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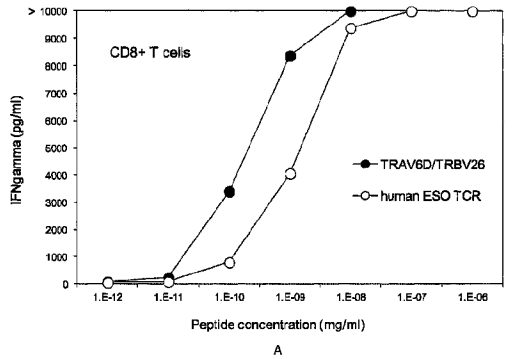

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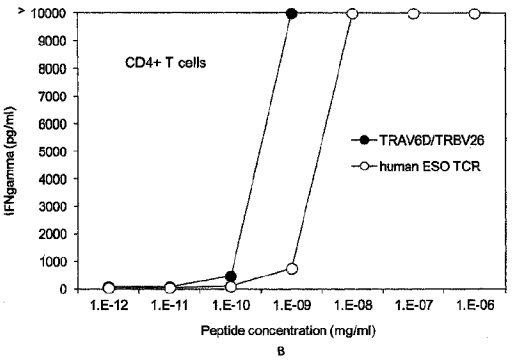

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(57) Abrégé/Abstract:
The invention provides an isolated or purified T cell receptor (TCR) having antigenic specificity for NY-ESO-1. Also provided are related polypeptides, proteins, nucleic acids, recombinant expression vectors, isolated host cells, populations of cells, antibodies, or antigen binding portions thereof, and pharmaceutical compositions. The invention further provides a method of detecting the presence of cancer in a mammal and a method of treating or preventing cancer in a mammal using the inventive TCRs or related materials.

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(54) Title: MURINE ANTI-NY-ESO-1 T CELL RECEPTORS

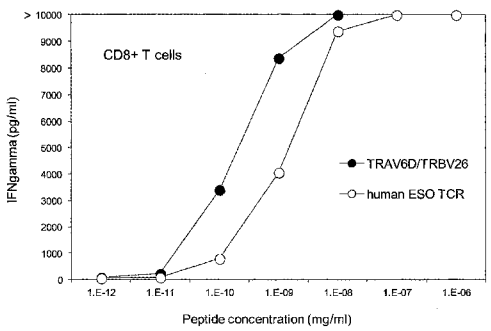

Fig. 1A

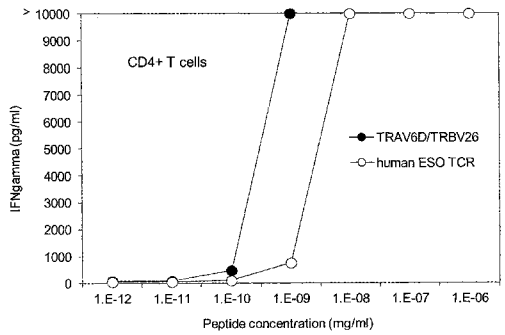

Fig. 1B

(57) Abstract: The invention provides an isolated or purified T cell receptor (TCR) having antigenic specificity for NY-ESO-1. Also provided are related polypeptides, proteins, nucleic acids, recombinant expression vectors, isolated host cells, populations of cells, antibodies, or antigen binding portions thereof, and pharmaceutical compositions. The invention further provides a method of detecting the presence of cancer in a mammal and a method of treating or preventing cancer in a mammal using the inventive TCRs or related materials.

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MURINE ANTI-NY-ESO-1 T CELL RECEPTORS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This invention was made with US Government support under project number ZIABC010984 by the National Institutes of Health, National Cancer Institute. The US Government has certain rights in the invention.

MATERIAL SUBMITTED ELECTRONICALLY

[0002] A computer-readable nucleotide/amino acid sequence listing is submitted concurrently herewith and identified as follows: one 23,462 Byte ASCII (Text) file named "713415ST25.TXT," dated April 30, 2013.

BACKGROUND OF THE INVENTION

[0003] Adoptive cell therapy can be an effective treatment for cancer in some patients. However, obstacles to the overall success of adoptive cell therapy still exist. For example, only 50% of melanoma tumor samples may generate tumor reactive T-cells. Generating tumor-reactive T-cells from non-melanoma cancers can also be difficult. Moreover, many patients may not have a tumor that is amenable to surgical resection. Accordingly, there is a need for T-cell receptors for use in treating patients with cancer.

BRIEF SUMMARY OF THE INVENTION

[0004] The invention provides an isolated or purified T-cell receptor (TCR) having antigenic specificity for NY-ESO-1 and comprising a murine variable region. The invention also provides related polypeptides and proteins, as well as related nucleic acids, recombinant expression vectors, host cells, and populations of cells. Further provided by the invention are antibodies, or an antigen binding portion thereof, and pharmaceutical compositions relating to the TCRs of the invention.

[0005] Methods of detecting the presence of cancer in a mammal and methods of treating or preventing cancer in a mammal are further provided by the invention. The inventive method of detecting the presence of cancer in a mammal comprises (i) contacting a sample comprising cells of the cancer with any of the inventive TCRs, polypeptides, proteins, nucleic

acids, recombinant expression vectors, host cells, populations of host cells, or antibodies, or antigen binding portions thereof, described herein, thereby forming a complex, and (ii) detecting the complex, wherein detection of the complex is indicative of the presence of cancer in the mammal.

[0006] The inventive method of treating or preventing cancer in a mammal comprises administering to the mammal any of the TCRs, polypeptides, or proteins described herein, any nucleic acid or recombinant expression vector comprising a nucleotide sequence encoding any of the TCRs, polypeptides, proteins described herein, or any host cell or population of host cells comprising a recombinant vector which encodes any of the TCRs, polypeptides, or proteins described herein, in an amount effective to treat or prevent cancer in the mammal.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0007] Figures 1A and 1B are graphs showing interferon (IFN)-γ secretion by human CD8+ (Fig. 1A) or CD4+ (Fig. 1B) T cells transfected with a murine anti-NY-ESO-1 TCR (shaded circles) or a human anti-NY-ESO-1 TCR (unshaded circles) upon co-culture with dendritic cells pulsed with various concentrations of NY-ESO-$1_{157-165}$.

[0008] Figures 2A and 2B are graphs showing IFN-γ secretion by human CD8+ (Fig. 2A) or CD4+ (Fig. 2B) T cells transfected with a murine anti-NY-ESO-1 TCR (shaded bars) or a human anti-NY-ESO-1 TCR (unshaded bars) cultured alone (media) or co-cultured with T2 cells pulsed with control peptide, T2 cells pulsed with NY-ESO-$1_{157-165}$ peptide, or one of various tumor cell lines 888mel (NY-ESO-1^-), Sk23mel (NY-ESO-1^-), COA-A2-CEA (NY-ESO-1^-), A375mel (NY-ESO-1^+), 1363mel (NY-ESO-1^+), or COS-A2-ESO (NY-ESO-1^+).

DETAILED DESCRIPTION OF THE INVENTION

[0009] The invention provides an isolated or purified T-cell receptor (TCR) having antigenic specificity for NY-ESO-1 and comprising a murine variable region. NY-ESO-1 is a cancer testis antigen (CTA), which is expressed only in tumor cells and non-MHC expressing germ cells of the testis and placenta. NY-ESO-1 is expressed in a variety of human cancers including, but not limited to, melanoma, breast cancer, lung cancer, prostate cancer, thyroid cancer, ovarian cancer, and synovial cell sarcoma. The NY-ESO-1 protein may comprise, consist, or consist essentially of, SEQ ID NO: 1.

[0010] The TCR may have antigenic specificity for any NY-ESO-1 protein, polypeptide or peptide. In an embodiment of the invention, the TCR has antigenic specificity for a NY-ESO-1 protein comprising, consisting of, or consisting essentially of, SEQ ID NO: 1. In a preferred embodiment of the invention, the TCR has antigenic specificity for a NY-ESO-1 157-165 peptide comprising, consisting of, or consisting essentially of, SLLMWITQC (SEQ ID NO: 2).

[0011] The phrase "having antigenic specificity" as used herein means that the TCR can specifically bind to and immunologically recognize NY-ESO-1, such that binding of the TCR to NY-ESO-1 elicits an immune response.

[0012] In an embodiment of the invention, the inventive TCRs are able to recognize NY-ESO-1 in a major histocompatibility complex (MHC) class I-dependent manner. By "MHC class I-dependent manner" as used herein means that the TCR elicits an immune response upon binding to NY-ESO-1 within the context of an MHC class I molecule. The MHC class I molecule can be any MHC class I molecule known in the art, e.g., HLA-A molecules. In an embodiment of the invention, the MHC class I molecule is an HLA-A2 molecule.

[0013] In an embodiment of the invention, the inventive TCRs comprise a murine variable region. The inventive TCRs may further comprise a constant region derived from any suitable species such as, e.g., human or mouse. Preferably, the inventive TCRs further comprise a murine constant region. In an especially preferred embodiment, the inventive TCRs are murine TCRs comprising both a murine variable region and a murine constant region.

[0014] As used herein, the term “murine,” when referring to a TCR or any component of a TCR described herein (e.g., complementarity determining region (CDR), variable region, constant region, alpha chain, and/or beta chain), means a TCR (or component thereof) which is derived from a mouse, i.e., a TCR (or component thereof) that originated from or was, at one time, expressed by a mouse T cell. Desirably, the TCR (or component thereof) is expressed on the surface of a human host cell.

[0015] The TCRs of the invention provide many advantages, including when used for adoptive cell transfer. For example, without being bound by a particular theory or mechanism, it is believed that because NY-ESO-1 is expressed by cells of multiple cancer types, the inventive TCRs advantageously provide the ability to destroy cells of multiple types of cancer and, accordingly, treat or prevent multiple types of cancer. Additionally, without being bound to a particular theory or mechanism, it is believed that because NY-

ESO-1 is a cancer testis antigen that is expressed only in tumor cells and non-MHC expressing germ cells of the testis and placenta, the inventive TCRs advantageously target the destruction of cancer cells while minimizing or eliminating the destruction of normal, non-cancerous cells, thereby reducing, for example, minimizing or eliminating, toxicity. It is also believed that murine TCRs may provide increased expression (e.g., higher numbers of TCRs) on the surface of a human host cell and/or increased functionality (as measured by, e.g., cytokine release and cytotoxicity) as compared to a human TCR. Without being bound to a particular theory of mechanism, it is believed that the improved expression and/or functionality results from a reduction in the mixing of endogenous and exogenous (transduced) TCR chains in the host cell. Accordingly, it is believed that murine TCRs can replace endogenous TCRs on the surface of a human host cell more effectively than an exogenous human TCR. It is also believed that murine TCRs provide improved pairing of TCR chains and/or improved interactions with the CD3 complex of the human host cell as compared to exogenous human TCRs expressed by a human host cell.

