimeric antigen receptors (CARs) or recombinant TCR technology.

[00231] In one embodiment, the CAR T cell or TCR T cell of the present disclosure may be an “armed” T cell which is transformed with a CA2-IL15 effector module to improve efficacy and persistence.

[00232] In one embodiment, patients may also be stratified according to the immunogenic peptides presented by their immune cells and may be utilized as a parameter to determine suitable patient cohorts that may therapeutically benefit for the compositions of the disclosure.

[00233] In some embodiments, cells of the disclosure may be autologous, allogeneic, syngeneic, or xenogeneic in relation to a particular individual subject.

[00234] In some embodiments, cells of the disclosure may be mammalian cells, particularly human cells. Cells of the disclosure may be primary cells or immortalized cell lines.

[00235] Engineered immune cells can be accomplished by transducing a cell composition with one or more polynucleotides encoding a polypeptide of a CA2 biocircuit, a CA2 effector module, an SRE and an IL15 payload, or a vector comprising said polynucleotide. The vector may be a viral vector such as a lentiviral vector or gamma retroviral vector. In some embodiments, immune cells of the disclosure are genetically modified to express at least one immunotherapeutic agent of the disclosure which is tunable using a stimulus.

DEFINITIONS

[00236] At various places in the present specification, features or functions of the compositions of the present disclosure are disclosed in groups or in ranges. It is specifically intended that the present disclosure include each and every individual sub combination of the members of such groups and ranges. The following is a non-limiting list of term definitions.

[00237] Activity: As used herein, the term “activity” refers to the condition in which things are happening or being done. Compositions of the disclosure may have activity and this activity may involve one or more biological events. In some embodiments, biological events may include cell signaling events. In some embodiments, biological events may include cell signaling events associated protein interactions with one or more corresponding proteins, receptors, small molecules or any of the biocircuit components described herein.

[00238] Adoptive cell therapy (ACT): The terms “Adoptive cell therapy” or “Adoptive cell transfer”, as used herein, refer to a cell therapy involving in the transfer of cells into a patient, wherein cells may have originated from the patient, or from another individual, and are engineered (altered) before being transferred back into the patient. The therapeutic cells may be

derived from the immune system, such as effector immune cells: CD4⁺ T cell; CD8⁺ T cell, Natural Killer cell (NK cell); and B cells and tumor infiltrating lymphocytes (TIL) derived from the resected tumors. Most commonly transferred cells are autologous anti-tumor T cells after ex vivo expansion or manipulation. For example, autologous peripheral blood lymphocytes can be genetically engineered to recognize specific tumor antigens by expressing T cell receptors (TCR) or chimeric antigen receptor (CAR).

[00239] Agent: As used herein, the term “agent” refers to a biological, pharmaceutical, or chemical compound. Non-limiting examples include simple or complex organic or inorganic molecule, a peptide, a protein, an oligonucleotide, an antibody, an antibody derivative, antibody fragment, a receptor, and soluble factor.

[00240] Antigen: the term “antigen” as used herein is defined as a molecule that provokes an immune response when it is introduced into a subject or produced by a subject such as tumor antigens which arise by the cancer development itself. This immune response may involve either antibody production, or the activation of specific immunologically-competent cells such as cytotoxic T lymphocytes and T helper cells, or both. An antigen can be derived from organisms, subunits of proteins/antigens, killed or inactivated whole cells or lysates. In the context of the disclosure, the terms “antigens of interest” or “desired antigens” refers to those proteins and/or other biomolecules provided herein that are immunospecifically bound or interact with antibodies of the present disclosure and/or fragments, mutants, variants, and/or alterations thereof described herein. In some embodiments, antigens of interest may comprise any of the polypeptides or payloads or proteins described herein, or fragments or portions thereof.

[00241] Associated with: As used herein, the terms “associated with,” “conjugated,” “linked,” “attached,” and “tethered,” when used with respect to two or more moieties, mean that the moieties are physically associated or connected with one another, either directly or via one or more additional moieties that serve as linking agents, to form a structure that is sufficiently stable so that the moieties remain physically associated under the conditions in which the structure is used, e.g., physiological conditions. An “association” need not be strictly through direct covalent chemical bonding. It may also suggest ionic or hydrogen bonding or a hybridization-based connectivity sufficiently stable such that the “associated” entities remain physically associated.

[00242] Autologous: the term “autologous” as used herein is meant to refer to any material derived from the same individual to which it is later to be re-introduced into the individual.

[00243] Cancer: the term “cancer” as used herein refers a broad group of various diseases characterized by the uncontrolled growth of abnormal cells in the body. Unregulated cell division and growth results in the formation of malignant tumors that invade neighboring tissues ultimately metastasize to distant parts of the body through the lymphatic system or bloodstream.

[00244] Co-stimulatory molecule: As used herein, in accordance with its meaning in immune T cell activation, refers to a group of immune cell surface receptor/ligands which engage between T cells and APCs and generate a stimulatory signal in T cells which combines with the stimulatory signal in T cells that results from T cell receptor (TCR) recognition of antigen/MHC complex (pMHC) on APCs

[00245] Cytokines: the term “cytokines”, as used herein, refers to a family of small soluble factors with pleiotropic functions that are produced by many cell types that can influence and regulate the function of the immune system.

[00246] Delivery: the term “delivery” as used herein refers to the act or manner of delivering a compound, substance, entity, moiety, cargo or payload. A “delivery agent” refers to any agent which facilitates, at least in part, the in vivo delivery of one or more substances (including, but not limited to a compound and/or composition of the present disclosure) to a cell, subject or other biological system cells.

[00247] Destabilized: As used herein, the term “destable,” “destabilize,” or “destabilizing region” means a region or molecule that is less stable than a starting, reference, wild-type or native form of the same region or molecule.

[00248] Engineered: As used herein, embodiments of the disclosure are “engineered” when they are designed to have a feature or property, whether structural or chemical, that varies from a starting point, wild type or native molecule.

[00249] Formulation: As used herein, a “formulation” includes at least a compound and/or composition of the present disclosure and a delivery agent.

[00250] Fragment: A “fragment,” as used herein, refers to a portion of a molecule that is less than the entire molecule. For example, fragments of proteins may comprise polypeptides obtained by digesting full-length protein. In some embodiments, fragments of an antibody include portions of an antibody.

[00251] Functional: As used herein, a “functional” biological molecule is a biological entity with a structure and in a form in which it exhibits a property and/or activity by which it is characterized.

[00252] Immune cells: the term “an immune cell”, as used herein, refers to any cell of the immune system that originates from a hematopoietic stem cell in the bone marrow, which gives rise to two major lineages, a myeloid progenitor cell (which give rise to myeloid cells such as monocytes, macrophages, dendritic cells, megakaryocytes and granulocytes) and a lymphoid progenitor cell (which give rise to lymphoid cells such as T cells, B cells and natural killer (NK) cells). Exemplary immune system cells include a CD4⁺ T cell, a CD8⁺ T cell, a CD4[−] CD8[−] double negative T cell, a T $\gamma\delta$ cell, a T $\alpha\beta$ cell, a regulatory T cell, a natural killer cell, and a dendritic cell. Macrophages and dendritic cells may be referred to as “antigen presenting cells” or “APCs,” which are specialized cells that can activate T cells when a major histocompatibility complex (MHC) receptor on the surface of the APC complexed with a peptide interacts with a TCR on the surface of a T cell.

[00253] Immunotherapy: the term “immunotherapy” as used herein, refers to a type of treatment of a disease by the induction or restoration of the reactivity of the immune system towards the disease.

[00254] Immunotherapeutic agent: the term “immunotherapeutic agent” as used herein, refers to the treatment of disease by the induction or restoration of the reactivity of the immune system towards the disease with a biological, pharmaceutical, or chemical compound.

[00255] In vitro: As used herein, the term “in vitro” refers to events that occur in an artificial environment, e.g., in a test tube or reaction vessel, in cell culture, in a Petri dish, etc., rather than within an organism (e.g., animal, plant, or microbe).

[00256] In vivo: As used herein, the term “in vivo” refers to events that occur within an organism (e.g., animal, plant, or microbe or cell or tissue thereof).

[00257] Linker: As used herein, a linker refers to a moiety that connects two or more domains, moieties or entities. In one embodiment, a linker may comprise 10 or more atoms. In a further embodiment, a linker may comprise a group of atoms, e.g., 10-1,000 atoms, and can be comprised of the atoms or groups such as, but not limited to, carbon, amino, alkylamino, oxygen, sulfur, sulfoxide, sulfonyl, carbonyl, and imine. In some embodiments, a linker may comprise one or more nucleic acids comprising one or more nucleotides. In some embodiments, the linker

may comprise an amino acid, peptide, polypeptide or protein. In some embodiments, a moiety bound by a linker may include, but is not limited to an atom, a chemical group, a nucleoside, a nucleotide, a nucleobase, a sugar, a nucleic acid, an amino acid, a peptide, a polypeptide, a protein, a protein complex, a payload (e.g., a therapeutic agent), or a marker (including, but not limited to a chemical, fluorescent, radioactive or bioluminescent marker). The linker can be used for any useful purpose, such as to form multimers or conjugates, as well as to administer a payload, as described herein. Examples of chemical groups that can be incorporated into the linker include, but are not limited to, alkyl, alkenyl, alkynyl, amido, amino, ether, thioether, ester, alkylene, heteroalkylene, aryl, or heterocyclyl, each of which can be optionally substituted, as described herein. Examples of linkers include, but are not limited to, unsaturated alkanes, polyethylene glycols (e.g., ethylene or propylene glycol monomeric units, e.g., diethylene glycol, dipropylene glycol, triethylene glycol, tripropylene glycol, tetraethylene glycol, or tetraethylene glycol), and dextran polymers. Other examples include, but are not limited to, cleavable moieties within the linker, such as, for example, a disulfide bond (-S-S-) or an azo bond (-N=N-), which can be cleaved using a reducing agent or photolysis. Non-limiting examples of a selectively cleavable bonds include an amido bond which may be cleaved for example by the use of tris(2-carboxyethyl) phosphine (TCEP), or other reducing agents, and/or photolysis, as well as an ester bond which may be cleaved for example by acidic or basic hydrolysis.

[00258] Modified: As used herein, the term “modified” refers to a changed state or structure of a molecule or entity as compared with a parent or reference molecule or entity. Molecules may be modified in many ways including chemically, structurally, and functionally. In some embodiments, compounds and/or compositions of the present disclosure are modified by the introduction of non-natural amino acids.

[00259] Mutation: As used herein, the term “mutation” refers to a change and/or alteration. In some embodiments, mutations may be changes and/or alterations to proteins (including peptides and polypeptides) and/or nucleic acids (including polynucleic acids). In some embodiments, mutations comprise changes and/or alterations to a protein and/or nucleic acid sequence. Such changes and/or alterations may comprise the addition, substitution and or deletion of one or more amino acids (in the case of proteins and/or peptides) and/or nucleotides (in the case of nucleic acids and or polynucleic acids e.g., polynucleotides). In some embodiments, wherein mutations comprise the addition and/or substitution of amino acids and/or nucleotides, such additions

and/or substitutions may comprise 1 or more amino acid and/or nucleotide residues and may include modified amino acids and/or nucleotides. The resulting construct, molecule or sequence of a mutation, change or alteration may be referred to herein as a mutant.

[00260] Neoantigen: the term “neoantigen”, as used herein, refers to a tumor antigen that is present in tumor cells but not normal cells and do not induce deletion of their cognate antigen specific T cells in thymus (i.e., central tolerance). These tumor neoantigens may provide a “foreign” signal, similar to pathogens, to induce an effective immune response needed for cancer immunotherapy. A neoantigen may be restricted to a specific tumor. A neoantigen be a peptide/protein with a missense mutation (missense neoantigen), or a new peptide with long, completely novel stretches of amino acids from novel open reading frames (neoORFs). The neoORFs can be generated in some tumors by out-of-frame insertions or deletions (due to defects in DNA mismatch repair causing microsatellite instability), gene-fusion, read-through mutations in stop codons, or translation of improperly spliced RNA (e.g., Saeterdal et al., Proc Natl Acad Sci USA, 2001, 98: 13255-13260).

[00261] Off-target: As used herein, “off target” refers to any unintended effect on any one or more target, gene, cellular transcript, cell, and/or tissue.

[00262] Operably linked: As used herein, the phrase “operably linked” refers to a functional connection between two or more molecules, constructs, transcripts, entities, moieties or the like.

[00263] Payload or payload of interest (POI): the terms “payload” and “payload of interest (POI)”, as used herein, are used interchangeable. A payload of interest (POI) refers to any protein or compound whose function is to be altered. In the context of the present disclosure, the POI is a component in the immune system, including both innate and adaptive immune systems. Payloads of interest may be a protein, a fusion construct encoding a fusion protein, or non-coding gene, or variant and fragment thereof. Payload of interest may, when amino acid based, may be referred to as a protein of interest.

[00264] Pharmaceutically acceptable excipients: the term “pharmaceutically acceptable excipient,” as used herein, refers to any ingredient other than active agents (e.g., as described herein) present in pharmaceutical compositions and having the properties of being substantially nontoxic and non-inflammatory in subjects. In some embodiments, pharmaceutically acceptable excipients are vehicles capable of suspending and/or dissolving active agents. Excipients may include, for example: antiadherents, antioxidants, binders, coatings, compression aids,

disintegrants, dyes (colors), emollients, emulsifiers, fillers (diluent), film formers or coatings, flavors, fragrances, glidants (flow enhancers), lubricants, preservatives, printing inks, sorbents, suspending or dispersing agents, sweeteners, and waters of hydration. Exemplary excipients include, but are not limited to: butylated hydroxytoluene (BHT), calcium carbonate, calcium phosphate (dibasic), calcium stearate, croscarmellose, crosslinked polyvinyl pyrrolidone, citric acid, crospovidone, cysteine, ethylcellulose, gelatin, hydroxypropyl cellulose, hydroxypropyl methylcellulose, lactose, magnesium stearate, maltitol, mannitol, methionine, methylcellulose, methyl paraben, microcrystalline cellulose, polyethylene glycol, polyvinyl pyrrolidone, povidone, pregelatinized starch, propyl paraben, retinyl palmitate, shellac, silicon dioxide, sodium carboxymethyl cellulose, sodium citrate, sodium starch glycolate, sorbitol, starch (corn), stearic acid, sucrose, talc, titanium dioxide, vitamin A, vitamin E, vitamin C, and xylitol.

[00265] Pharmaceutically acceptable salts: Pharmaceutically acceptable salts of the compounds described herein are forms of the disclosed compounds wherein the acid or base moiety is in its salt form (e.g., as generated by reacting a free base group with a suitable organic acid). Examples of pharmaceutically acceptable salts include, but are not limited to, mineral or organic acid salts of basic residues such as amines; alkali or organic salts of acidic residues such as carboxylic acids; and the like. Representative acid addition salts include acetate, adipate, alginate, ascorbate, aspartate, benzenesulfonate, benzoate, bisulfate, borate, butyrate, camphorate, camphorsulfonate, citrate, cyclopentanepropionate, digluconate, dodecylsulfate, ethanesulfonate, fumarate, glucoheptonate, glycerophosphate, hemisulfate, heptonate, hexanoate, hydrobromide, hydrochloride, hydroiodide, 2-hydroxy-ethanesulfonate, lactobionate, lactate, laurate, lauryl sulfate, malate, maleate, malonate, methanesulfonate, 2-naphthalenesulfonate, nicotinate, nitrate, oleate, oxalate, palmitate, pamoate, pectinate, persulfate, 3-phenylpropionate, phosphate, picrate, pivalate, propionate, stearate, succinate, sulfate, tartrate, thiocyanate, toluenesulfonate, undecanoate, valerate salts, and the like. Representative alkali or alkaline earth metal salts include sodium, lithium, potassium, calcium, magnesium, and the like, as well as nontoxic ammonium, quaternary ammonium, and amine cations, including, but not limited to ammonium, tetramethylammonium, tetraethylammonium, methylamine, dimethylamine, trimethylamine, triethylamine, ethylamine, and the like. Pharmaceutically acceptable salts include the conventional non-toxic salts, for example, from non-toxic inorganic or organic acids. In some embodiments, a pharmaceutically acceptable salt is prepared from a parent compound

which contains a basic or acidic moiety by conventional chemical methods. Generally, such salts can be prepared by reacting the free acid or base forms of these compounds with a stoichiometric amount of the appropriate base or acid in water or in an organic solvent, or in a mixture of the two; generally, nonaqueous media like ether, ethyl acetate, ethanol, isopropanol, or acetonitrile are preferred. Lists of suitable salts are found in Remington's Pharmaceutical Sciences, 17th ed., Mack Publishing Company, Easton, Pa., 1985, p. 1418, Pharmaceutical Salts: Properties, Selection, and Use, P.H. Stahl and C.G. Wermuth (eds.), Wiley-VCH, 2008, and Berge et al., Journal of Pharmaceutical Science, 66, 1-19 (1977), each of which is incorporated herein by reference in its entirety. Pharmaceutically acceptable solvate: The term "pharmaceutically acceptable solvate," as used herein, refers to a crystalline form of a compound wherein molecules of a suitable solvent are incorporated in the crystal lattice. For example, solvates may be prepared by crystallization, recrystallization, or precipitation from a solution that includes organic solvents, water, or a mixture thereof. Examples of suitable solvents are ethanol, water (for example, mono-, di-, and tri-hydrates), N-methylpyrrolidinone (NMP), dimethyl sulfoxide (DMSO), N, N'-dimethylformamide (DMF), N, N'-dimethylacetamide (DMAC), 1,3-dimethyl-2-imidazolidinone (DMEU), 1,3-dimethyl-3,4,5,6-tetrahydro-2-(1H)-pyrimidinone (DMPU), acetonitrile (ACN), propylene glycol, ethyl acetate, benzyl alcohol, 2-pyrrolidone, benzyl benzoate, and the like. When water is the solvent, the solvate is referred to as a "hydrate." In some embodiments, the solvent incorporated into a solvate is of a type or at a level that is physiologically tolerable to an organism to which the solvate is administered (e.g., in a unit dosage form of a pharmaceutical composition).

[00266] Stable: As used herein "stable" refers to a compound or entity that is sufficiently robust to survive isolation to a useful degree of purity from a reaction mixture, and preferably capable of formulation into an efficacious therapeutic agent.

[00267] Stabilized: As used herein, the term "stabilize", "stabilized," "stabilized region" means to make or become stable. In some embodiments, stability is measured relative to an absolute value. In some embodiments, stability is measured relative to a secondary status or state or to a reference compound or entity.

[00268] Standard CAR: As used herein, the term "standard CAR" refers to the standard design of a chimeric antigen receptor. The components of a CAR fusion protein including the

extracellular scFv fragment, transmembrane domain and one or more intracellular domains are linearly constructed as a single fusion protein.

[00269] Subject: As used herein, the term “subject” or “patient” refers to any organism to which a composition in accordance with the disclosure may be administered, e.g., for experimental, diagnostic, prophylactic, and/or therapeutic purposes. Typical subjects include animals (e.g., mammals such as mice, rats, rabbits, non-human primates, and humans) and/or plants.

[00270] T cell: A T cell is an immune cell that produces T cell receptors (TCRs). T cells can be naïve (not exposed to antigen; increased expression of CD62L, CCR7, CD28, CD3, CD127, and CD45RA, and decreased expression of CD45RO as compared to TCM), memory T cells (TM) (antigen-experienced and long-lived), and effector cells (antigen-experienced, cytotoxic). TM can be further divided into subsets of central memory T cells (TCM, increased expression of CD62L, CCR7, CD28, CD127, CD45RO, and CD95, and decreased expression of CD54RA as compared to naïve T cell and effector memory T cells (TEM, decreased expression of CD62L, CCR7, CD28, CD45RA, and increased expression of CD127 as compared to naïve T cells or TCM). Effector T cells (TE) refers to antigen-experienced CD8⁺ cytotoxic T lymphocytes that have decreased expression of CD62L, CCR7, CD28, and are positive for granzyme and perforin as compared to TCM. Other exemplary T cells include regulatory T cells, such as CD4⁺ CD25⁺ (Foxp3⁺) regulatory T cells and Treg17 cells, as well as Tr1, Th3, CD8⁺CD28[−], and Qa-1 restricted T cells.

[00271] T cell receptor: T cell receptor (TCR) refers to an immunoglobulin superfamily member having a variable antigen binding domain, a constant domain, a transmembrane region, and a short cytoplasmic tail, which is capable of specifically binding to an antigen peptide bound to a MHC receptor. A TCR can be found on the surface of a cell or in soluble form and generally is comprised of a heterodimer having α and β chains (also known as TCR α and TCR β , respectively), or γ and δ chains (also known as TCR γ and TCR δ , respectively). The extracellular portion of TCR chains (e.g., α -chain, β -chain) contains two immunoglobulin domains, a variable domain (e.g., α -chain variable domain or V α , β -chain variable domain or V β) at the N terminus, and one constant domain (e.g., α -chain constant domain or C α and β -chain constant domain or C β ,) adjacent to the cell membrane. Similar to immunoglobulin, the variable domains contain complementary determining regions (CDRs) separated by framework regions (FRs). A TCR is

usually associated with the CD3 complex to form a TCR complex. As used herein, the term “TCR complex” refers to a complex formed by the association of CD3 with TCR. For example, a TCR complex can be composed of a CD3 γ chain, a CD3 δ chain, two CD3 ϵ chains, a homodimer of CD3 ζ chains, a TCR α chain, and a TCR β chain. Alternatively, a TCR complex can be composed of a CD3 γ chain, a CD3 δ chain, two CD3 ϵ chains, a homodimer of CD3 ζ chains, a TCR γ chain, and a TCR δ chain. A “component of a TCR complex,” as used herein, refers to a TCR chain (i.e., TCR α , TCR β , TCR γ or TCR δ), a CD3 chain (i.e., CD3 γ , CD3 δ , CD3 ϵ or CD3 ζ), or a complex formed by two or more TCR chains or CD3 chains (e.g., a complex of TCR α and TCR β , a complex of TCR γ and TCR δ , a complex of CD3 ϵ and CD3 δ , a complex of CD3 γ and CD3 ϵ , or a sub-TCR complex of TCR α , TCR β , CD3 γ , CD3 δ , and two CD3 ϵ chains.