[0016] An embodiment of the invention provides a TCR comprising two polypeptides (i.e., polypeptide chains), such as an α chain of a TCR, a β chain of a TCR, a γ chain of a TCR, a δ chain of a TCR, or a combination thereof. The polypeptides of the inventive TCR can comprise any amino acid sequence, provided that the TCR has antigenic specificity for NY-ESO-1 and comprises a murine variable region.

[0017] In a preferred embodiment of the invention, the TCR comprises two polypeptide chains, each of which comprises a variable region comprising a complementarity determining region (CDR) 1, a CDR2, and a CDR3 of a TCR. Preferably, the first polypeptide chain comprises a CDR1 comprising the amino acid sequence of SEQ ID NO: 3 (CDR1 of α chain), a CDR2 comprising the amino acid sequence of SEQ ID NO: 4 (CDR2 of α chain), and a CDR3 comprising the amino acid sequence of SEQ ID NO: 5 (CDR3 of α chain), and the second polypeptide chain comprises a CDR1 comprising the amino acid sequence of SEQ ID NO: 6 (CDR1 of β chain), a CDR2 comprising the amino acid sequence of SEQ ID NO: 7 (CDR2 of β chain), and a CDR3 comprising the amino acid sequence of SEQ ID NO: 8 (CDR3 of β chain). In this regard, the inventive TCR can comprise the amino acid sequences selected from the group consisting of SEQ ID NOs: 3-5, 6-8, and 3-8. Preferably the TCR comprises the amino acid sequences of SEQ ID NOs: 3-8.

[0018] Alternatively or additionally, the TCR can comprise an amino acid sequence of a variable region of a TCR comprising the CDRs set forth above. In this regard, the TCR can

comprise the amino acid sequence of SEQ ID NO: 9 (the variable region of an α chain) or 10 (the variable region of a β chain), or both SEQ ID NOs: 9 and 10. Preferably, the inventive TCR comprises the amino acid sequences of SEQ ID NOs: 9 and 10.

[0019] Alternatively or additionally, the TCR can comprise an α chain of a TCR and a β chain of a TCR. Each of the α chain and β chain of the inventive TCR can independently comprise any amino acid sequence. Preferably, the α chain comprises the variable region of an α chain as set forth above. In this regard, the inventive TCR can comprise the amino acid sequence of SEQ ID NO: 11. An inventive TCR of this type can be paired with any β chain of a TCR. Preferably, the β chain of the inventive TCR comprises the variable region of a β chain as set forth above. In this regard, the inventive TCR can comprise the amino acid sequence of SEQ ID NO: 12. The inventive TCR, therefore, can comprise the amino acid sequence of SEQ ID NO: 11 or 12, or both SEQ ID NOs: 11 and 12. Preferably, the inventive TCR comprises the amino acid sequences of SEQ ID NOs: 11 and 12.

[0020] Also provided by the invention is an isolated or purified polypeptide comprising a functional portion of any of the TCRs described herein. The term "polypeptide" as used herein includes oligopeptides and refers to a single chain of amino acids connected by one or more peptide bonds.

[0021] With respect to the inventive polypeptides, the functional portion can be any portion comprising contiguous amino acids of the TCR of which it is a part, provided that the functional portion specifically binds to NY-ESO-1. The term "functional portion" when used in reference to a TCR refers to any part or fragment of the TCR of the invention, which part or fragment retains the biological activity of the TCR of which it is a part (the parent TCR). Functional portions encompass, for example, those parts of a TCR that retain the ability to specifically bind to NY-ESO-1, or detect, treat, or prevent cancer, to a similar extent, the same extent, or to a higher extent, as the parent TCR. In reference to the parent TCR, the functional portion can comprise, for instance, about 10%, 25%, 30%, 50%, 68%, 80%, 90%, 95%, or more, of the parent TCR.

[0022] The functional portion can comprise additional amino acids at the amino or carboxy terminus of the portion, or at both termini, which additional amino acids are not found in the amino acid sequence of the parent TCR. Desirably, the additional amino acids do not interfere with the biological function of the functional portion, e.g., specifically binding to NY-ESO-1, having the ability to detect cancer, treat or prevent cancer, etc. More

desirably, the additional amino acids enhance the biological activity, as compared to the biological activity of the parent TCR.

[0023] The polypeptide can comprise a functional portion of either or both of the α and β chains of the TCRs of the invention, such as a functional portion comprising one or more of CDR1, CDR2, and CDR3 of the variable region(s) of the α chain and/or β chain of a TCR of the invention. In this regard, the polypeptide can comprise a functional portion comprising the amino acid sequence of SEQ ID NO: 3 (CDR1 of α chain), 4 (CDR2 of α chain), 5 (CDR3 of α chain), 6 (CDR1 of β chain), 7 (CDR2 of β chain), 8 (CDR3 of β chain), or a combination thereof. Preferably, the inventive polypeptide comprises a functional portion comprising SEQ ID NOs: 3-5, 6-8, or all of SEQ ID NOs: 3-8. More preferably, the polypeptide comprises a functional portion comprising the amino acid sequences of SEQ ID NOs: 3-8.

[0024] Alternatively or additionally, the inventive polypeptide can comprise, for instance, the variable region of the inventive TCR comprising a combination of the CDR regions set forth above. In this regard, the TCR can comprise the amino acid sequence of SEQ ID NO: 9 (the variable region of an α chain) or 10 (the variable region of a β chain), or both SEQ ID NOs: 9 and 10. Preferably, the polypeptide comprises the amino acid sequences of SEQ ID NOs: 9 and 10.

[0025] Alternatively or additionally, the inventive polypeptide can comprise the entire length of an α or β chain of one of the TCRs described herein. In this regard, the inventive polypeptide can comprise an amino acid sequence of SEQ ID NO: 11 or 12. Alternatively, the polypeptide of the invention can comprise both chains of the TCRs described herein. For example, the inventive polypeptide can comprise both amino acid sequences of SEQ ID NOs: 11 and 12.

[0026] The invention further provides an isolated or purified protein comprising at least one of the polypeptides described herein. By "protein" is meant a molecule comprising one or more polypeptide chains.

[0027] The protein of the invention can comprise a first polypeptide chain comprising the amino acid sequence of SEQ ID NO: 9 and a second polypeptide chain comprising the amino acid sequence of SEQ ID NO: 10. The protein of the invention can, for example, comprise a first polypeptide chain comprising the amino acid sequence of SEQ ID NO: 11 and a second polypeptide chain comprising the amino acid sequence of SEQ ID NO: 12. In this instance, the protein of the invention can be a TCR. Alternatively, if, for example, the protein

comprises a single polypeptide chain comprising SEQ ID NO: 11 and SEQ ID NO: 12, or if the first and/or second polypeptide chain(s) of the protein further comprise(s) other amino acid sequences, e.g., an amino acid sequence encoding an immunoglobulin or a portion thereof, then the inventive protein can be a fusion protein. In this regard, the invention also provides a fusion protein comprising at least one of the inventive polypeptides described herein along with at least one other polypeptide. The other polypeptide can exist as a separate polypeptide of the fusion protein, or can exist as a polypeptide, which is expressed in frame (in tandem) with one of the inventive polypeptides described herein. The other polypeptide can encode any peptidic or proteinaceous molecule, or a portion thereof, including, but not limited to an immunoglobulin, CD3, CD4, CD8, an MHC molecule, a CD1 molecule, e.g., CD1a, CD1b, CD1c, CD1d, etc.

[0028] The fusion protein can comprise one or more copies of the inventive polypeptide and/or one or more copies of the other polypeptide. For instance, the fusion protein can comprise 1, 2, 3, 4, 5, or more, copies of the inventive polypeptide and/or of the other polypeptide. Suitable methods of making fusion proteins are known in the art, and include, for example, recombinant methods. See, for instance, Choi et al., *Mol. Biotechnol.* 31: 193-202 (2005).

[0029] In some embodiments of the invention, the TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants) may be expressed as a single protein comprising a linker peptide linking the α chain and the β chain. Any linker peptide suitable for linking the α chain and the β chain may be used in the TCRs, polypeptides, and proteins (including functional portions and functional variants) of the invention. In an embodiment of the invention, the linker peptide is a picornavirus 2A peptide. In this regard, the TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants) may further comprise a linker peptide comprising an amino acid sequence comprising SEQ ID NO: 13. The linker peptide may advantageously facilitate the expression of a recombinant TCR, polypeptide, and/or protein in a host cell. Upon expression of the construct including the linker peptide by a host cell, the linker peptide may be cleaved, resulting in separated α and β chains.

[0030] The protein of the invention can be a recombinant antibody comprising at least one of the inventive polypeptides described herein. As used herein, "recombinant antibody" refers to a recombinant (e.g., genetically engineered) protein comprising at least one of the polypeptides of the invention and a polypeptide chain of an antibody, or a portion thereof.

The polypeptide of an antibody, or portion thereof, can be a heavy chain, a light chain, a variable or constant region of a heavy or light chain, a single chain variable fragment (scFv), or an Fc, Fab, or $F(ab)_2'$ fragment of an antibody, etc. The polypeptide chain of an antibody, or portion thereof, can exist as a separate polypeptide of the recombinant antibody. Alternatively, the polypeptide chain of an antibody, or portion thereof, can exist as a polypeptide, which is expressed in frame (in tandem) with the polypeptide of the invention. The polypeptide of an antibody, or portion thereof, can be a polypeptide of any antibody or any antibody fragment, including any of the antibodies and antibody fragments described herein.

[0031] Included in the scope of the invention are functional variants of the inventive TCRs, polypeptides, and proteins described herein. The term "functional variant" as used herein refers to a TCR, polypeptide, or protein having substantial or significant sequence identity or similarity to a parent TCR, polypeptide, or protein, which functional variant retains the biological activity of the TCR, polypeptide, or protein of which it is a variant. Functional variants encompass, for example, those variants of the TCR, polypeptide, or protein described herein (the parent TCR, polypeptide, or protein) that retain the ability to specifically bind to NY-ESO-1 to a similar extent, the same extent, or to a higher extent, as the parent TCR, polypeptide, or protein. In reference to the parent TCR, polypeptide, or protein, the functional variant can, for instance, be at least about 30%, 50%, 75%, 80%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or more identical in amino acid sequence to the parent TCR, polypeptide, or protein.

[0032] The functional variant can, for example, comprise the amino acid sequence of the parent TCR, polypeptide, or protein with at least one conservative amino acid substitution. Conservative amino acid substitutions are known in the art, and include amino acid substitutions in which one amino acid having certain physical and/or chemical properties is exchanged for another amino acid that has the same chemical or physical properties. For instance, the conservative amino acid substitution can be an acidic amino acid substituted for another acidic amino acid (e.g., Asp or Glu), an amino acid with a nonpolar side chain substituted for another amino acid with a nonpolar side chain (e.g., Ala, Gly, Val, Ile, Leu, Met, Phe, Pro, Trp, Val, etc.), a basic amino acid substituted for another basic amino acid (Lys, Arg, etc.), an amino acid with a polar side chain substituted for another amino acid with a polar side chain (Asn, Cys, Gln, Ser, Thr, Tyr, etc.), etc.

[0033] Alternatively or additionally, the functional variants can comprise the amino acid sequence of the parent TCR, polypeptide, or protein with at least one non-conservative amino acid substitution. In this case, it is preferable for the non-conservative amino acid substitution to not interfere with or inhibit the biological activity of the functional variant. Preferably, the non-conservative amino acid substitution enhances the biological activity of the functional variant, such that the biological activity of the functional variant is increased as compared to the parent TCR, polypeptide, or protein.

[0034] The TCR, polypeptide, or protein can consist essentially of the specified amino acid sequence or sequences described herein, such that other components of the functional variant, e.g., other amino acids, do not materially change the biological activity of the functional variant. In this regard, the inventive TCR, polypeptide, or protein can, for example, consist essentially of the amino acid sequence of SEQ ID NO: 11 or 12, or both SEQ ID NOs: 11 and 12. Also, for instance, the inventive TCRs, polypeptides, or proteins can consist essentially of the amino acid sequence(s) of SEQ ID NO: 9 or 10, or both SEQ ID NOs: 9 and 10. Furthermore, the inventive TCRs, polypeptides, or proteins can consist essentially of the amino acid sequence of SEQ ID NO: 3 (CDR1 of α chain), 4 (CDR2 of α chain), 5 (CDR3 of α chain), 6 (CDR1 of β chain), 7 (CDR2 of β chain), 8 (CDR3 of β chain), or any combination thereof, e.g., SEQ ID NOs: 3-5, 6-8, or 3-8.

[0035] The TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants) can be of any length, i.e., can comprise any number of amino acids, provided that the TCRs, polypeptides, or proteins (or functional portions or functional variants thereof) retain their biological activity, e.g., the ability to specifically bind to NY-ESO-1, detect cancer in a mammal, or treat or prevent cancer in a mammal, etc. For example, the polypeptide can be 50 to 5000 amino acids long, such as 50, 70, 75, 100, 125, 150, 175, 200, 300, 400, 500, 600, 700, 800, 900, 1000 or more amino acids in length. In this regard, the polypeptides of the invention also include oligopeptides.

[0036] The TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants) of the invention can comprise synthetic amino acids in place of one or more naturally-occurring amino acids. Such synthetic amino acids are known in the art, and include, for example, aminocyclohexane carboxylic acid, norleucine, α-amino n-decanoic acid, homoserine, S-acetylaminomethyl-cysteine, trans-3- and trans-4-hydroxyproline, 4-aminophenylalanine, 4- nitrophenylalanine, 4-chlorophenylalanine, 4-carboxyphenylalanine, β-phenylserine β-hydroxyphenylalanine, phenylglycine, α-

naphthylalanine, cyclohexylalanine, cyclohexylglycine, indoline-2-carboxylic acid, 1,2,3,4-tetrahydroisoquinoline-3-carboxylic acid, aminomalonic acid, aminomalonic acid monoamide, N'-benzyl-N'-methyl-lysine, N',N'-dibenzyl-lysine, 6-hydroxylysine, ornithine, α-aminocyclopentane carboxylic acid, α-aminocyclohexane carboxylic acid, α-aminocycloheptane carboxylic acid, α-(2-amino-2-norbornane)-carboxylic acid, α,γ-diaminobutyric acid, α,β-diaminopropionic acid, homophenylalanine, and α-tert-butylglycine.

[0037] The TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants) can be glycosylated, amidated, carboxylated, phosphorylated, esterified, N-acylated, cyclized via, e.g., a disulfide bridge, or converted into an acid addition salt and/or optionally dimerized or polymerized, or conjugated.

[0038] When the TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants) are in the form of a salt, preferably, the polypeptides are in the form of a pharmaceutically acceptable salt. Suitable pharmaceutically acceptable acid addition salts include those derived from mineral acids, such as hydrochloric, hydrobromic, phosphoric, metaphosphoric, nitric, and sulphuric acids, and organic acids, such as tartaric, acetic, citric, malic, lactic, fumaric, benzoic, glycolic, gluconic, succinic, and arylsulphonic acids, for example, *p*-toluenesulphonic acid.

[0039] The TCR, polypeptide, and/or protein of the invention (including functional portions and functional variants thereof) can be obtained by methods known in the art. Suitable methods of *de novo* synthesizing polypeptides and proteins are described in references, such as Chan et al., Fmoc Solid Phase Peptide Synthesis, Oxford University Press, Oxford, United Kingdom, 2005; Peptide and Protein Drug Analysis, ed. Reid, R., Marcel Dekker, Inc., 2000; Epitope Mapping, ed. Westwoood et al., Oxford University Press, Oxford, United Kingdom, 2000; and U.S. Patent 5,449,752. Also, polypeptides and proteins can be recombinantly produced using the nucleic acids described herein using standard recombinant methods. See, for instance, Sambrook et al., Molecular Cloning: A Laboratory Manual, 3rd ed., Cold Spring Harbor Press, Cold Spring Harbor, NY 2001; and Ausubel et al., Current Protocols in Molecular Biology, Greene Publishing Associates and John Wiley & Sons, NY, 1994. Further, some of the TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants thereof) can be isolated and/or purified from a source, such as a plant, a bacterium, an insect, a mammal, e.g., a mouse, a human, etc. Methods of isolation and purification are well-known in the art. Alternatively, the TCRs,

polypeptides, and/or proteins described herein (including functional portions and functional variants thereof) can be commercially synthesized by companies, such as Synpep (Dublin, CA), Peptide Technologies Corp. (Gaithersburg, MD), and Multiple Peptide Systems (San Diego, CA). In this respect, the inventive TCRs, polypeptides, and proteins can be synthetic, recombinant, isolated, and/or purified.

[0040] Included in the scope of the invention are conjugates, e.g., bioconjugates, comprising any of the inventive TCRs, polypeptides, or proteins (including any of the functional portions or variants thereof), nucleic acids, recombinant expression vectors, host cells, populations of host cells, or antibodies, or antigen binding portions thereof. Conjugates, as well as methods of synthesizing conjugates in general, are known in the art (See, for instance, Hudecz, F., *Methods Mol. Biol.* 298: 209-223 (2005) and Kirin et al., *Inorg Chem.* 44(15): 5405-5415 (2005)).

[0041] Further provided by the invention is a nucleic acid comprising a nucleotide sequence encoding any of the TCRs, polypeptides, or proteins described herein (including functional portions and functional variants thereof).

[0042] By "nucleic acid" as used herein includes "polynucleotide," "oligonucleotide," and "nucleic acid molecule," and generally means a polymer of DNA or RNA, which can be single-stranded or double-stranded, synthesized or obtained (e.g., isolated and/or purified) from natural sources, which can contain natural, non-natural or altered nucleotides, and which can contain a natural, non-natural or altered internucleotide linkage, such as a phosphoroamidate linkage or a phosphorothioate linkage, instead of the phosphodiester found between the nucleotides of an unmodified oligonucleotide. It is generally preferred that the nucleic acid does not comprise any insertions, deletions, inversions, and/or substitutions. However, it may be suitable in some instances, as discussed herein, for the nucleic acid to comprise one or more insertions, deletions, inversions, and/or substitutions.

[0043] Preferably, the nucleic acids of the invention are recombinant. As used herein, the term "recombinant" refers to (i) molecules that are constructed outside living cells by joining natural or synthetic nucleic acid segments to nucleic acid molecules that can replicate in a living cell, or (ii) molecules that result from the replication of those described in (i) above. For purposes herein, the replication can be *in vitro* replication or *in vivo* replication.

[0044] The nucleic acids can be constructed based on chemical synthesis and/or enzymatic ligation reactions using procedures known in the art. See, for example, Sambrook et al., *supra*, and Ausubel et al., *supra*. For example, a nucleic acid can be chemically

synthesized using naturally occurring nucleotides or variously modified nucleotides designed to increase the biological stability of the molecules or to increase the physical stability of the duplex formed upon hybridization (e.g., phosphorothioate derivatives and acridine substituted nucleotides). Examples of modified nucleotides that can be used to generate the nucleic acids include, but are not limited to, 5-fluorouracil, 5-bromouracil, 5-chlorouracil, 5-iodouracil, hypoxanthine, xanthine, 4-acetylcytosine, 5-(carboxyhydroxymethyl) uracil, 5-carboxymethylaminomethyl-2-thiouridine, 5-carboxymethylaminomethyluracil, dihydrouracil, beta-D-galactosylqueosine, inosine, N^6-isopentenyladenine, 1-methylguanine, 1-methylinosine, 2,2-dimethylguanine, 2-methyladenine, 2-methylguanine, 3-methylcytosine, 5-methylcytosine, N^6-substituted adenine, 7-methylguanine, 5-methylaminomethyluracil, 5-methoxyaminomethyl-2-thiouracil, beta-D-mannosylqueosine, 5'-methoxycarboxymethyluracil, 5-methoxyuracil, 2-methylthio-N^6-isopentenyladenine, uracil-5-oxyacetic acid (v), wybutoxosine, pseudouracil, queosine, 2-thiocytosine, 5-methyl-2-thiouracil, 2-thiouracil, 4-thiouracil, 5-methyluracil, uracil-5-oxyacetic acid methylester, 3-(3-amino-3-N-2-carboxypropyl) uracil, and 2,6-diaminopurine. Alternatively, one or more of the nucleic acids of the invention can be purchased from companies, such as Macromolecular Resources (Fort Collins, CO) and Synthegen (Houston, TX).