[00272] Therapeutically effective amount: As used herein, the term “therapeutically effective amount” means an amount of an agent to be delivered (e.g., nucleic acid, drug, therapeutic agent, diagnostic agent, prophylactic agent, etc.) that is sufficient, when administered to a subject suffering from or susceptible to an infection, disease, disorder, and/or condition, to treat, improve symptoms of, diagnose, prevent, and/or delay the onset of the infection, disease, disorder, and/or condition. In some embodiments, a therapeutically effective amount is provided in a single dose. In some embodiments, a therapeutically effective amount is administered in a dosage regimen comprising a plurality of doses. Those skilled in the art will appreciate that in some embodiments, a unit dosage form may be considered to comprise a therapeutically effective amount of a particular agent or entity if it comprises an amount that is effective when administered as part of such a dosage regimen.

[00273] Treatment or treating: As used herein, the terms “treatment” or “treating” denote an approach for obtaining a beneficial or desired result including and preferably a beneficial or desired clinical result. Such beneficial or desired clinical results include, but are not limited to, one or more of the following: reducing the proliferation of (or destroying) cancerous cells or other diseased, reducing metastasis of cancerous cells found in cancers, shrinking the size of the tumor, decreasing symptoms resulting from the disease, increasing the quality of life of those suffering from the disease, decreasing the dose of other medications required to treat the disease, delaying the progression of the disease, and/or prolonging survival of individuals.

[00274] Tune: As used herein, the term “tune” means to adjust, balance or adapt one thing in response to a stimulus or toward a particular outcome. In one non-limiting example, the SREs

and/or DRDs of the present disclosure adjust, balance or adapt the function or structure of compositions to which they are appended, attached or associated with in response to particular stimuli and/or environments.

EQUIVALENTS AND SCOPE

[00275] Those skilled in the art will recognize or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments in accordance with the disclosure described herein. The scope of the present disclosure is not intended to be limited to the above Description, but rather is as set forth in the appended claims.

[00276] In the claims, articles such as “a,” “an,” and “the” may mean one or more than one unless indicated to the contrary or otherwise evident from the context. Claims or descriptions that include “or” between one or more members of a group are considered satisfied if one, more than one, or all of the group members are present in, employed in, or otherwise relevant to a given product or process unless indicated to the contrary or otherwise evident from the context. The disclosure includes embodiments in which exactly one member of the group is present in, employed in, or otherwise relevant to a given product or process. The disclosure includes embodiments in which more than one, or the entire group members are present in, employed in or otherwise relevant to a given product or process.

[00277] It is also noted that the term “comprising” is intended to be open and permits but does not require the inclusion of additional elements or steps. When the term “comprising” is used herein, the term “consisting of” is thus also encompassed and disclosed.

[00278] Where ranges are given, endpoints are included. Furthermore, it is to be understood that unless otherwise indicated or otherwise evident from the context and understanding of one of ordinary skill in the art, values that are expressed as ranges can assume any specific value or subrange within the stated ranges in different embodiments of the disclosure, to the tenth of the unit of the lower limit of the range, unless the context clearly dictates otherwise.

[00279] In addition, it is to be understood that any particular embodiment of the present disclosure that falls within the prior art may be explicitly excluded from any one or more of the claims. Since such embodiments are deemed to be known to one of ordinary skill in the art, they may be excluded even if the exclusion is not set forth explicitly herein. Any particular embodiment of the compositions of the disclosure (e.g., any antibiotic, therapeutic or active

ingredient; any method of production; any method of use; etc.) can be excluded from any one or more claims, for any reason, whether or not related to the existence of prior art.

[00280] It is to be understood that the words which have been used are words of description rather than limitation, and that changes may be made within the purview of the appended claims without departing from the true scope and spirit of the disclosure in its broader aspects.

[00281] While the present disclosure has been described at some length and with some particularity with respect to the several described embodiments, it is not intended that it should be limited to any such particulars or embodiments or any particular embodiment, but it is to be construed with references to the appended claims so as to provide the broadest possible interpretation of such claims in view of the prior art and, therefore, to effectively encompass the intended scope of the disclosure. The present disclosure is further illustrated by the following nonlimiting examples.

EXAMPLES

[00282] FIG. 1 depicts a representative procedure for *in vitro* characterization and/or validation of ACZ-regulated mbIL15 expression in T cells. As shown in FIG. 1, T cells may be transduced with an mbIL15 construct, for example, by following the procedures described in Example 1. Following transduction, T cells may be treated with control condition or ACZ and assayed for IL15 expression and/or antigen-independent cell expansion *in vitro*, for example, by following the procedures described in Example 2.

[00283] FIG. 2 depicts a representative procedure for *in vivo* characterization and/or validation of ACZ-regulated mbIL15 expression in T cells. As shown in FIG. 2, T cells may be transduced with an mbIL15 construct, for example, by following the procedures described in Example 1. Following transduction, T cells may be infused into a murine subject (e.g., an NSG mouse) and samples from mice treated with vehicle or ACZ may be assayed for IL15 expression and/or antigen-independent cell expansion, for example, by following the procedures described in Example 3.

Example 1. T cell transduction with Acetazolamide (ACZ)-regulated mbIL15 construct

[00284] The present example demonstrates methods that may be used for preparing ACZ-regulated mbIL15 constructs and methods that may be used for transduction of T cells with ACZ-regulated mbIL15 constructs.

IL15 construct assembly

[00285] OT-IL15-292, OT-IL15-293, OT-IL15-294, and OT-IL15-295 were each constructed in a pELNS vector (a third-generation self-inactivating lentiviral expression vector) using standard molecular biology techniques. Gene fragments (Gblocks) encoding codon-optimized IL15, GS linker, B7-1 hinge, transmembrane domain and cytoplasmic tails were purchased from Integrated DNA Technologies, Inc. (IDT, Coralville, Iowa). The gene fragments were inserted into the pELNS vector and placed under the control of the EF1a promoter using Gibson assembly (NEBuilder Hifi). The assembled plasmid was transformed into *E. coli* (NEB stable) for amplification and sequence confirmed before proceeding with virus production.

[00286] Table 4 presents the nucleic acid and amino acid sequences for components of constitutive IL15 constructs (OT-IL15-292 and OT-IL15-294) and ACZ-regulated IL15 constructs (OT-IL15-293 and OT-IL15-295) disclosed herein. Bold and underlined amino acids in Table 4 indicate differences in the B7-1 cytoplasmic tail between constructs OT-IL15-292/OT-IL15-293 and OT-IL15-294/OT-IL15-295. Constructs OT-IL15-293 and OT-IL15-295 comprise a destabilizing domain labeled as CA2 (M1del, L156H) in Table 4.

Table 4: components of constitutive and ACZ-regulated IL15 constructs

Description	DNA Sequence	DNA NO.	AA Sequence	AA SEQ ID NO.
Leader sequence	ATGGACATGCGGGTGCCTGCACAAC TTCTGGGCCTGCTGTTGTTGTGGCTG TCTGGAGCCCGGTGT	7	MDMRVPAQLLGLLLWLSG ARC	6
IL15	AATTGGGTAATGTTATCACTGATCTC AAGAAGATAGAGGATCTCATCCAGTC CATGCATATTGATGCCACGCTGTACA CAGAAAGCGATGTGCATCCTAGCTGT AAGGTGACAGCGATGAAGTGTCTTCT TTTGGAGCTGCAGGTAATTAGTCTTG AGTCCGGCGATGCCAGCATTATGAT ACCGTAGAAACTTGATTATCCTGGC CAACAATTCTCTGTCTCAAACGGAA ACGTAACCGAGAGCGGTTGTAAAGAA TGTGAAGAACTGGAAGAAAAGAACAT CAAGGAGTTTCTGCAATCATTCGTTT	9	NWNVISDLKKIEDLIQSMHI DATLYTESDVHPSCVKVTAM KCFLLQLQVISLESGDASIHD TVENLIILANNSLSSNGNVTE SGCKECEELEEKNKEFLQS FVHIVQMFINTS	8

	ACATCGTACAAATGTTTCATAAATACGT CA			
Linker (GS)15	GGATCTGGTTCTGGTTCCGGAAGTG GATCTGGTTCAGGGTCCGGTAGTGG ATCTGGGTCAGGAAGTGGAAGCGGT AGTGGGTCTGGATCT	11	GSGSGSGSGSGSGSGSGS GSGSGSGSGSGS	10
Hinge	AAACAAGAGCACTTTCCTGATAAC	13	KQEHFPDN	12
Transmembrane domain	CTGTTGCCGAGCTGGGCGATTACGC TTATCAGTGTAACGGCATCTTTGTAA TATGCTGTCTG	15	LLPSWAITLISVNGIFVICCL	14
Intracellular tail (OT-IL15-292 and OT-IL15- 293)	ACCTACTGCTTCGCACCAAGGTGCCG GGAGAGAAGGAGAAATGAAAGACTG AGAAGGGAGAGCGTGAGACCTGTG	17	TYCFAPRCRERRRNERLRR ESVRPV	16
Intracellular tail (OT-IL15-294 and OT-IL15- 295)	ACCTACTGCTTCGCACCAAGGTGCCG GGAGAGAGCAAGAAATGAAAGACTG AGAAGGGAGACCGTGAGACCTGTG	19	TYCFAPRCRERARNERLRR ETVRPV	18
Linker (GS)	GGATCC	21	GS	20

CA2 (M1del, L156H) (OT-IL15-293 and OT-IL15-295)	TCCCATCACTGGGGGTACGGCAAAC ACAACGGACCTGAGCACTGGCATAA GGACTTCCCCATTGCCAAGGGAGAG CGCCAGTCCCCTGTTGACATCGACAC TCATACAGCCAAGTATGACCCTTCCC TGAAGCCCCTGTCTGTTTCCTATGAT CAAGCAACTTCCCTGAGAATCCTCAA CAATGGTCATGCTTCAACGTGGAGT TTGATGACTCTCAGGACAAAGCAGTG CTCAAGGGAGGACCCCTGGATGGCA CTTACAGATTGATTCACTTTCCTTTC ACTGGGGTTCACTTGATGGACAAGGT TCAGAGCATACTGTGGATAAAAAGAA ATATGCTGCAGAACTTCACTTGTTTC ACTGGAACACCAAATATGGGGATTTT GGGAAAGCTGTGCAGCAACCTGATG GACTGGCCGTTCTAGGTATTTTTTTG AAGGTTGGCAGCGCTAAACCGGGCC ATCAGAAAGTTGTTGATGTGCTGGAT TCCATTAAACAAAGGGCAAGAGTGC TGACTTCACTAACTTCGATCCTCGTG GCCTCCTTCTGAATCCCTGGATTAC TGGACCTACCCAGGCTCACTGACCAC CCCTCCTTCTGGAATGTGTGACCT GGATTGTGCTCAAGGAACCCATCAGC GTCAGCAGCGAGCAGGTGTTGAAATT CCGTAAACTTAACTTCAATGGGGAGG GTGAACCCGAAGAACTGATGGTGGA CAACTGGCGCCCAGCTCAGCCACTG AAGAACAGGCAAATCAAAGCTTCCTT CAAA	5	SHHWGYGKHNGPEHWHKD FPIAKGERQSPVDIDHTAK YDPSLKPLSVSYDQATSLRI LNNGHAFNVEFDDSQDKAV LKGGPLDGTYRLIQHFHW GSLDGQGSEHTVDKKKYAA ELHLVHWNTKYGDFGKAVQ QPDGLAVLGIFLKVGSAPG HQQVVDVLSIKTKGKSADF TNFDPRLLPESLDYWTYP GSLTTPPLLECVTWIVLKEPI SVSSEQVLKFRKLNFNNEG EPEELMVDNWRPAQPLKNR QIKASFK	4
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[00287] Table 5 presents the nucleic acid and amino acid sequences of the constitutive IL15 (IL15-292 and IL15-294) and ACZ-regulated IL15 (IL15-293 and IL15-295 constructs disclosed herein.