[0045] The nucleic acid can comprise any nucleotide sequence which encodes any of the inventive TCRs, polypeptides, or proteins, or functional portions or functional variants thereof. For example, the nucleic acid can comprise a nucleotide sequence comprising, consisting of, or consisting essentially of SEQ ID NO: 19 (wild-type α chain) or SEQ ID NO: 20 (wild-type β chain) or both SEQ ID NOs: 19 and 20.

[0046] In some embodiments, the nucleotide sequence may be codon-optimized. Without being bound to a particular theory or mechanism, it is believed that codon optimization of the nucleotide sequence increases the translation efficiency of the mRNA transcripts. Codon optimization of the nucleotide sequence may involve substituting a native codon for another codon that encodes the same amino acid, but can be translated by tRNA that is more readily available within a cell, thus increasing translation efficiency. Optimization of the nucleotide sequence may also reduce secondary mRNA structures that would interfere with translation, thus increasing translation efficiency. In an embodiment of the invention, the codon-optimized nucleotide sequence may comprise, consist, or consist essentially of SEQ ID NO: 15 (codon-optimized α chain), SEQ ID NO: 16 (codon-optimized β chain), SEQ ID NO: 21 (codon-optimized variable region of α chain), SEQ ID NO: 22 (codon-optimized variable

region of β chain), both SEQ ID NOs: 15 and 16, both SEQ ID NOs: 21 and 22, both SEQ ID NOs: 15 and 20, or both SEQ ID NOs: 16 and 19.

[0047] In an embodiment of the invention, the nucleotide sequence encoding the TCRs, polypeptides, and proteins of the invention (including functional portions and functional variants thereof) may further comprise a nucleotide sequence encoding any of the linker peptides described herein with respect to other aspects of the invention. In an embodiment of the invention, the linker peptide may be encoded by a nucleotide sequence comprising SEQ ID NO: 14.

[0048] The invention also provides a nucleic acid comprising a nucleotide sequence that is at least about 70% or more, e.g., about 80%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, or about 99% identical to any of the nucleic acids described herein.

[0049] The nucleotide sequence alternatively can comprise a nucleotide sequence which is degenerate to SEQ ID NO: 15, SEQ ID NO: 16, SEQ ID NO: 19, SEQ ID NO: 20, SEQ ID NO: 21, SEQ ID NO: 22, both SEQ ID NOs: 15 and 16, both SEQ ID NOs: 19 and 20, both SEQ ID NOs: 21 and 22, both SEQ ID NOs: 15 and 20, or both SEQ ID NOs: 16 and 19. Preferably, the nucleic acid comprises a nucleotide sequence comprising SEQ ID NO: 15, 16, 19, 20, 21, or 22, SEQ ID NOs: 15 and 16, SEQ ID NOs: 19 and 20, SEQ ID NOs: 21 and 22, SEQ ID NOs: 15 and 20, or SEQ ID NOs: 16 and 19, or a nucleotide sequence which is degenerate thereto.

[0050] The invention also provides an isolated or purified nucleic acid comprising a nucleotide sequence which is complementary to the nucleotide sequence of any of the nucleic acids described herein or a nucleotide sequence which hybridizes under stringent conditions to the nucleotide sequence of any of the nucleic acids described herein.

[0051] The nucleotide sequence which hybridizes under stringent conditions preferably hybridizes under high stringency conditions. By "high stringency conditions" is meant that the nucleotide sequence specifically hybridizes to a target sequence (the nucleotide sequence of any of the nucleic acids described herein) in an amount that is detectably stronger than non-specific hybridization. High stringency conditions include conditions which would distinguish a polynucleotide with an exact complementary sequence, or one containing only a few scattered mismatches from a random sequence that happened to have a few small regions (e.g., 3-10 bases) that matched the nucleotide sequence. Such small regions of complementarity are more easily melted than a full-length complement of 14-17 or more

bases, and high stringency hybridization makes them easily distinguishable. Relatively high stringency conditions would include, for example, low salt and/or high temperature conditions, such as provided by about 0.02-0.1 M NaCl or the equivalent, at temperatures of about 50-70 °C. Such high stringency conditions tolerate little, if any, mismatch between the nucleotide sequence and the template or target strand, and are particularly suitable for detecting expression of any of the inventive TCRs. It is generally appreciated that conditions can be rendered more stringent by the addition of increasing amounts of formamide.

[0052] The nucleic acids of the invention can be incorporated into a recombinant expression vector. In this regard, the invention provides recombinant expression vectors comprising any of the nucleic acids of the invention. For purposes herein, the term "recombinant expression vector" means a genetically-modified oligonucleotide or polynucleotide construct that permits the expression of an mRNA, protein, polypeptide, or peptide by a host cell, when the construct comprises a nucleotide sequence encoding the mRNA, protein, polypeptide, or peptide, and the vector is contacted with the cell under conditions sufficient to have the mRNA, protein, polypeptide, or peptide expressed within the cell. The vectors of the invention are not naturally-occurring as a whole. However, parts of the vectors can be naturally-occurring. The inventive recombinant expression vectors can comprise any type of nucleotides, including, but not limited to DNA and RNA, which can be single-stranded or double-stranded, synthesized or obtained in part from natural sources, and which can contain natural, non-natural or altered nucleotides. The recombinant expression vectors can comprise naturally-occurring, non-naturally-occurring internucleotide linkages, or both types of linkages. Preferably, the non-naturally occurring or altered nucleotides or internucleotide linkages do not hinder the transcription or replication of the vector.

[0053] The recombinant expression vector of the invention can be any suitable recombinant expression vector, and can be used to transform or transfect any suitable host cell. Suitable vectors include those designed for propagation and expansion or for expression or both, such as plasmids and viruses. The vector can be selected from the group consisting of the pUC series (Fermentas Life Sciences), the pBluescript series (Stratagene™, LaJolla, CA), the pET series (Novagen, Madison, WI), the pGEX series (Pharmacia™ Biotech, Uppsala, Sweden), and the pEX series (Clontech, Palo Alto, CA). Bacteriophage vectors, such as λGT10, λGT11, λZapII (Stratagene), λEMBL4, and λNM1149, also can be used. Examples of plant expression vectors include pBI01, pBI101.2, pBI101.3, pBI121 and pBIN19 (Clontech). Examples of animal expression vectors include pEUK-Cl, pMAM and

pMAMneo (Clontech). Preferably, the recombinant expression vector is a viral vector, e.g., a retroviral vector or a lentiviral vector.

[0054] The recombinant expression vectors of the invention can be prepared using standard recombinant DNA techniques described in, for example, Sambrook et al., *supra*, and Ausubel et al., *supra*. Constructs of expression vectors, which are circular or linear, can be prepared to contain a replication system functional in a prokaryotic or eukaryotic host cell. Replication systems can be derived, e.g., from ColEl, 2 μ plasmid, λ, SV40, bovine papilloma virus, and the like.

[0055] Desirably, the recombinant expression vector comprises regulatory sequences, such as transcription and translation initiation and termination codons, which are specific to the type of host cell (e.g., bacterium, fungus, plant, or animal) into which the vector is to be introduced, as appropriate and taking into consideration whether the vector is DNA- or RNA-based.

[0056] The recombinant expression vector can include one or more marker genes, which allow for selection of transformed or transfected host cells. Marker genes include biocide resistance, e.g., resistance to antibiotics, heavy metals, etc., complementation in an auxotrophic host to provide prototrophy, and the like. Suitable marker genes for the inventive expression vectors include, for instance, neomycin/G418 resistance genes, hygromycin resistance genes, histidinol resistance genes, tetracycline resistance genes, and ampicillin resistance genes.

[0057] The recombinant expression vector can comprise a native or nonnative promoter operably linked to the nucleotide sequence encoding the TCR, polypeptide, or protein (including functional portions and functional variants thereof), or to the nucleotide sequence which is complementary to or which hybridizes to the nucleotide sequence encoding the TCR, polypeptide, or protein. The selection of promoters, e.g., strong, weak, inducible, tissue-specific and developmental-specific, is within the ordinary skill of the artisan. Similarly, the combining of a nucleotide sequence with a promoter is also within the skill of the artisan. The promoter can be a non-viral promoter or a viral promoter, e.g., a cytomegalovirus (CMV) promoter, an SV40 promoter, an RSV promoter, and a promoter found in the long-terminal repeat of the murine stem cell virus.

[0058] The inventive recombinant expression vectors can be designed for either transient expression, for stable expression, or for both. Also, the recombinant expression vectors can

be made for constitutive expression or for inducible expression. Further, the recombinant expression vectors can be made to include a suicide gene.

[0059] As used herein, the term "suicide gene" refers to a gene that causes the cell expressing the suicide gene to die. The suicide gene can be a gene that confers sensitivity to an agent, e.g., a drug, upon the cell in which the gene is expressed, and causes the cell to die when the cell is contacted with or exposed to the agent. Suicide genes are known in the art (see, for example, Suicide Gene Therapy: Methods and Reviews, Springer, Caroline J. (Cancer Research UK Centre for Cancer Therapeutics at the Institute of Cancer Research, Sutton, Surrey, UK), Humana Press, 2004) and include, for example, the Herpes Simplex Virus (HSV) thymidine kinase (TK) gene, cytosine daminase, purine nucleoside phosphorylase, and nitroreductase.