Table 5: Constitutive and ACZ-regulated IL15 constructs

Description	DNA Sequence	DNA SEQ	AA Sequence	AA SEQ
IL15-292	ATGGACATGCGGGTGCCTG CACAACCTTCTGGGCCTGCTGTTGTT GTGGCTGTCTGGAGCCCGGTGTAAT TGGGTAAATGTTATCAGTGATCTCAA GAAGATAGAGGATCTCATCCAGTCC ATGCATATTGATGCCACGCTGTACA CAGAAAGCGATGTGCATCCTAGCTG TAAGGTGACAGCGATGAAGTGTTTT CTTTTGGAGCTGCAGGTAATTAGTCT TGAGTCCGGCGATGCCAGCATTGAT GATACCGTAGAAAATTGATTATCCT GGCCAAACAATTCTCTGTCTCAAAC GGAAACGTAACCGAGAGCGGTTGTA AAGAATGTGAAGAACTGGAAGAAAA GAACATCAAGGAGTTTCTGCAATCAT TCGTTCACATCGTACAAATGTTGATA AATACGTCAGGATCTGGTTCTGGTT CCGGAAGTGGATCTGGTTCAGGGTC CGGTAGTGGATCTGGGTCAGGAAGT GGAAGCGGTAGTGGGTCTGGATCTA AACAAAGAGCACTTTCCTGATAACCT GTTGCCGAGCTGGGCGATTACGCTT ATCAGTGTAACGGCATCTTTGTAAT ATGCTGTCTGACCTACTGCTTCGCA CCAAGGTGCCGGGAGAGAAGGAGA AATGAAAGACTGAGAAGGGAGAGCG TGAGACCTGTGGGATCC	23	MDMRVPAQLLGLLLWL SGARCNWVNVISDLKKIEDLIQSM HIDATLYTESDVHPCKVTAMKCF LLELQVISLESGDASIHDTVENLIIL ANNSLSSNGNVTESGCKECEELE EKNIKEFLQSFVHIVQMFINTSGS GSGSGSGSGSGSGSGSGSGSGSG SGSGSGSKQEHFPDNLPSWAIT LISVNGIFVICCLTYCFAPRCRERR RNERLRRESVRPVGS	22

IL15-293	ATGGACATGCGGGTGCCTG CACAACTTCTGGGCCTGCTGTTGTT GTGGCTGTCTGGAGCCCGGTGTAAT TGGGTAAATGTTATCAGTGATCTCAA GAAGATAGAGGATCTCATCCAGTCC ATGCATATTGATGCCACGCTGTACA CAGAAAGCGATGTGCATCCTAGCTG TAAGGTGACAGCGATGAAGTGTTTT CTTTTGGAGCTGCAGGTAATTAGTCT TGAGTCCGGCGATGCCAGCATTGAT GATACCGTAGAAAATTGATTATCCT GGCCAACAATTCTCTGTCCTCAAAC GGAAACGTAACCGAGAGCGGTTGTA AAGATGTGAAGAACTGGAAGAAAA GAACATCAAGGAGTTTCTGCAATCAT TCGTTACATCGTACAAATGTTGATA AATACGTCAGGATCTGGTTCTGGTT CCGGAAGTGGATCTGGTTCAGGGTC CGGTAGTGGATCTGGGTCAGGAAGT GGAAGCGGTAGTGGGTCGGATCTA AACAAGAGCACTTTCCTGATAACCT GTTGCCGAGCTGGGCGATTACGCTT ATCAGTGTAACGGCATCTTTGTAAT ATGCTGTCTGACCTACTGCTTCGCA CCAAGGTGCCGGGAGAGAAGGAGA AATGAAAGACTGAGAAGGGAGAGCG TGAGACCTGTGGGATCCTCCCATCA CTGGGGGTACGGCAAACACAACGG ACCTGAGCACTGGCATAAGGACTTC CCCATTGCCAAGGGAGAGCGCCAG TCCCCTGTTGACATCGACACTCATA CAGCCAAGTATGACCCCTCCCTGAA GCCCCGTCTGTTTCCTATGATCAA GCAACTTCCCTGAGAATCCTCAACA ATGGTCATGCTTTCAACGTGGAGTTT GATGACTCTCAGGACAAAGCAGTGC TCAAGGGAGGACCCCTGGATGGCA CTTACAGATTGATTGATTTCACTTT CACTGGGGTTCACTTGATGGACAAG GTTTACAGCATACTGTGGATAAAAA GAAATATGCTGCAGAACTTCACTTG	25	MDMRVPAQLLGLLLWL SGARCNWVNVISDLKKIEDLIQSM HIDATLYTESDVHPSCVTAMKCF LLELQVISLESGDASIHDTVENLIIL ANNSLSSNGNVTESGCKECEELE EKNIKEFLQSFVHIVQMFINTSGS SGSGSGSGSGSGSGSGSGSGSG SGSGSGSKQEHFPDNLPSWAIT LISVNGIFVICCLTYCFAPRCRERR RNERLRRESVRPVGSSHHWGYG KHNGPEHWHKDFPIAKGERQSP VDIDHTAKYDPSLKPLSVSYDQA TSLRILNNGHAFNVEFDDSDQKA VLKGGPLDGTyrLIQHFHWGSL DGQGEHTVDKKKYAAELHLVH WNTKYGDFGKAVQQPDGLAVLGI FLKVGSAPGHQKVVDVLDIITK GKSADFTNFDPRGLLPESLDYWT YPGSLTTPPLECVTWIVLKEPISV SSEQVLKFRKLNFNGEPEELM VDNWRPAQLPLKNRQIKASFK	24
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	GTTCACTGGAACACCAAATATGGGG ATTTTGGGAAAGCTGTGCAGCAACC TGATGGACTGGCCGTTCTAGGTATT TTTTTGAAGGTTGGCAGCGCTAAAC CGGGCCATCAGAAAGTTGTTGATGT GCTGGATTCCATTAAACAAAGGGC AAGAGTGCTGACTTCACTAACTTCG ATCCTCGTGGCCTCCTTCCTGAATC CCTGGATTACTGGACCTACCCAGGC TCACTGACCACCCCTCCTCTTCTGG AATGTGTGACCTGGATTGTGCTCAA GGAACCCATCAGCGTCAGCAGCGA GCAGGTGTTGAAATTCGTAACCTTA ACTTCAATGGGGAGGGTGAACCCGA AGAACTGATGGTGGACAACCTGGCGC CCAGCTCAGCCACTGAAGAACAGGC AAATCAAAGCTTCCTTCAAA			
IL15-294	ATGGACATGCGGGTGCCTG CACAACCTTCTGGGCCTGCTGTTGTT GTGGCTGTCTGGAGCCCGGTGTAAT TGGGTAAATGTTATCAGTGATCTCAA GAAGATAGAGGATCTCATCCAGTCC ATGCATATTGATGCCACGCTGTACA CAGAAAGCGATGTGCATCCTAGCTG TAAGGTGACAGCGATGAAGTGTTTT CTTTTGGAGCTGCAGGTAATTAGTCT TGAGTCCGGCGATGCCAGCATTGAT GATACCGTAGAAAACCTTGATTATCCT GGCCAACAATTCTGTCTCCTCAAAC GGAAACGTAACCGAGAGCGGTTGTA AAGAATGTGAAGAACTGGAAGAAAA GAACATCAAGGAGTTTCTGCAATCAT TCGTTACATCGTACAAATGTTTATA	27	MDMRVPAQLLGLLLWL SGARCNWVNVISDLKKIEDLIQSM HIDATLYTESDVHPCKVTAMKCF LLELQVISLESGDASIHDTVENLIIL ANNSLSSNGNVTESGCKECEELE EKNIKEFLQSFVHIVQMFINTSGS SGSGSGSGSGSGSGSGSGSGSG SGSGSGSKQEHFPDNLPSWAIT LISVNGIFVICCLTYCFAPRCRERA RNERLRRETVPVGS	26

	AATACGTCAGGATCTGGTTCTGGTT CCGGAAGTGATCTGGTTCAGGGTC CGGTAGTGATCTGGGTCAGGAAGT GGAAGCGGTAGTGGGTCTGGATCTA ACAAGAGCACTTTCCTGATAACCT GTTGCCGAGCTGGGCGATTACGCTT ATCAGTGTAACGGCATCTTTGTAAT ATGCTGTCTGACCTACTGCTTCGCA CCAAGGTGCCGGGAGAGAGCAAGA AATGAAAGACTGAGAAGGGAGACCG TGAGACCTGTGGGATCC			
IL15-295	ATGGACATGCGGGTGCCTG CACAACCTTCTGGGCCTGCTGTTGTT GTGGCTGTCTGGAGCCCGGTGTAAT TGGGTAAATGTTATCAGTGATCTCAA GAAGATAGAGGATCTCATCCAGTCC ATGCATATTGATGCCACGCTGTACA CAGAAAGCGATGTGCATCCTAGCTG TAAGGTGACAGCGATGAAGTGTTTT CTTTTGGAGCTGCAGGTAATTAGTCT TGAGTCCGGCGATGCCAGCATTGAT GATACCGTAGAAAACCTTGATTATCCT GGCCAACAATTCTCTGTCTCAAAC GGAACGTAACCGAGAGCGGTTGTA AAGAATGTGAAGAACTGGAAGAAAA GAACATCAAGGAGTTTCTGCAATCAT TCGTTACATCGTACAAATGTTTCATA AATACGTCAGGATCTGGTTCTGGTT CCGGAAGTGATCTGGTTCAGGGTC CGGTAGTGATCTGGGTCAGGAAGT GGAAGCGGTAGTGGGTCTGGATCTA ACAAGAGCACTTTCCTGATAACCT GTTGCCGAGCTGGGCGATTACGCTT ATCAGTGTAACGGCATCTTTGTAAT ATGCTGTCTGACCTACTGCTTCGCA CCAAGGTGCCGGGAGAGAGCAAGA AATGAAAGACTGAGAAGGGAGACCG TGAGACCTGTGGGATCCTCCCATCA CTGGGGGTACGGCAAACACAACGG ACCTGAGCACTGGCATAAGGACTTC	29	MDMRVPAQLLGLLLWL SGARCNWVNVISDLKKIEDLIQSM HIDATLYTESDVHPCKVTAMKCF LLELQVISLESGDASIHDTVENLIL ANNSLSSNGNVTESGCKECEEELE EKNIKEFLQSFVHIVQMFINTSGS SGSGSGSGSGSGSGSGSGSGSG SGSGSGSKQEHFPDNLPSWAIT LISVNGIFVICCLTYCFAPRCRERA RNERLRRETVRPVGSSHWWGYG KHNGPEHWHKDFPIAKGERQSP VDIDHTAKYDPSLKPLSVSYDQA TSLRILNNGHAFNVEFDDSDQKA VLKGGPLDGTyrLIQFHFHWGSL DGQGSSEHTVDKKYAAELHLVH WNTKYGDFGKAVQQPDGLAVLGI FLKVGSAPKPGHQKVVVDLDSIKTK GKSADFTNFDPRGLLPESLDYWT YPSLTTPLLECVTWIVLKEPISV SSEQVLKFRKLNFNAGEPEPEELM VDNWRPAQLPLNRQIKASFK	28