[0060] The inventive recombinant expression vectors may comprise a nucleotide sequence encoding all or a portion of the alpha chain positioned 5' of the nucleotide sequence encoding all or a portion of the beta chain. In this regard, an embodiment of the invention provides a recombinant expression vector comprising a nucleotide sequence encoding a CDR 1α, CDR2α, CDR3α, CDR1β, CDR2β, and CDR3β, and the nucleotide sequence encoding the CDR1α, CDR2α, and CDR3α is 5' of the nucleotide sequence encoding the CDR1β, CDR2β, and CDR3β. Likewise, the nucleotide sequence encoding the CDR1β, CDR2β, and CDR3β may be 3' of the nucleotide sequence encoding the CDR1α, CDR2α, and CDR3α. In another embodiment of the invention, the recombinant expression vector comprises a nucleotide sequence encoding a variable region of the alpha chain and a variable region of the beta chain, and the nucleotide sequence encoding the variable region of the alpha chain is 5' of the nucleotide sequence encoding the variable region of the beta chain. Likewise, the nucleotide sequence encoding the variable region of the beta chain may be 3' of the nucleotide sequence encoding the variable region of the alpha chain. In still another embodiment of the invention, the recombinant expression vector comprises a nucleotide sequence encoding an alpha chain and a beta chain, and the nucleotide sequence encoding the alpha chain is 5' of the nucleotide sequence encoding the beta chain. Likewise, the nucleotide sequence encoding the beta chain may be 3' of the nucleotide sequence encoding the alpha chain. The recombinant expression vector comprising a nucleotide sequence encoding all or a portion of the alpha chain positioned 5' of the nucleotide sequence encoding all or a portion of the beta chain may comprise SEQ ID NO: 17.

[0061] The inventive recombinant expression vectors may comprise a nucleotide sequence encoding all or a portion of the alpha chain positioned 3' of the nucleotide sequence encoding all or a portion of the beta chain. Without being bound by a particular theory or mechanism, it is believed that a TCR, polypeptide, or protein (or functional portion or variant thereof) encoded by a recombinant expression vector in which the nucleotide sequence encoding all or a portion of the alpha chain is positioned 3' of the nucleotide sequence encoding all or a portion of the beta chain provides improved functionality and antigen recognition as compared to a TCR, polypeptide, or protein (or functional portion or functional variant thereof) encoded by a recombinant expression vector in which the nucleotide sequence encoding all or a portion of the alpha chain is positioned 5' of the nucleotide sequence encoding all or a portion of the beta chain. In this regard, an embodiment of the invention provides a recombinant expression vector comprising a nucleotide sequence encoding a CDR 1α, CDR2α, CDR3α, CDR1β, CDR2β, and CDR3β, and the nucleotide sequence encoding the CDR1α, CDR2α, and CDR3α is 3' of the nucleotide sequence encoding the CDR1β, CDR2β, and CDR3β. Likewise, the nucleotide sequence encoding the CDR1β, CDR2β, and CDR3β may be 5' of the nucleotide sequence encoding the CDR1α, CDR2α, and CDR3α. In another embodiment of the invention, the recombinant expression vector comprises a nucleotide sequence encoding a variable region of the alpha chain and a variable region of the beta chain, and the nucleotide sequence encoding the variable region of the alpha chain is 3' of the nucleotide sequence encoding the variable region of the beta chain. Likewise, the nucleotide sequence encoding the variable region of the beta chain may be 5' of the nucleotide sequence encoding the variable region of the alpha chain. In still another embodiment of the invention, the recombinant expression vector comprises a nucleotide sequence encoding an alpha chain and a beta chain, and the nucleotide sequence encoding the alpha chain is 3' of the nucleotide sequence encoding the beta chain. Likewise, the nucleotide sequence encoding the beta chain may be 5' of the nucleotide sequence encoding the alpha chain. The recombinant expression vector comprising a nucleotide sequence encoding all or a portion of the alpha chain positioned 3' of the nucleotide sequence encoding all or a portion of the beta chain may comprise SEQ ID NO: 18.

[0062] In an embodiment of the invention, the recombinant expression vector may comprise a DNA tag. The DNA tag may distinguish the recombinant expression vector from another vector encoding the same protein sequence. The DNA tag may not be included

within the nucleotide sequence encoding the inventive TCR (including functional portions and functional variants thereof), polypeptide, or protein and, therefore, may not affect its expression. Recombinant expression vectors including the DNA tag make it possible to put the same nucleotide sequence into several different cell populations and subsequently distinguish between those populations based on which vector they contain.

[0063] The invention further provides a host cell comprising any of the recombinant expression vectors described herein. As used herein, the term "host cell" refers to any type of cell that can contain the inventive recombinant expression vector. The host cell can be a eukaryotic cell, e.g., plant, animal, fungi, or algae, or can be a prokaryotic cell, e.g., bacteria or protozoa. The host cell can be a cultured cell or a primary cell, i.e., isolated directly from an organism, e.g., a human. The host cell can be an adherent cell or a suspended cell, i.e., a cell that grows in suspension. Suitable host cells are known in the art and include, for instance, DH5α *E. coli* cells, Chinese hamster ovarian cells, monkey VERO cells, COS cells, HEK293 cells, and the like. For purposes of amplifying or replicating the recombinant expression vector, the host cell is preferably a prokaryotic cell, e.g., a DH5α cell. For purposes of producing a recombinant TCR, polypeptide, or protein, the host cell is preferably a mammalian cell. Most preferably, the host cell is a human cell. While the host cell can be of any cell type, can originate from any type of tissue, and can be of any developmental stage, the host cell may be a peripheral blood lymphocyte (PBL) or a peripheral blood mononuclear cell (PBMC). Preferably, the host cell may be a T cell.

[0064] For purposes herein, the T cell can be any T cell, such as a cultured T cell, e.g., a primary T cell, or a T cell from a cultured T cell line, e.g., Jurkat, SupT1, etc., or a T cell obtained from a mammal. If obtained from a mammal, the T cell can be obtained from numerous sources, including but not limited to blood, bone marrow, lymph node, the thymus, or other tissues or fluids. T cells can also be enriched for or purified. The T cell may be a human T cell. The T cell may be a T cell isolated from a human. The T cell can be any type of T cell and can be of any developmental stage, including but not limited to, $CD4^+/CD8^+$ double positive T cells, $CD4^+$ helper T cells, e.g., Th_1 and Th_2 cells, $CD8^+$ T cells, cytotoxic T cells, tumor infiltrating lymphocyte cells, memory T cells, naïve T cells, and the like. Preferably, the T cell may be a $CD8^+$ T cell or a $CD4^+$ T cell.

[0065] Also provided by the invention is a population of cells comprising at least one host cell described herein. The population of cells can be a heterogeneous population comprising the host cell comprising any of the recombinant expression vectors described, in

addition to at least one other cell, e.g., a host cell (e.g., a T cell), which does not comprise any of the recombinant expression vectors, or a cell other than a T cell, e.g., a B cell, a macrophage, a neutrophil, an erythrocyte, a hepatocyte, an endothelial cell, an epithelial cells, a muscle cell, a brain cell, etc. Alternatively, the population of cells can be a substantially homogeneous population, in which the population comprises mainly of host cells (e.g., consisting essentially of) comprising the recombinant expression vector. The population also can be a clonal population of cells, in which all cells of the population are clones of a single host cell comprising a recombinant expression vector, such that all cells of the population comprise the recombinant expression vector. In one embodiment of the invention, the population of cells is a clonal population comprising host cells comprising a recombinant expression vector as described herein.

[0066] The invention further provides an antibody, or antigen binding portion thereof, which specifically binds to a functional portion of any of the TCRs described herein. Preferably, the functional portion specifically binds to NY-ESO-1, e.g., the functional portion comprising the amino acid sequence SEQ ID NO: 3 (CDR1 of α chain), 4 (CDR2 of α chain), 5 (CDR3 of α chain), 6 (CDR1 of β chain), 7 (CDR2 of β chain), 8 (CDR3 of β chain), SEQ ID NO: 9, SEQ ID NO: 10, or a combination thereof, e.g., 3-5, 6-8, 3-8, or 9-10. More preferably, the functional portion comprises the amino acid sequences of SEQ ID NOs: 3-8. In a preferred embodiment, the antibody, or antigen binding portion thereof, binds to an epitope which is formed by all 6 CDRs (CDR1-3 of the alpha chain and CDR1-3 of the beta chain). The antibody can be any type of immunoglobulin that is known in the art. For instance, the antibody can be of any isotype, e.g., IgA, IgD, IgE, IgG, IgM, etc. The antibody can be monoclonal or polyclonal. The antibody can be a naturally-occurring antibody, e.g., an antibody isolated and/or purified from a mammal, e.g., mouse, rabbit, goat, horse, chicken, hamster, human, etc. Alternatively, the antibody can be a genetically-engineered antibody, e.g., a humanized antibody or a chimeric antibody. The antibody can be in monomeric or polymeric form. Also, the antibody can have any level of affinity or avidity for the functional portion of the inventive TCR. Desirably, the antibody is specific for the functional portion of the inventive TCR, such that there is minimal cross-reaction with other peptides or proteins.

[0067] Methods of testing antibodies for the ability to bind to any functional portion of the inventive TCR are known in the art and include any antibody-antigen binding assay, such as, for example, radioimmunoassay (RIA), ELISA, Western blot, immunoprecipitation, and competitive inhibition assays (see, e.g., Janeway et al., *infra*).

[0068] Suitable methods of making antibodies are known in the art. For instance, standard hybridoma methods are described in, e.g., Köhler and Milstein, *Eur. J.* Immunol., *5*, 511-519 (1976), Harlow and Lane (eds.), *Antibodies: A Laboratory Manual*, CSH Press (1988), and C.A. Janeway et al. (eds.), *Immunobiology*, 5th Ed., Garland Publishing, New York, NY (2001)). Alternatively, other methods, such as EBV-hybridoma methods (Haskard and Archer, *J. Immunol. Methods*, *74*(2), 361-67 (1984), and Roder et al., *Methods Enzymol.*, *121*, 140-67 (1986)), and bacteriophage vector expression systems (see, e.g., Huse et al., *Science*, *246*, 1275-81 (1989)) are known in the art. Further, methods of producing antibodies in non-human animals are described in, e.g., U.S. Patents 5,545,806, 5,569,825, and 5,714,352).

[0069] Phage display furthermore can be used to generate the antibody of the invention. In this regard, phage libraries encoding antigen-binding variable (V) domains of antibodies can be generated using standard molecular biology and recombinant DNA techniques (see, e.g., Sambrook et al. (eds.), *Molecular Cloning, A Laboratory Manual*, 3rd Edition, Cold Spring Harbor Laboratory Press, New York (2001)). Phage encoding a variable region with the desired specificity are selected for specific binding to the desired antigen, and a complete or partial antibody is reconstituted comprising the selected variable domain. Nucleic acid sequences encoding the reconstituted antibody are introduced into a suitable cell line, such as a myeloma cell used for hybridoma production, such that antibodies having the characteristics of monoclonal antibodies are secreted by the cell (see, e.g., Janeway et al., *supra*, Huse et al., *supra*, and U.S. Patent 6,265,150).

[0070] Antibodies can be produced by transgenic mice that are transgenic for specific heavy and light chain immunoglobulin genes. Such methods are known in the art and described in, for example U.S. Patents 5,545,806 and 5,569,825, and Janeway et al., *supra*.

[0071] Methods for generating humanized antibodies are well known in the art and are described in detail in, for example, Janeway et al., *supra*, U.S. Patents 5,225,539, 5,585,089 and 5,693,761, European Patent No. 0239400 B1, and United Kingdom Patent No. 2188638. Humanized antibodies can also be generated using the antibody resurfacing technology described in U.S. Patent 5,639,641 and Pedersen et al., *J. Mol. Biol.*, *235*, 959-973 (1994).

[0072] The invention also provides antigen binding portions of any of the antibodies described herein. The antigen binding portion can be any portion that has at least one antigen binding site, such as Fab, $F(ab')_2$, dsFv, sFv, diabodies, and triabodies.

[0073] A single-chain variable region fragment (sFv) antibody fragment, which consists of a truncated Fab fragment comprising the variable (V) domain of an antibody heavy chain linked to a V domain of a light antibody chain via a synthetic peptide, can be generated using routine recombinant DNA technology techniques (see, e.g., Janeway et al., *supra*). Similarly, disulfide-stabilized variable region fragments (dsFv) can be prepared by recombinant DNA technology (see, e.g., Reiter et al., *Protein Engineering, 7*, 697-704 (1994)). Antibody fragments of the invention, however, are not limited to these exemplary types of antibody fragments.

[0074] Also, the antibody, or antigen binding portion thereof, can be modified to comprise a detectable label, such as, for instance, a radioisotope, a fluorophore (e.g., fluorescein isothiocyanate (FITC), phycoerythrin (PE)), an enzyme (e.g., alkaline phosphatase, horseradish peroxidase), and element particles (e.g., gold particles).

[0075] The inventive TCRs, polypeptides, proteins, (including functional portions and functional variants thereof), nucleic acids, recombinant expression vectors, host cells (including populations thereof), and antibodies (including antigen binding portions thereof), can be isolated and/or purified. The term "isolated" as used herein means having been removed from its natural environment. The term "purified" as used herein means having been increased in purity, wherein "purity" is a relative term, and not to be necessarily construed as absolute purity. For example, the purity can be at least about 50%, can be greater than 60%, 70% or 80%, or can be 100%.

[0076] The inventive TCRs, polypeptides, proteins (including functional portions and variants thereof), nucleic acids, recombinant expression vectors, host cells (including populations thereof), and antibodies (including antigen binding portions thereof), all of which are collectively referred to as "inventive TCR materials" hereinafter, can be formulated into a composition, such as a pharmaceutical composition. In this regard, the invention provides a pharmaceutical composition comprising any of the TCRs, polypeptides, proteins, functional portions, functional variants, nucleic acids, expression vectors, host cells (including populations thereof), and antibodies (including antigen binding portions thereof), and a pharmaceutically acceptable carrier. The inventive pharmaceutical compositions containing any of the inventive TCR materials can comprise more than one inventive TCR material, e.g., a polypeptide and a nucleic acid, or two or more different TCRs. Alternatively, the pharmaceutical composition can comprise an inventive TCR material in combination with another pharmaceutically active agents or drugs, such as a chemotherapeutic agents, e.g.,

asparaginase, busulfan, carboplatin, cisplatin, daunorubicin, doxorubicin, fluorouracil, gemcitabine, hydroxyurea, methotrexate, paclitaxel, rituximab, vinblastine, vincristine, etc.

[0077] Preferably, the carrier is a pharmaceutically acceptable carrier. With respect to pharmaceutical compositions, the carrier can be any of those conventionally used and is limited only by chemico-physical considerations, such as solubility and lack of reactivity with the active compound(s), and by the route of administration. The pharmaceutically acceptable carriers described herein, for example, vehicles, adjuvants, excipients, and diluents, are well-known to those skilled in the art and are readily available to the public. It is preferred that the pharmaceutically acceptable carrier be one which is chemically inert to the active agent(s) and one which has no detrimental side effects or toxicity under the conditions of use.

[0078] The choice of carrier will be determined in part by the particular inventive TCR material, as well as by the particular method used to administer the inventive TCR material. Accordingly, there are a variety of suitable formulations of the pharmaceutical composition of the invention. The following formulations for parenteral, subcutaneous, intravenous, intramuscular, intraarterial, intrathecal, and interperitoneal administration are exemplary and are in no way limiting. More than one route can be used to administer the inventive TCR materials, and in certain instances, a particular route can provide a more immediate and more effective response than another route.

[0079] Formulations suitable for parenteral administration include aqueous and non-aqueous, isotonic sterile injection solutions, which can contain anti-oxidants, buffers, bacteriostats, and solutes that render the formulation isotonic with the blood of the intended recipient, and aqueous and non-aqueous sterile suspensions that can include suspending agents, solubilizers, thickening agents, stabilizers, and preservatives. The inventive TCR material can be administered in a physiologically acceptable diluent in a pharmaceutical carrier, such as a sterile liquid or mixture of liquids, including water, saline, aqueous dextrose and related sugar solutions, an alcohol, such as ethanol or hexadecyl alcohol, a glycol, such as propylene glycol or polyethylene glycol, dimethylsulfoxide, glycerol, ketals such as 2,2-dimethyl-1,3-dioxolane-4-methanol, ethers, poly(ethyleneglycol) 400, oils, fatty acids, fatty acid esters or glycerides, or acetylated fatty acid glycerides with or without the addition of a pharmaceutically acceptable surfactant, such as a soap or a detergent, suspending agent, such as pectin, carbomers, methylcellulose, hydroxypropylmethylcellulose, or carboxymethylcellulose, or emulsifying agents and other pharmaceutical adjuvants.

[0080] Oils, which can be used in parenteral formulations include petroleum, animal, vegetable, or synthetic oils. Specific examples of oils include peanut, soybean, sesame, cottonseed, corn, olive, petrolatum, and mineral. Suitable fatty acids for use in parenteral formulations include oleic acid, stearic acid, and isostearic acid. Ethyl oleate and isopropyl myristate are examples of suitable fatty acid esters.

[0081] Suitable soaps for use in parenteral formulations include fatty alkali metal, ammonium, and triethanolamine salts, and suitable detergents include (a) cationic detergents such as, for example, dimethyl dialkyl ammonium halides, and alkyl pyridinium halides, (b) anionic detergents such as, for example, alkyl, aryl, and olefin sulfonates, alkyl, olefin, ether, and monoglyceride sulfates, and sulfosuccinates, (c) nonionic detergents such as, for example, fatty amine oxides, fatty acid alkanolamides, and polyoxyethylenepolypropylene copolymers, (d) amphoteric detergents such as, for example, alkyl-β-aminopropionates, and 2-alkyl-imidazoline quaternary ammonium salts, and (e) mixtures thereof.

[0082] The parenteral formulations will typically contain from about 0.5% to about 25% by weight of the inventive TCR material in solution. Preservatives and buffers may be used. In order to minimize or eliminate irritation at the site of injection, such compositions may contain one or more nonionic surfactants having a hydrophile-lipophile balance (HLB) of from about 12 to about 17. The quantity of surfactant in such formulations will typically range from about 5% to about 15% by weight. Suitable surfactants include polyethylene glycol sorbitan fatty acid esters, such as sorbitan monooleate and the high molecular weight adducts of ethylene oxide with a hydrophobic base, formed by the condensation of propylene oxide with propylene glycol. The parenteral formulations can be presented in unit-dose or multi-dose sealed containers, such as ampoules and vials, and can be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid excipient, for example, water, for injections, immediately prior to use. Extemporaneous injection solutions and suspensions can be prepared from sterile powders, granules, and tablets of the kind previously described.

[0083] Injectable formulations are in accordance with the invention. The requirements for effective pharmaceutical carriers for injectable compositions are well-known to those of ordinary skill in the art (see, e.g., *Pharmaceutics and Pharmacy Practice*, J.B. Lippincott Company, Philadelphia, PA, Banker and Chalmers, eds., pages 238-250 (1982), and *ASHP Handbook on Injectable Drugs*, Toissel, 4th ed., pages 622-630 (1986)). Preferably, when administering cells, e.g., dendritic cells, the cells are administered via injection.

[0084] It will be appreciated by one of skill in the art that, in addition to the above-described pharmaceutical compositions, the inventive TCR materials of the invention can be formulated as inclusion complexes, such as cyclodextrin inclusion complexes, or liposomes.

[0085] For purposes of the invention, the amount or dose of the inventive TCR material administered should be sufficient to effect, e.g., a therapeutic or prophylactic response, in the subject or animal over a reasonable time frame. For example, the dose of the inventive TCR material should be sufficient to bind to NY-ESO-1, or detect, treat or prevent cancer in a period of from about 2 hours or longer, e.g., 12 to 24 or more hours, from the time of administration. In certain embodiments, the time period could be even longer. The dose will be determined by the efficacy of the particular inventive TCR material and the condition of the animal (e.g., human), as well as the body weight of the animal (e.g., human) to be treated.

[0086] Many assays for determining an administered dose are known in the art. For purposes of the invention, an assay, which comprises comparing the extent to which target cells are lysed or IFN-γ is secreted by T cells expressing the inventive TCR, polypeptide, or protein upon administration of a given dose of such T cells to a mammal among a set of mammals of which is each given a different dose of the T cells, could be used to determine a starting dose to be administered to a mammal. The extent to which target cells are lysed or IFN-γ is secreted upon administration of a certain dose can be assayed by methods known in the art, including, for instance, the methods described herein as Example 3.