CCCATTGCCAAGGGAGAGCGCCAG TCCCCTGTTGACATCGACACTCATA CAGCCAAGTATGACCCCTCCCTGAA GCCCCTGTCTGTTTCTATGATCAA GCAACTTCCCTGAGAATCCTCAACA ATGGTCATGCTTTCAACGTGGAGTTT GATGACTCTCAGGACAAAGCAGTGC TCAAGGGAGGACCCCTGGATGGCA CTTACAGATTGATTCACTTTCACTTT CACTGGGGTTCACTTGATGGACAAG GTTCAGAGCATACTGTGGATAAAAA GAAATATGCTGCAGAACTTCACTTG GTTCACTGGAACACCAAATATGGGG ATTTTGGGAAAGCTGTGCAGCAACC TGATGGACTGGCCGTTCTAGGTATT TTTTGAAGGTTGGCAGCGCTAAAC CGGGCCATCAGAAAGTTGTTGATGT GCTGGATTCCATTAAACAAAGGGC AAGAGTGCTGACTTCACTAACTTCG ATCCTCGTGGCCTCCTTCTGAATC CCTGGATTACTGGACCTACCCAGGC TCACTGACCACCCCTCCTTCTCTGG AATGTGTGACCTGGATTGTGCTCAA GGAACCCATCAGCGTCAGCAGCGA GCAGGTGTTGAAATTCCGTAACTTA ACTTCAATGGGGAGGGTGAACCCGA AGAACTGATGGTGGACAACCTGGCGC CCAGCTCAGCCACTGAAGAACAGGC AAATCAAAGCTTCCTTCAAA			
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Lentivirus production

[00288] HEK293T cells were seeded on collagen coated tissue culture plates until 70% confluent. Cells were transfected with pELNS transfer vector carrying constitutive (IL15-292 or IL15-294) or regulated (IL15-293 or IL15-295) IL15 constructs, as well as packaging plasmids (pRSV.REV, pMDLg/p.RRE and pMD2.G) using Lipofectamine 3000 transfection reagent in Opti-MEM media. Media was replaced 6-8 hrs post-transfection with serum-free media. Supernatants containing virus were harvested 24 hr post-transfection, fresh media was added,

and supernatants were harvested again at 48 hr post-transfection. Viral supernatants were filtered to remove debris and concentrated by ultracentrifugation in 20% sucrose gradient. Virus were resuspended, aliquoted and stored at -80C freezer.

[00289] The nucleotide sequences of the pELNS transfer vectors OT-IL15-292, OT-IL15-293, OT-IL15-294 and OT-IL15-295 are SEQ ID NO: 34, SEQ ID NO: 35, SEQ ID NO: 36 and SEQ ID NO: 37, respectively.

[00290] As used herein, the lentiviruses used to transduce cells are referred to by their construct name (e.g., IL15-292, IL15-293, IL15-294, IL15-295, CD19-IL15-057, CD19-IL15-058 or CD19-063) or their transfer vector name (e.g., OT-IL15-292, OT-IL15-293, OT-IL15-294, OT-IL15-295, OT-CD19-IL15-057, OT-CD19-IL15-058 or OT-CD19-063).

T cell stocks

[00291] T cells were isolated from Leukopaks collected from human healthy donors. After PBMC isolation with Ficoll gradients, T cells were isolated using negative selection kit (StemCell Technologies) according to manufacturer's protocol. T cells were resuspended in cell freezing media (Bambanker), aliquoted and stored in liquid nitrogen.

Lentivirus transduction of T cells

[00292] T cells were thawed, cells were washed and counted. T cells were mixed with CD3/CD28 beads (Invitrogen cat#11141D) at 3:1 bead to T cell ratio. 5×10^5 cells/well were added to 24-well plates in 500 μ L media. Cells were activated for 24 hrs. Next day, lentivirus was thawed and added to each well at different volumes. After 24 hrs, 500 μ L of fresh media was added to wells, and cells were expanded by adding equal volume of fresh media every 2-3 days to keep cell density at $0.5-1 \times 10^6$ /mL. Cells were analyzed by flow cytometry to confirm expression on day 5 or 6. Cells were expanded for 9-10 days.

Example 2. *In vitro* analysis of ACZ-regulated mbIL15 expression and ACZ-regulated T cell expansion

[00293] The present example demonstrates *in vitro* validation of (i) ACZ-regulated mbIL15 expression in T cells and (ii) ACZ-regulated expansion of T cells expressing ACZ-regulated mbIL15.

[00294] Human primary T cells capable of expressing constitutive mbIL15 or ACZ-regulated mbIL15 were prepared in accordance with methods described in Example 1 above. See FIG. 1.

[00295] After T cell transduction and expansion, CD3/CD28 beads were removed using magnets, cells were washed twice, resuspended in fresh media and counted. Cells were plated in 12-well plates at 1×10^6 in 2 mL. One well of untransduced cells was cultured in the presence of 2 ng/mL IL15 as a control. T cells expressing regulated constructs were cultured in the absence or presence of acetazolamide (ACZ, 30, 10, 3, 1, 0.3 μ M). Cell numbers were monitored by flow cytometry every 3-4 days and cells were cultured for 10-12 days. At each time point 100 μ L of cells were collected from wells and analyzed by flow cytometry. Cells were split as needed. Cell cultures were maintained in 12-well plates by taking a portion and adding media in a new plate. Volumes for each well were recorded before and after split to calculate final volume in cell number assessment. IL15 or ACZ were replenished at final concentration of the fresh media added during each split. See FIG. 1.

[00296] T cell numbers were determined by flow cytometry. Empty vector (EV) transduced cell numbers decreased to background levels between 3-5 days in the absence of IL15, and cells expanded 11-fold in the presence of 2 ng/mL exogenous IL15 (FIG. 3A). T cells expressing constitutive IL15-292 and IL15-294 expanded between 18 and 21-fold, respectively, in 10 days (FIG. 3A). In T cells expressing IL15-293, maximum expansion was 9.5-11x with 30, 10, 3 μ M (FIG. 3B). At the lowest concentration tested (0.3 μ M), cells expanded 3.3x. These cells survived longer (0.8x) compared to EV cells without drug treatment (0.8x). In T cells expressing IL15-295, maximum expansion was 8.2-10x with 30, 10, 3 μ M and cells expanded 4.9x at the lowest concentration (0.3 μ M) tested (FIG. 3C). Without drug treatment, these cells survived (0.9x) longer compared to EV.

[00297] The effect of different concentrations of ACZ on IL15 expression was tested. T cells were treated with ACZ for 24 hrs starting at 100 μ M, diluted 3-fold for 9 points. Both %IL15+ T Cells (FIG. 4A) and IL15 Mean Fluorescence Intensity (MFI) (FIG. 4B) analysis indicated similar dose curves for OT-IL15-293 and OT-IL15-295. There was 4-5-fold increase in expression (both %IL15+ T cells and IL15 MFI) between highest and lowest concentrations of ACZ. EC₅₀ values were 0.29 μ M and 0.22 μ M EC₅₀ based on %IL15+ T Cells, 0.65 μ M and 0.44 μ M based on MFI of IL15 for OT-IL15-293 and OT-IL15-295, respectively.

Example 3. *In vivo* analysis of ACZ-regulated mbIL15 expression and ACZ-regulated T cell expansion

[00298] The present example demonstrates *in vivo* validation of (i) ACZ-regulated mbIL15 expression in T cells and (ii) ACZ-regulated expansion of T cells expressing ACZ-regulated mbIL15.

NK cell expansion

[00299] A portion of the PBMCs isolated from Leukopaks were used to enrich NK cells using negative selection kits (StemCell Technologies) according to manufacturer's protocol. Cells were cultured in 1:1 ratio with feeder K562 cells expressing 4-1BB-L and membrane-bound IL21, and recombinant IL2 (100 U/mL) for 7-14 days. Expansion was monitored by cell counts and purity was evaluated by flow cytometry.

In vivo analysis

[00300] Human primary T cells capable of expressing constitutive mbIL15 or ACZ-regulated mbIL15 were prepared in accordance with methods described in Example 1 above. After T cell transduction and expansion, CD3/CD28 beads were removed using magnets, cells were washed twice, resuspended in fresh media and counted. T cells were mixed with expanded NK cells and each animal received 5×10^6 T cells and 2×10^6 expanded NK cells. Cells were infused by intravenous injections into NSG mice. Animals infused with T cells expressing regulated constructs were dosed daily with 200 mg/kg ACZ or vehicle by PO injections. Every 3-4 days, 50 μ L blood was analyzed by flow cytometry for presence of T cells and NK cells using antibodies against mouse and human CD45, CD3 and CD56. IL15 expression on day 25 was analyzed using IL15Ra-Fc and fluorochrome conjugated anti-human IgG antibody. See FIG. 2.

[00301] Expansion of T cells expressing constitutive and regulated IL15 constructs, and their effects on bystander NK cells were evaluated *in vivo* in NSG mice over a course of 25 days (FIG. 5A- FIG. 5B). Empty vector (EV) transduced cell numbers slowly declined over time. T cells expressing constitutive IL15-292 and IL15-294 expanded up to 13x compared to the frequencies on day 3. In mice infused with T cells expressing regulated constructs, cell frequencies decreased in the presence of vehicle treatment. In groups treated with daily ACZ, cells expanded up to 7-8x compared to the frequencies on day 3. Bystander NK cells survived and expanded in the presence of T cells expressing constitutive IL15 constructs, or in the presence of T cells expressing regulated IL15 constructs treated daily with ACZ.

[00302] IL15 expression on T cells *in vivo* on day 25 was analyzed by flow cytometry (FIG. 5C). T cells transduced with constitutive constructs IL15-292 and IL15-294 expressed high

levels of IL15 (82% and 61%). IL15 expression was <1.5% in vehicle-treated IL15-293 and IL15-295 as well as EV groups. IL15 expression levels were 11% and 9% on T cells transduced with IL15-293 and IL15-295 in groups treated with ACZ.

Example 4: *In vivo* Analysis of Efficacy and Expansion in CART Cells Expressing Constitutive and Regulated mbIL15

[00303] The present example demonstrates that regulated mbIL15 coupled to ACZ dosing enhances anti-tumor efficacy and expansion of CD19 CART cells in the presence of CD19-positive tumors.

Generation of tandem CD19 CAR and mbIL15 constructs and lentivirus stocks

[00304] Lentiviral vector constructs and lentivirus stocks that co-express CD19 CAR and mbIL15 were generated essentially as described in Example 1. A CD19 CAR sequence (AA sequence: SEQ ID NO: 38; NA sequence: SEQ ID NO: 39) was constructed consisting of a CD8a leader sequence (aa1-21 in Uniprot ID P01732), FMC63 (anti-CD19) single chain variable fragment (scFv), a hinge and transmembrane domain derived from CD8 (aa138-206 in Uniprot ID P01732), a costimulatory domain derived from 4-1BB (aa214-255 in Uniprot ID Q07011) and CD3zeta signaling domains (aa52-164 in Uniprot ID P20963).

[00305] The bicistronic transgene expression cassette (5' to 3' as described) was comprised of a regulated or constitutive mbIL15, a P2A sequence (AA sequence: SEQ ID NO: 40; NA sequence: SEQ ID NO: 41), and the anti-CD19 CAR downstream from the P2A (see FIG. 6). For the regulated construct (CD19-IL15-058; AA Sequence: SEQ ID NO: 42; NA Sequence: SEQ ID NO: 43), the IL15-293 construct comprising mbIL15 operably linked to the CA2(L156H) DRD was used (AA sequence: SEQ ID NO: 24, NA sequence: SEQ ID NO: 25). For the constitutive construct (CD19-IL15-057; AA Sequence: SEQ ID NO: 45; NA Sequence: SEQ ID NO: 46), a construct comprising mbIL15 operably linked to the CA2 wildtype sequence was used (See FIG. 6). The nucleotide sequence of lentivirus OT-CD19-IL15-058 is SEQ ID NO:44; the nucleotide sequence of lentivirus OT-CD19-IL15-057 is SEQ ID NO:45.