[0087] The dose of the inventive TCR material also will be determined by the existence, nature and extent of any adverse side effects that might accompany the administration of a particular inventive TCR material. Typically, the attending physician will decide the dosage of the inventive TCR material with which to treat each individual patient, taking into consideration a variety of factors, such as age, body weight, general health, diet, sex, inventive TCR material to be administered, route of administration, and the severity of the condition being treated. By way of example and not intending to limit the invention, the dose of the inventive TCR material can be about 0.001 to about 1000 mg/kg body weight of the subject being treated/day, from about 0.01 to about 10 mg/kg body weight/day, about 0.01 mg to about 1 mg/kg body weight/day.

[0088] One of ordinary skill in the art will readily appreciate that the inventive TCR materials of the invention can be modified in any number of ways, such that the therapeutic or prophylactic efficacy of the inventive TCR materials is increased through the modification. For instance, the inventive TCR materials can be conjugated either directly or indirectly

through a bridge to a targeting moiety. The practice of conjugating compounds, e.g., inventive TCR materials, to targeting moieties is known in the art. See, for instance, Wadwa et al., *J. Drug Targeting* 3: 111 (1995) and U.S. Patent 5,087,616. The term "targeting moiety" as used herein, refers to any molecule or agent that specifically recognizes and binds to a cell-surface receptor, such that the targeting moiety directs the delivery of the inventive TCR materials to a population of cells on which surface the receptor is expressed. Targeting moieties include, but are not limited to, antibodies, or fragments thereof, peptides, hormones, growth factors, cytokines, and any other natural or non-natural ligands, which bind to cell surface receptors (e.g., Epithelial Growth Factor Receptor (EGFR), T-cell receptor (TCR), B-cell receptor (BCR), CD28, Platelet-derived Growth Factor Receptor (PDGF), nicotinic acetylcholine receptor (nAChR), etc.). The term "bridge" as used herein, refers to any agent or molecule that bridges the inventive TCR materials to the targeting moiety. One of ordinary skill in the art recognizes that sites on the inventive TCR materials, which are not necessary for the function of the inventive TCR materials, are ideal sites for attaching a bridge and/or a targeting moiety, provided that the bridge and/or targeting moiety, once attached to the inventive TCR materials, do(es) not interfere with the function of the inventive TCR materials, i.e., the ability to bind to NY-ESO-1, or to detect, treat, or prevent cancer.

[0089] Alternatively, the inventive TCR materials can be modified into a depot form, such that the manner in which the inventive TCR materials is released into the body to which it is administered is controlled with respect to time and location within the body (see, for example, U.S. Patent 4,450,150). Depot forms of inventive TCR materials can be, for example, an implantable composition comprising the inventive TCR materials and a porous or non-porous material, such as a polymer, wherein the inventive TCR materials is encapsulated by or diffused throughout the material and/or degradation of the non-porous material. The depot is then implanted into the desired location within the body and the inventive TCR materials are released from the implant at a predetermined rate.

[0090] It is contemplated that the inventive pharmaceutical compositions, TCRs (including functional portions or variants thereof), polypeptides, proteins, nucleic acids, recombinant expression vectors, host cells, or populations of cells can be used in methods of treating or preventing cancer. Without being bound to a particular theory or mechanism, the inventive TCRs are believed to bind specifically to NY-ESO-1, such that the TCR (or related inventive polypeptide or protein, or functional portion or variant thereof) when expressed by

a cell is able to mediate an immune response against the cell expressing NY-ESO-1. In this regard, the invention provides a method of treating or preventing cancer in a mammal, comprising administering to the mammal any of the TCRs, polypeptides, or proteins described herein, any nucleic acid or recombinant expression vector comprising a nucleotide sequence encoding any of the TCRs, polypeptides, proteins described herein, or any host cell or population of cells comprising a recombinant vector which encodes any of the TCRs, polypeptides, or proteins described herein, in an amount effective to treat or prevent cancer in the mammal.

[0091] The terms "treat," and "prevent" as well as words stemming therefrom, as used herein, do not necessarily imply 100% or complete treatment or prevention. Rather, there are varying degrees of treatment or prevention of which one of ordinary skill in the art recognizes as having a potential benefit or therapeutic effect. In this respect, the inventive methods can provide any amount of any level of treatment or prevention of cancer in a mammal. Furthermore, the treatment or prevention provided by the inventive method can include treatment or prevention of one or more conditions or symptoms of the disease, e.g., cancer, being treated or prevented. Also, for purposes herein, "prevention" can encompass delaying the onset of the disease, or a symptom or condition thereof.

[0092] Also provided is a method of detecting the presence of cancer in a mammal. The method comprises (i) contacting a sample comprising cells of the cancer any of the inventive TCRs, polypeptides, proteins, nucleic acids, recombinant expression vectors, host cells, populations of cells, or antibodies, or antigen binding portions thereof, described herein, thereby forming a complex, and detecting the complex, wherein detection of the complex is indicative of the presence of cancer in the mammal.

[0093] With respect to the inventive method of detecting cancer in a mammal, the sample of cells of the cancer can be a sample comprising whole cells, lysates thereof, or a fraction of the whole cell lysates, e.g., a nuclear or cytoplasmic fraction, a whole protein fraction, or a nucleic acid fraction.

[0094] For purposes of the inventive detecting method, contacting can take place *in vitro* or *in vivo* with respect to the mammal. Preferably, the contacting is *in vitro*.

[0095] Also, detection of the complex can occur through any number of ways known in the art. For instance, the inventive TCRs, polypeptides, proteins, nucleic acids, recombinant expression vectors, host cells, populations of cells, or antibodies, or antigen binding portions thereof, described herein, can be labeled with a detectable label such as, for instance, a

radioisotope, a fluorophore (e.g., fluorescein isothiocyanate (FITC), phycoerythrin (PE)), an enzyme (e.g., alkaline phosphatase, horseradish peroxidase), and element particles (e.g., gold particles).

[0096] For purposes of the inventive methods, wherein host cells or populations of cells are administered, the cells can be cells that are allogeneic or autologous to the mammal. Preferably, the cells are autologous to the mammal.

[0097] With respect to the inventive methods, the cancer can be any cancer, including any of acute lymphocytic cancer, acute myeloid leukemia, alveolar rhabdomyosarcoma, bone cancer, brain cancer, breast cancer, cancer of the anus, anal canal, or anorectum, cancer of the eye, cancer of the intrahepatic bile duct, cancer of the joints, cancer of the neck, gallbladder, or pleura, cancer of the nose, nasal cavity, or middle ear, cancer of the oral cavity, cancer of the vulva, chronic lymphocytic leukemia, chronic myeloid cancer, colon cancer, esophageal cancer, cervical cancer, gastrointestinal carcinoid tumor. Hodgkin lymphoma, hypopharynx cancer, kidney cancer, larynx cancer, liver cancer, lung cancer, malignant mesothelioma, melanoma, multiple myeloma, nasopharynx cancer, non-Hodgkin lymphoma, ovarian cancer, pancreatic cancer, peritoneum, omentum, and mesentery cancer, pharynx cancer, prostate cancer, rectal cancer, renal cancer (e.g., renal cell carcinoma (RCC)), small intestine cancer, soft tissue cancer, stomach cancer, synovial cell sarcoma, testicular cancer, thyroid cancer, ureter cancer, and urinary bladder cancer. Preferably, the cancer is melanoma, breast cancer, lung cancer, prostate cancer, thyroid cancer, ovarian cancer, or synovial cell sarcoma.

[0098] The mammal referred to in the inventive methods can be any mammal. As used herein, the term "mammal" refers to any mammal, including, but not limited to, mammals of the order Rodentia, such as mice and hamsters, and mammals of the order Logomorpha, such as rabbits. It is preferred that the mammals are from the order Carnivora, including Felines (cats) and Canines (dogs). It is more preferred that the mammals are from the order Artiodactyla, including Bovines (cows) and Swines (pigs) or of the order Perssodactyla, including Equines (horses). It is most preferred that the mammals are of the order Primates, Ceboids, or Simoids (monkeys) or of the order Anthropoids (humans and apes). An especially preferred mammal is the human.

EXAMPLES

[0099] The following examples further illustrate the invention but, of course, should not be construed as in any way limiting its scope.

Cell Lines

[0100] Melanoma lines 1300mel (NY-ESO-1$^+$, HLA-A2$^+$), 624.38mel (NY-ESO-1$^+$, HLA-A2$^+$), A375mel (NY-ESO-1$^+$, HLA-A2$^+$), 938mel (NY-ESO-1$^+$, HLA-A2$^-$), 888mel (NY-ESO-1$^-$, HLA-A2$^-$), SK23mel (NY-ESO-1$^-$, HLA-A2$^+$), 1359mel (NY-ESO-1$^+$, HLA-A2$^-$), 1359-A2mel (NY-ESO-1$^+$, HLA-A2$^+$), 624mel (NY-ESO-1$^+$, HLA-A2$^+$), and 1390mel (NY-ESO-1$^+$, HLA-A2$^+$), were generated from resected tumor lesions and were cultured in R10 medium consisting of RPMI 1640 supplemented with 10% fetal bovine serum, 2 mmol/L L-glutamine, 50 units/mL penicillin, and 50 μg/mL (Invitrogen) and 25mmol/L HEPES (GIBCO, Invitrogen™). Other cell lines used included: the cervical cancer cell line Caski (NY-ESO-1$^+$, HLA-A2$^+$), (ATCC CRL-1550) the osteosarcoma cell line Saos2 (NY-ESO-1$^+$, HLA-A2$^+$), (ATCC HTB-85), and the neuroblastoma cell line SK NAS-A2 (NY-ESO-1$^+$, HLA-A2$^+$), (ATCC CRL-2137), the non-small cell lung cancer cell line H1299A2 (NY-ESO-1$^+$, HLA-A2$^+$), the breast carcinoma cell line MDA-MB-435S-A2 (NY-ESO-1$^+$, HLA-A2$^+$), (ATCC® HTB-129), all three of which were transduced with retroviral construct to express HLA-A*0201 (Navuaux et al., *J. Virol.*, 70: 5701-05 (1996), Parkhurst et al., *Clin. Cancer Res.*, 15: 169-180 (2009), Robbins et al., *J. Immunol.*, 180: 6116-31 (2008), Wargo et al., *Cancer Immunol. Immunother.*, 58: 394 (2009)), COS-A2-ESO, which was transduced with a retroviral vector expressing the NY-ESO-1 gene, and COS-A2-CEA, which was transduced with a retroviral vector expressing the CEA gene.