Expression of mbIL15-CAR constructs in peripheral blood T cells

[00306] Peripheral blood T cells were activated, transduced, expanded for up to 10 days, and frozen in cell freezing medium essentially as described in Example 1 to be used in the *in vivo* human Nalm6-Luc xenograft tumor model. mbIL15 and CAR expression were analyzed by flow cytometry using anti-IL15 antibody and recombinant protein comprised of the extracellular

domain of human CD19 fused to human IgG1 Fc domain (CD19-Fc), respectively. CD19 CAR-only transduced cell or untransduced cells were used as controls. 72% of cells transduced with control CD19 CAR construct were CAR+mbIL15- (FIG. 7A). For cells transduced with lentiviral vector expressing constitutive mbIL15 and CAR (CD19-IL15-057), 26% of the cells were CAR+ and 13% were double positive for CAR+mbIL15+. For cells transduced with vector expressing regulated mbIL15 and CAR (CD19-IL15-058), 25% were CAR+mbIL15- in the absence of ACZ and 9.7% were CAR+mbIL15+ double positive after a 24-hr exposure to 10 μ M ACZ. These results confirmed expression of both CAR and mbIL15 after transduction of T cells with lentiviral vector expressing CD19CAR in combination with constitutive or regulated mbIL15.

Evaluation of mbIL15-CART cells in Nalm6-Luc xenograft model

[00307] To evaluate the effect of mbIL15 on anti-tumor activity of CART cells, T cells that were transduced with lentiviral vectors expressing CD19 CAR with or without constitutive or regulated mbIL15 were infused into mice after implantation of CD19+ Nalm6-Luc tumors. CD19+ Nalm6 cells expressing luciferase (Nalm6-Luc) were injected by intravenous route (1×10^6 /mouse) into NSG mice and tumor growth was measured once or twice per week by bioluminescence imaging measurement (total flux units in photons per second (p/s)) after intraperitoneal injections of D-luciferin. On day 6, animals were randomized into new cages (N=8 for each group) when average tumor size reached approximately 10^6 total p/s. CD19 CART cells (engineered with or without constitutive or regulated mbIL15) were thawed for infusion into tumor bearing mice. CAR expression in T cells was determined post-thaw and after 24-hr restimulation with anti-CD3/CD28 beads. CART cells across different groups were normalized based on %CAR+ cells. Each mouse received 0.3×10^6 CAR+ cells and the total number of T cells in the infusion product was adjusted to 7×10^6 T cells by addition of EV-transduced T cells.

[00308] The first group received T cells engineered with EV as a negative control, the second group received control CART cells without mbIL15 (CD19-063; AA Sequence: SEQ ID NO: 48; NA Sequence: SEQ ID NO: 49; vector sequence: SEQ ID NO: 50) and the third group received CART cells expressing constitutive mbIL15 (CD19-IL15-057). Groups 4 and 5 received CART cells that co-expressed regulated mbIL15 (CD19-IL15-058), and while one group was treated daily PO with 200 mg/kg ACZ, the other group was treated daily with vehicle until the end of the

study (~50 days). To monitor T cell expansion, additional animals were included in each group (n=4 for blood, and n=4 for bone marrow). Blood (50 μ L) was withdrawn from submandibular veins on days 7, 14, and 21, and bone marrow (from femur) was harvested on day 14 after T cell infusion. Red blood cells were lysed, stained with fluorochrome-conjugated antibodies against human CD45, CD3 and mouse CD45, and cells were analyzed by flow cytometry. Tumor growth was measured up to 55 days after tumor implantation; endpoints included 10^{10} total flux units as well as effects on animal health such as hind-limb paralysis and decrease in body weight.

[00309] Tumor growth in individual mice in each group is shown in FIG. 7B and group averages are shown in FIG. 7C. Rapid tumor growth was observed in all animals in group 2 treated with EV-transduced T cells, and tumor growth was delayed up to ~25 days upon treatment with control CART cells with no complete response. Tumor growth rate in mice treated with CART cells expressing regulated mbIL15 and vehicle treatment were similar to control CART group. In contrast, tumors regressed to background levels in 5 and 6 of 8 animals in groups treated with CART cells expressing constitutive mbIL15 and CART cells expressing regulated mbIL15 plus ACZ, respectively. T cells numbers were reduced over time in blood (<0.2% on day 21, FIG. 7D) and were low in bone marrow (<1% on day 14, FIG. 7E) from mice treated with control T cells, control CART, and CART expressing regulated mbIL15 with vehicle treatment. In contrast, in mice treated with CART expressing constitutive mbIL15 or regulated mbIL15 with ACZ, T cell numbers increased in blood over time (>1% on day 21, FIG. 7D) and were high in bone marrow (20% for constitutive, 10% for regulated plus ACZ, FIG. 7E). These results demonstrate that regulated mbIL15 coupled to ACZ treatment enhanced CART anti-tumor responses compared to T cells expressing CAR alone after infusion of a suboptimal CART cell dose, and promoted CAR engineered T cell expansion post-tumor clearance.

Example 5: Isolation of TIL From Patient Tumor Samples

[00310] Head and neck tumor samples were obtained from Cooperative Human Tissue Network. Tumor samples were cut into 1-3 mm fragments in Hanks' Balanced Salt Solution (HBSS) buffer and fragments were placed in 24-well plates at 1 fragment/well in 2 ml of culture media (RPMI-1640 supplemented with 1X Penicillin/Streptomycin, 1 mM Sodium Pyruvate, 1X HEPES, 50 μ M 2-Mercaptoethanol (Invitrogen) and 10% heat-inactivated human AB serum (Valley Bio)) containing 6000 IU/mL IL2. Half of the media was replaced with fresh media containing IL2 starting on day 5 and cells were split into multiple wells as they became confluent

for a duration of 3 weeks. This culture process is referred to as pre-rapid expansion protocol (REP). TIL from other tumor types have been isolated using essentially the same process.

[00311] In order to determine the change in frequency of T cells before and after pre-REP culture, a portion of tumor fragments were digested with collagenase and DNase I to generate single cell suspension prior to the pre-REP culture and compared to cells obtained after the pre-REP culture. Frequency of T cells were analyzed by flow cytometry using fluorochrome conjugated anti-CD45 and anti-CD3 antibodies. As shown in FIG. 8A, nearly half of the cells ($44.29 \pm 21.67\%$) in the pre-culture tumor cell suspension were CD45+ and among these only $\sim 39.85 \pm 23.69\%$ were CD3+ T cells. After 3 weeks of culture in the presence of IL2 (pre-REP), the majority of the cells were CD45+ ($90.35 \pm 7.28\%$), indicating an enrichment of hematopoietic cells, and CD3+ ($80.64 \pm 15.19\%$), indicating an enrichment of T cells.

[00312] TIL from numerous other human tumor types, including melanoma tumors and malignant tumors from breast, lung, kidney, endometrium, liver, pancreas and ovary, have been isolated in the same manner.

Example 6. *In vitro* Analysis of Regulated mbIL15 Expression by ACZ in TIL

BaEV-Pseudotyped lentivirus production

[00313] HEK293T cells were seeded on collagen coated tissue culture plates until 70% confluent. Cells were transfected with pELNS transfer vector carrying constitutive (IL15-292) or regulated (IL15-293) IL15 constructs, as well as packaging plasmids (pRSV.REV, pMDLg/pRRE and OT-BaEVg-002 (SEQ ID NO: 51)) using Lipofectamine 3000 transfection reagent in Opti-MEM media. Media was replaced 6-8 hrs post-transfection with serum-free media. Supernatants containing virus were harvested 24 hr post-transfection, fresh media was added, and supernatants were harvested again at 48 hr post-transfection. Viral supernatants were filtered to remove debris and concentrated by low speed ultracentrifugation. Virus were resuspended, aliquoted and stored at -80C freezer.

Transduction of TIL with lentivirus

[00314] 96-well non-coated tissue culture plates were incubated with 35 μg per mL RetroNectin (Takara Bio) in PBS for 2h at 37°C or overnight at 4°C. RetroNectin was removed and the plates washed with PBS. BaEV-pseudotyped lentivirus, prepared as described above, and TIL cell media, at a total volume of 50 μL per well, were added to each well and the plates were centrifuged at low speed for 2 hours at 32°C. TIL generated from a head and neck tumor

sample prepared as described in Example 5 were engineered after 3 weeks in the pre-REP culture. TIL were activated for 24 hrs in 24-well plates with anti-CD3/CD28 beads at 3:1 bead to T cell ratio. Activated TIL were placed in virus-coated plates and centrifuged at 800g for 2 hrs and incubated at 37°C for 4 days in culture media. One well of cells was processed similarly without virus addition and used as negative control (“untransduced”). Cells that were transduced with the regulated mbIL15 construct were treated either with 10 μ M ACZ or DMSO for 24 hrs.

Expression of regulated mbIL15 in TIL in response to ACZ

[00315] mbIL15 expression was determined by flow cytometry using two staining reagents: fluorochrome-conjugated anti-IL15 antibody as well as a recombinant protein comprised of extracellular domain of IL15Ra fused to human IgG1 Fc domain (IL15Ra-Fc). mbIL15+ cell frequency was determined based on co-staining with anti-IL15 and IL15Ra-Fc (identified as the IL15+ IL15Ra-Fc+ double positive population). As shown in FIG. 8B, 45.5% of TIL expressed constitutive mbIL15 (IL15-292). In the presence of DMSO, regulated mbIL15 (IL15-293) expression was 17.1% with low MFI. In contrast, in the presence of ACZ, regulated mbIL15 expression increased to 42.5% with high MFI. These data indicate that ACZ induces CA2 DRD-regulated mbIL15 in transduced TIL.

Example 7: *In Vivo* Analysis of TIL Expressing Constitutive and Regulated mbIL15

[00316] To evaluate the effect of regulated mbIL15 on the anti-tumor activity of tumor infiltrating lymphocytes (TIL), a human PDX (hPDX) model is used. TIL are isolated from a patient tumor sample, for example, a head and neck tumor sample, as described in Example 6. TIL are transduced with BaEV-pseudotyped lentiviral vectors containing either the IL15-292 construct or the IL15-293 construct, as described in Example 6, or with BaEV-pseudotyped lentiviral empty vector (EV), and then optionally frozen. TIL-matched patient-derived xenografts (hPDX) from the tumor sample are established via subcutaneous implant into the right flank of NSG mice. Tumor growth is measured once or twice per week using calipers. On study start, tumors are measured, and mice are randomized and placed in cohorts based on similar mean tumor volume across all groups into new cages (N=8 for each group). The engineered matched TIL are thawed if necessary, stimulated with PMA, and then infused into the tumor-bearing mice. Each mouse receives an equal number of engineered TIL.

[00317] Group 1 receives untransduced TIL supplemented with recombinant human IL2 (hIL2) as benchmark control, and group 2 receives TIL transduced with constitutive mbIL15

(IL15-292). Groups 3 and 4 receive TIL transduced with regulated mbIL15 (IL15-293). Group 3 is treated daily PO with 200 mg/kg ACZ, and group 4 is treated daily with vehicle until the end of the study. To monitor TIL persistence, additional animals are included in each group (n=4 for blood). Blood (50 μ L) was withdrawn from submandibular veins on pre-determined days. Red blood cells are lysed, stained with fluorochrome-conjugated antibodies against human CD45, CD3 and mouse CD45, and cells are analyzed by flow cytometry. Tumor growth is measured for up to approximately 90 days; endpoints include maximal caliper measurements as well as effects on animal health, such as tumor necrosis and decrease in body weight.

[00318] Tumor growth in individual mice in each group is followed and group averages are collected. Delayed tumor growth is expected in animals in group 1 treated with untransduced TIL plus hIL2. No tumor growth inhibition will be observed in group 4 because little or no mbIL15 will be expressed by the TIL. In contrast, tumors will substantially regress, in some cases to baseline, in groups 2 and 3 because both groups have TIL expressing mbIL15, which will enhance their persistence and correlated anti-tumor activity.

Example 8: Isolation of NK Cells from Cord Blood

[00319] Cryopreserved mononuclear cell-fractionated cord blood units were obtained from BioBridge Global. Cord blood was diluted 1:1 with phosphate-buffered saline (PBS) and centrifuged over a cushion of Ficoll-Paque+ (Sigma Cat. No. GE17-1440-02). The buffy coat comprising mononuclear cells (MNC) was collected, and the MNC were washed and counted. NK cells were isolated from MNC using EasySep Human NK Cell Isolation Kit (Stemcell Technologies Cat. No. 17955). NK cells were counted and checked for purity by FACS using CD56, CD16, CD3 and viability stain.

Example 9: In vitro Analysis of Regulated mbIL15 Expression by ACZ in NK Cells

NK cell expansion

[00320] One day prior to NK cell isolation as described in Example 8, feeder cells (K562 cells expressing 4-1BBL and mbIL-21) were thawed in complete NK cell media (RPMI with Glutamax (ThermoFisher), 10% heat-inactivated fetal bovine serum (Gibco), 1X Penicillin/Streptomycin, 1 mM Sodium Pyruvate, 1X HEPES, 50 μ M 2-Mercaptoethanol). On the day of NK cell isolation, 10×10^6 feeder cells were treated with mitomycin C to inhibit their proliferation and washed to remove excess drug. NK cells were added to the feeder cells at a 1:2 effector to target ratio in NK cell media with 200U/mL recombinant human IL2 (rhIL2;

PeproTech). NK cell cultures were expanded by replenishing cell cultures with NK cell media and rhIL2 every two days, and analyzed by FACS for NK cell expansion.

Transduction of NK cells with lentivirus

[00321] 96-well non-coated tissue culture plates were incubated with 35 µg per mL RetroNectin (Takara Bio) in PBS for 2h at 37°C or overnight at 4°C. RetroNectin was removed and the plates washed with PBS. BaEV-pseudotyped lentivirus, prepared as described in Example 6, and NK cell media, at a total volume of 50 µL per well, were added to each well and the plates were centrifuged at low speed for 2 hours at 32°C. 1×10^5 NK cells in 100 µL NK cell transduction media (NK cell media with 1 mg/mL Synperonic F 108 (Sigma-Aldrich) and 200U/mL rhIL2) were added to each well and the cells were expanded for four days in NK cell media.

Regulation of mbIL15 construct with ACZ

[00322] NK cells from three different donors were isolated, expanded and transduced with BaEV-pseudotyped lentivirus containing either the IL15-292 construct or the IL15-293 construct. The titer of the IL15-292 lentivirus was 2.38×10^8 TU/mL while the titer for the IL15-293 lentivirus was 6.51×10^8 TU/mL (as measured by a Jurkat qPCR titer), and 4 µL lentivirus and 46 µL NK cell media were added to each well. After cells were expanded for four days, 10 µM ACZ or vehicle (DMSO) was added and the cells were incubated overnight. Expression of mbIL15 was analyzed via FACS the following day (five days post-transduction).

[00323] mbIL15 expression was determined by flow cytometry using two staining reagents: IL15Ra-Fc and an anti-CD56 antibody. mbIL15+ cell frequency was determined relative to the number of NK cells as determined by the anti-CD56 antibody. As shown in FIG. 9, greater than 40% of cord blood-derived NK cells from two of the three donors expressed mbIL15, and approximately 70% of cord blood-derived NK cells from one of the three donors expressed mbIL15. In the presence of DMSO, regulated mbIL15 expression was 10% or less in NK cells regardless of donor. In contrast, in the presence of ACZ, regulated mbIL15 expression increased to greater than 40% in NK cells regardless of donor. These data indicate that ACZ induces CA2 DRD-regulated mbIL15 in transduced NK.

Example 10: In Vivo Analysis of NK Cells Expressing Constitutive and Regulated mbIL15

[00324] To evaluate the effect of regulated mbIL15 on the anti-tumor activity of NK cells, an HL-60 animal model of acute myeloid leukemia is used. Cord blood NK cells are transduced

with BaEV-pseudotyped lentiviral vectors containing either the IL15-292 construct or the IL15-293 construct, as described in Example 9, or with BaEV-pseudotyped lentiviral empty vector (EV), and optionally frozen after transduction. HL-60 cells expressing luciferase (HL-60-luc) are injected intravenously (1×10^6 /mouse) into NSG mice and tumor growth is measured once or twice per week by bioluminescence imaging measurement (total flux units in photons per second (p/s) after intraperitoneal injections of D-luciferin). On day 6, animals are randomized into new cages (N=8 for each group) when average tumor size reaches approximately 10^6 total p/s. The engineered NK cells are thawed if necessary and infused into the HL-60 tumor-bearing mice. Each mouse receives an equal number of mbIL15+ cells and the total number of NK cells in the infusion product is adjusted by addition of EV-transduced NK cells.

[00325] Group 1 receives NK cells engineered with EV as a negative control, and group 2 receives NK cells transduced with constitutive mbIL5 (construct IL15-292). Groups 3 and 4 receive NK cells transduced with regulated mbIL15 (construct IL15-293). Group 3 is treated daily PO with 200 mg/kg ACZ, and group 4 is treated daily with vehicle until the end of the study. To monitor NK expansion, additional animals are included in each group (n=4 for blood analyses). Blood (50 μ L) is withdrawn from submandibular veins on days 7, 14, and 21. Red blood cells are lysed, stained with fluorochrome-conjugated antibodies against human CD45, CD3 and mouse CD45, and cells are analyzed by flow cytometry. Tumor growth is measured up to approximately 30 days; endpoints include maximal total flux units (10^{10}) as well as effects on animal health such as hind-limb paralysis and decrease in body weight.

Tumor growth in individual mice in each group is measured and group averages are collected. Rapid tumor growth is expected in all animals in group 1 infused with EV-transduced NK cells. Tumor growth rate in group 4 mice will be similar to the control EV group because little or no mbIL15 will be expressed. In contrast, tumors will regress substantially in groups 2 and 3 because both groups of mice express mbIL15 on NK cells such that these cells will exhibit higher expansion and persistence compared to NK cells from groups 1 and 4. This example will demonstrate that ACZ can induce expression in vivo of mbIL15 in transduced NK cells, leading to enhanced NK anti-tumor responses, compared to transduced vehicle-treated NK cells that express little or no mbIL15.

[00326] In the foregoing detailed description, the invention has been described with reference to specific embodiments. However, it may be appreciated that various modifications and changes

can be made without departing from the scope of the invention as set forth in the appended claims.

[00327] The following Items are illustrative of various embodiments of the present disclosure.

[00328] Item 1. A nucleic acid molecule comprising a polynucleotide encoding a recombinant protein comprising a drug responsive domain (DRD) operably linked to an IL15 payload, wherein said DRD is derived from human carbonic anhydrase II (CA2) and comprises one, two, three, four or more mutations relative to SEQ ID NO:1 or SEQ ID NO:2.

[00329] Item 2. The nucleic acid molecule of Item 1, wherein the DRD comprises one, two, three or four amino acid additions, substitutions and/or deletions relative to SEQ ID NO:1 or SEQ ID NO:2.

[00330] Item 3. The nucleic acid molecule of Item 2, wherein the DRD comprises the amino acid sequence of SEQ ID NO:4.

[00331] Item 4. The nucleic acid molecule of Item 3, wherein the DRD consists of the amino acid sequence of SEQ ID NO:4.

[00332] Item 5. The nucleic acid molecule of any of Items 1-4, wherein the IL15 payload comprises the amino acid sequence of SEQ ID NO:8.

[00333] Item 6. The nucleic acid molecule of any one of Items 1-5, wherein the IL15 payload is N-terminal to the DRD.

[00334] Item 7. The nucleic acid molecule of Item 6, wherein the IL15 payload is a membrane-bound IL15 polypeptide.

[00335] Item 8. The nucleic acid molecule of Item 7, wherein the membrane-bound IL15 polypeptide comprises an IL15 polypeptide component comprising the amino acid sequence of SEQ ID NO:8, a transmembrane domain and an intracellular tail, wherein the transmembrane domain is C-terminal to the IL15 polypeptide component and the intracellular tail is C-terminal to the transmembrane domain.

[00336] Item 9. The nucleic acid molecule of Item 8, wherein the membrane-bound IL15 polypeptide further comprises a linker between the IL15 polypeptide component and the transmembrane domain.

[00337] Item 10. The nucleic acid molecule of any one of Items 1-7, wherein the IL15 payload further comprises one or more components selected from the group consisting of: (a) a leader

sequence; (b) a GS linker; (c) a hinge domain; (d) a transmembrane domain; and (e) an intracellular tail.

[00338] Item 11. The nucleic acid molecule of any one of Items 1-7, wherein the IL15 payload further comprises: (a) a leader sequence; (b) a GS linker; (c) a hinge domain; (d) a transmembrane domain; and (e) an intracellular tail.

[00339] Item 12. The nucleic acid molecule of Item 11, wherein the polynucleotide encodes the amino acid sequence of SEQ ID NO:24.

[00340] Item 13. The nucleic acid molecule of Item 12, wherein the polynucleotide comprises the nucleic acid sequence of SEQ ID NO:25.

[00341] Item 14. The nucleic acid molecule of Item 11, wherein the polynucleotide encodes the amino acid sequence of SEQ ID NO:28.

[00342] Item 15. The nucleic acid molecule of Item 14, wherein the polynucleotide comprises the nucleic acid sequence of SEQ ID NO:29.

[00343] Item 16. The nucleic acid molecule of any one of Items 1-15, wherein the nucleic acid molecule further comprises a second polynucleotide encoding a chimeric antigen receptor (CAR) or T cell receptor (TCR), wherein the CAR or TCR comprises an antigen-binding domain specific to an antigen of interest.

[00344] Item 17. The nucleic acid molecule of Item 16, wherein the second polynucleotide encodes a CAR comprising an antigen-binding domain specific to an antigen of interest.

[00345] Item 18. The nucleic acid molecule of Item 17, wherein the CAR comprises an antigen-binding domain specific to CD19.

[00346] Item 19. A vector comprising the nucleic acid molecule of any one of Items 1-19.

[00347] Item 20. The vector of Item 19, wherein the vector is a plasmid or a viral vector.

[00348] Item 21. The vector of Item 20, wherein the vector is a viral vector derived from an adenovirus, adeno-associated virus (AAV), alphavirus, flavivirus, herpes virus, measles virus, rhabdovirus, retrovirus, lentivirus, Newcastle disease virus (NDV), poxvirus, or picornavirus.

[00349] Item 22. The vector of Item 21, wherein the viral vector is selected from a lentiviral vector, adenoviral vector, AAV vector, herpes simplex viral vector, retroviral vector or oncolytic viral vector.

[00350] Item 23. The vector of Item 22, wherein the viral vector is selected from a lentiviral vector or a gamma retroviral vector.

- [00351]** Item 24. A recombinant protein encoded by the nucleic acid molecule of any one of Items 1-15.
- [00352]** Item 25. A cell comprising the nucleic acid molecule of any one of Items 1-18, the vector of any one of Items 18-23, or the recombinant protein of Item 24.
- [00353]** Item 26. The cell of Item 25, wherein the cell is a bacterial cell.
- [00354]** Item 27. The cell of Item 25, wherein the cell is a mammalian cell.
- [00355]** Item 28. The cell of Item 27, wherein the mammalian cell is a human cell.
- [00356]** Item 29. The cell of Item 28, wherein the human cell is a T cell, natural killer (NK) cell, or tumor infiltrating lymphocyte (TIL).
- [00357]** Item 30. The cell of Item 29, wherein the cell is a CD4⁺ or CD8⁺ T cell.
- [00358]** Item 31. The cell of Item 29, wherein the cell is isolated.
- [00359]** Item 32. The cell of Item 29, wherein the human cell is a T cell or an NK cell, and wherein the human T cell or the human NK cell further comprises a second polynucleotide encoding a chimeric antigen receptor (CAR) or T cell receptor (TCR), wherein the CAR or TCR comprises an antigen-binding domain specific to an antigen of interest.
- [00360]** Item 33. The cell of Item 32, wherein the second polynucleotide encodes a CAR comprising an antigen-binding domain specific to an antigen of interest.
- [00361]** Item 34. The cell of Item 33, wherein the CAR comprises an antigen-binding domain specific to CD19.
- [00362]** Item 35. A pharmaceutical composition comprising the cell of any one of Items 25-34 and a pharmaceutically acceptable carrier.
- [00363]** Item 36. The pharmaceutical composition of Item 35, wherein the cell is a human T cell, human NK cell or human TIL.
- [00364]** Item 37. A method of modulating the expression, function, and/or level of IL15 in the cell of any one of Items 25-34, said method comprising administering to the cell a stimulus to which the DRD is responsive, wherein the stimulus is administered in an amount sufficient to modulate the expression, function and/or level of IL15.
- [00365]** Item 38. The method of Item 37, wherein the stimulus is selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide.
- [00366]** Item 39. The method of Item 38, wherein the stimulus is acetazolamide.

[00367] Item 40. The method of Item 37, wherein the cell is a human T cell or a human NK cell, and wherein the human T cell or the human NK cell further comprises a second polynucleotide encoding a chimeric antigen receptor (CAR) or T cell receptor (TCR), wherein the CAR or TCR comprises an antigen-binding domain specific to an antigen of interest.

[00368] Item 41. The method of Item 40, wherein the second polynucleotide encodes a CAR comprising an antigen-binding domain specific to an antigen of interest.

[00369] Item 42. The method of Item 41, wherein the CAR comprises an antigen-binding domain specific to CD19.

[00370] Item 43. A method of treating a disease or disorder responsive to regulated IL15 in a subject in need thereof, said method comprising: (a) administering to the subject a therapeutically effective amount of the nucleic acid molecule of any one of Items 1-18, the vector of any one of Items 19-23, the recombinant protein of Item 24, the cell of any one of Items 25-34 or the pharmaceutical composition of any one of Items 35-36; and (b) administering a therapeutically effective amount of a stimulus to the subject, wherein the DRD is responsive to the stimulus and wherein expression of the IL15 payload is modulated in response to the stimulus.

[00371] Item 44. The method of Item 43, wherein the stimulus is selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide.

[00372] Item 45. The method of Item 44, wherein the stimulus is acetazolamide.

[00373] Item 46. The method of any of Items 43-45, wherein the disease or disorder is cancer.

[00374] Item 47. A method of treating a malignant tumor in a subject in need thereof, wherein said tumor expresses a tumor-associated antigen, said method comprising: (a) administering to the subject a therapeutically effective amount of the human T cell or the human NK cell of any one of Items 32-34, or a pharmaceutical composition thereof, wherein the CAR or TCR comprises an antigen-binding domain specific to the tumor-associated antigen; and (b) administering a therapeutically effective amount of a stimulus to the subject, wherein the DRD is responsive to the stimulus and wherein expression of the IL15 payload is modulated in response to the stimulus.

[00375] Item 48. The method according to Item 48, wherein the subject is administered a therapeutically effective amount of the human T cell comprising a CAR, or a pharmaceutical composition thereof.

[00376] Item 49. The method according to either of Items 47 or 48, wherein the stimulus is selected from acetazolamide, celecoxib, valdecoxib, rofecoxib, methazolamide, dorzolamide, brinzolamide, diclofenamide, ethoxzolamide, zonisamide, dansylamide, or dichlorphenamide.

[00377] Item 50. The method of Item 49, wherein the stimulus is acetazolamide.

[00378] Item 51. A method of producing a genetically engineered T cell, natural killer (NK) cell or tumor infiltrating lymphocyte (TIL), comprising introducing into the T cell, NK cell or TIL a polynucleotide encoding a protein comprising a drug responsive domain (DRD) operably linked to an IL15 payload, wherein the polynucleotide encodes an amino acid sequence of SEQ ID NOS:24 or 28.

[00379] Item 52. The method of Item 51, wherein the polynucleotide comprises a nucleotide sequence of SEQ ID NOS:25 or 29.

[00380] Item 53. The method of Item 52, wherein the polynucleotide is introduced into the T cell, NK cell or TIL by lentiviral transduction.

[00381] Item 54. The method of Item 52, wherein the polynucleotide is introduced into the T cell, NK cell or TIL by a non-viral vector delivery method.

[00382] Item 55. A modified cell comprising a recombinant protein, said recombinant protein comprising: (i) an effector module, wherein said effector module comprises a stimulus response element (SRE) that comprises a drug responsive domain (DRD), wherein said DRD is derived from a parent protein or a mutant protein having one or more amino acid mutations in the amino acid sequence of human carbonic anhydrase 2 (CA2) (SEQ ID NO: 1) and comprises the amino acid sequence of SEQ ID NO:4; and (ii) a recombinant IL15 linked to the SRE.

[00383] Item 56. The cell of Item 55, wherein the recombinant IL15 comprises the amino acid sequence of SEQ ID NO:8.

[00384] Item 57. The cell of Item 55 or 56, wherein the recombinant IL15 can be expressed on the cell surface.

[00385] Item 58. The cell of Item 55 or 56, wherein the recombinant IL15 is a membrane bound IL15 (mbIL15).

[00386] Item 59. The cell of any of Items 55-58, wherein the recombinant protein comprises the whole or a portion of SEQ ID NO: 16.

[00387] Item 60. The cell of any of Items 55-59, wherein the recombinant protein comprises the whole or a portion of SEQ ID NO: 18.

[00388] Item 61. The cell of Item 55, wherein the recombinant protein further comprises one or more components selected from the group consisting of: (a) a leader sequence; (b) a GS linker; (c) a hinge domain; (d) a transmembrane domain; and (e) a cytoplasmic tail domain.

[00389] Item 62. The cell of Item 55, wherein the recombinant protein comprises the amino acid sequence of SEQ ID NO:24.

[00390] Item 63. The cell of Item 55, wherein the recombinant protein comprises the amino acid sequence of SEQ ID NO:28.

[00391] Item 64. The cell of any one of Items 55-63, wherein the recombinant IL15 is further linked to at least one of: (a) a leader sequence; (b) a signal peptide; (c) a linker; (d) a spacer; (e) a cleavage site; (f) a tag; (g) a co-stimulatory domain; (h) a fluorescence protein; and (i) a hinge.

[00392] Item 65. The cell of any of Items 55-64, wherein the SRE is responsive to or interacts with Acetazolamide (ACZ).

[00393] Item 66. The cell of Item 55, wherein the cell is a T cell, a natural killer cell (NK cell), or a tumor infiltrating lymphocyte (TIL).

[00394] Item 67. A nucleic acid molecule, comprising: a polynucleotide, optionally a first expression cassette, encoding a first recombinant protein comprising a stimulus response element (SRE) linked to an IL15 polypeptide; wherein the SRE comprises a DRD, wherein said DRD comprises an amino acid sequence of SEQ ID NO:4.

[00395] Item 68. The nucleic acid molecule of Item 67, wherein the IL15 is under control of the SRE.

[00396] Item 69. The nucleic acid molecule of Item 67, wherein the polynucleotide further encodes: (a) a leader sequence; (b) a GS linker; (c) a hinge domain; (d) a transmembrane domain; and (e) a cytoplasmic tail domain.

[00397] Item 70. The nucleic acid molecule of Item 67, wherein the polynucleotide comprises the nucleic acid sequence of SEQ ID NO:25.

[00398] Item 71. The nucleic acid molecule of Item 67, wherein the polynucleotide comprises the nucleic acid sequence of SEQ ID NO:29.

[00399] Item 72. The nucleic acid molecule of any of Items 67-71 that is isolated.

[00400] Item 73. A recombinant protein encoded by a nucleic acid molecule of any one of Items 67-72.

[00401] Item 74. The recombinant protein of Item 73, wherein the recombinant protein comprises an amino acid sequence of SEQ ID NO:24 or 28.

[00402] Item 75. A vector comprising a nucleic acid molecule of any one of Items 67-72.

[00403] Item 76. The vector of Item 75, wherein the vector is a plasmid, or lentiviral vector.

[00404] Item 77. The vector of Item 76 that is integrase defective.

[00405] Item 78. A T cell, NK cell or TIL, comprising the nucleic acid molecule of any one of Items 67-72, a recombinant protein of Items 73-74, or a vector of any one of Items 75-77.

[00406] Item 79. The T cell of Item 78 that is a CD4⁺ or CD8⁺ T cell.

[00407] Item 80. The T cell of Item 79 or Item 42 that is a human T cell.

[00408] Item 81. The T cell of any of Items 78-80 that is isolated.

[00409] Item 82. A pharmaceutical composition, comprising the cell, T cell, NK cell or TIL of any one of Items 55-66 or 78-81 and a pharmaceutically acceptable carrier.

[00410] Item 83. A method of producing a genetically engineered T cell, NK cell or TIL, comprising: introducing into a T cell, NK cell or TIL: a first polynucleotide encoding a stimulus response element comprising a CA2 DRD linked to an IL15 polypeptide payload, wherein the first polynucleotide has a nucleotide sequence of SEQ ID NO:25 or 29.

[00411] Item 84. The method of Item 83, wherein the first polynucleotide is introduced into the T cell, NK cell or TIL via a lentiviral virus transfection of said T cell, NK cell or TIL.

[00412] While the present disclosure has been described at some length and with some particularity with respect to the several described embodiments, it is not intended that it should be limited to any such particulars or embodiments or any particular embodiment, but it is to be construed with references to the appended claims so as to provide the broadest possible interpretation of such claims in view of the prior art and, therefore, to effectively encompass the intended scope of the disclosure.

[00413] All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification,

including definitions, will control. In addition, section headings, the materials, methods, and examples are illustrative only and not intended to be limiting.