EXAMPLE 1

[0101] This example demonstrates the identification of murine anti-NY-ESO-1 T cell clones.

[0102] HLA-A2 transgenic mice were immunized with 100 μg of peptide (NY-ESO-$1_{157-165}$) and 120 μg of helper peptide (hepatitis B virus core peptide (HBVc):128-140) in 100 μl Incomplete Freund's adjuvant (IFA) subcutaneously (s.c.) at the base of the tail (50 μg of NY-ESO-$1_{157-165}$ peptide on each of two sides of the tail), followed by a boost one week later with the same immunization.

[0103] *Day 0*: One week after the second immunization, splenocytes were harvested and stimulated *in vitro* with one of the following: (i) LPS-activated HLA-A2+ splenocytes (3,000 rads) ("LPS blast") pulsed with 1 μg/ml priming peptide and 10 μg/ml human β2-microgobulin or (ii) T2 cells (17,000 rads) pulsed with 1, 0.1 or 0.01 μg/ml peptide.

[0104] *Day 7*: Bulk cultures were evaluated for specific reactivity via IFNγ secretion upon co-culture with one of the tumor cell lines set forth in Table 1. The results are shown in Table 1 (IFN-γ (pg/ml) post 1 bulk stimulation; "nt" = not tested). Because cytokine release was sometimes very high in response to T2 cells loaded with the HBV peptide, the underlined values for tumor targets indicate twice the background values obtained with media alone and negative tumors, and the underlined values for peptides indicate twice background values obtained with T2 and HBV peptide.

TABLE 1

	HLA-A2	NY-ESO-1	RNA copies per GAPDH (x100)	LPS blasts + 1 μg/ml peptide	T2 + 1 μg/ml peptide	T2 + 0.1 μg/ml peptide	T2 + 0.01 μg/ml peptide
T2+HBV	+	-	nt	41	266	200	71
T2+ESO:157	+	+	nt	549	4505	4,464	406
media	-	-	nt	22	53	69	41
888mel	-	-	0.02	36	133	110	88
Sk23mel	+	-	0.01	24	76	134	17
1359mel	-	+	5.68	55	92	21	26
1359-A2	+	+	nt	22	98	73	48
A375mel	+	+	59.08	41	47	143	49
624mel	+	+	4.14	41	73	200	22
1390mel	+	+	nt	-	-	-	-
1363mel	+	+	nt	-	-	-	-
COS-A2-CEA	+	-	nt	32	94	67	56
COS-A2-ESO	+	+	nt	33	92	65	61
293-A2-gp100	+	-	nt	-	-	-	-
293-A2-ESO	+	+	nt	-	-	-	-

[0105] *Day 11*: Peptide/tumor reactive bulk cultures were cloned at 10 cells/well under the following conditions (10 plates per condition): (i) irradiated T2 cells (18,000 rads) pulsed with 1, 0.1, or 0.01 μg/ml peptide: $5x10^4$ cells/well; (ii) irradiated C57BL/6 splenocyte feeders (3,000 rads): $5x10^4$ cells/well; and (iii) 10 CU/ml IL-2.

[0106] *Days 25-30*: Growth positive wells were selected and restimulated in 48-well plates under the following conditions: (i) irradiated T2 cells (18,000 rads) pulsed with 1, 0.1, or 0.01 μg/ml peptide: $2x10^5$ cells/well; (ii) irradiated C57BL/6 splenocyte feeders (3,000 rads): $1x10^6$ cells/well; and (iii) 10 CU/ml IL-2.

[0107] *Days 37-44*: Clones were evaluated for specific reactivity via IFNγ secretion upon co-culture with the tumor cell lines set forth in Table 2. Tumor cells were treated with IFNγ (20 ng/ml) and tumor necrosis factor alpha (3 ng/ml) overnight prior to the assay.

[0108] The splenocytes stimulated with LPS-activated HLA-A2+ splenocytes (3,000 rads) pulsed with 1 μg/ml priming peptide and 10 μg/ml human β2-microgobulin on Day 0 produced 8 out of 960 growth positive wells. Data for the two most reactive clones are shown in Table 2 (post 1 bulk stimulation; IFN-γ (pg/ml)).

TABLE 2

	HLA-A2	NY-ESO-1	RNA copies per GAPDH (x100)	B	H
T2+HBV	+	-	nt	393	283
T2+ESO:157	+	+	nt	>14,000	>14,000
media	-	-	nt	404	292
888mel	-	-	0.02	386	288
Sk23mel	+	-	0.01	-	-
1359mel	-	+	5.68	354	285
1359-A2	+	+	nt	11,781	16,436
A375mel	+	+	59.08	383	1,954
624mel	+	+	4.14	363	14,298
1390mel	+	+	nt	288	17,567
1363mel	+	+	nt	3,582	-
COS-A2-CEA	+	-	nt	348	289
COS-A2-ESO	+	+	nt	>14,000	>14,000
293-A2-gp100	+	-	nt	373	274
293-A2-ESO	+	+	nt	335	8,813

[0109] *Days 46-49*: Clones of interest were restimulated in 24-well plates under the following conditions: (i) irradiated T2 cells (18,000 rads) pulsed with 1, 0.1, or 0.01 μg/ml peptide: $5x10^5$ cells/well; (ii) irradiated C57BL/6 splenocyte feeders (3,000 rads): $1x10^6$ cells/well; and (iii) 10 CU/ml IL-2. Restimulated clones were flash-frozen for RNA preparation.

EXAMPLE 2

[0110] This example demonstrates the identification of murine anti-NY-ESO-1 T cell clones.

[0111] HLA-A2 transgenic mice were immunized and the splenocytes were harvested, stimulated, and evaluated for specific reactivity as described in Example 1.

[0112] *Day 11*: The bulk cultures were restimulated in 24-well plates under the following conditions: (i) irradiated T2 cells (18,000 rads) pulsed with 1, 0.1, or 0.01 μg/ml peptide: $4x10^5$ cells/well; (ii) irradiated C57BL/6 splenocyte feeders (3,000 rads): $1x10^6$ cells/well; and (iii) 10 CU/ml IL-2.

[0113] *Day 19*: The bulk cultures (post two stimulations) were evaluated for specific reactivity via IFN-γ secretion upon co-culture with the tumor cell lines set forth in Table 3. Tumor cells were treated with IFNγ (20 ng/ml) and tumor necrosis factor alpha (3 ng/ml) overnight prior to the assay. The results are shown in Table 3 (IFN-γ (pg/ml)).

TABLE 3

				Post 2 bulk stims.			
	HLA-A2	NY-ESO-1	RNA copies per GAPDH (x100)	LPS blasts + 1 μg/ml peptide	T2 + 1 μg/ml peptide	T2 + 0.1 μg/ml peptide	T2 + 0.01 μg/ml peptide
T2+HBV	+	-	nt	195	2,860	16,156	1,058
T2+ESO:157	+	+	nt	79,524	72,730	47,871	1,899
media	-	-	nt	137	131	156	406
888mel	-	-	0.02	40	201	112	562
Sk23mel	+	-	0.01	79	245	562	424
1359mel	-	+	5.68	73	169	188	357
1359-A2	+	+	nt	966	320	1,597	258
A375mel	+	+	59.08	150	176	258	332
624mel	+	+	4.14	320	144	697	301
1390mel	+	+	nt	-	-	-	-
1363mel	+	+	nt	-	-	-	-
COS-A2-CEA	+	-	nt	226	369	400	308
COS-A2-ESO	+	+	nt	424	351	326	295
293-A2-gp100	+	-	nt	-	-	-	-
293-A2-ESO	+	+	nt	-	-	-	-

[0114] *Day 21*: Bulk cultures were restimulated in 24-well plates under the following conditions: (i) irradiated T2 cells (18,000 rads) pulsed with 1, 0.1, or 0.01 μg/ml peptide: $5x10^5$ cells/well; (ii) irradiated C57BL/6 splenocyte feeders (3,000 rads): $1x10^6$ cells/well; and (iii) 10 CU/ml IL-2.

[0115] *Day 30*: The bulk cultures (post three stimulations) were evaluated for specific reactivity via IFN-γ secretion upon co-culture with the tumor cell lines set forth in Table 4. Tumor cells were treated with IFNγ (20 ng/ml) and tumor necrosis factor alpha (3 ng/ml) overnight prior to the assay. The results are shown in Table 4 (IFN-γ (pg/ml); * indicates bulk cultures that were cloned after three bulk stimulations).

TABLE 4

	HLA-A2	NY-ESO-1	RNA copies per GAPDH (x100)	* LPS blasts + 1 μg/ml peptide	* T2 + 1 μg/ml peptide	T2 + 0.1 μg/ml peptide	T2 + 0.01 μg/ml peptide	TE8 (human T cell clone)
T2+HBV	+	-	nt	1,794	4,700	28,797	23,897	16
T2+ESO :157	+	+	nt	78,316	63,793	96,164	19,698	16,254
media	-	-	nt	1,992	389	8,856	10,711	7
888mel	-	-	0.02	1,268	188	6,611	7,614	13
Sk23mel	+	-	0.01	662	202	7,585	6,225	69
1359mel	-	+	5.68	623	64	5,684	7,026	996
1359-A2	+	+	nt	27,572	7,774	10,324	7,204	7,936
A375mel	+	+	59.08	1,263	342	7,232	9,425	4,095
624mel	+	+	4.14	14,098	3,211	10,061	8,727	3,262
1390mel	+	+	nt	852	179	5,966	6,191	7,123
1363mel	+	+	nt	42,970	15,673	20,398	9,958	12,149
COS-A2-CEA	+	-	nt	981	119	3,995	6,744	18
COS-A2-ESO	+	+	nt	19,523	3,334	9,116	8,187	14,662
293-A2-gp100	+	-	nt	-	-	-	-	-
293-A2-ESO	+	+	nt	-	-	-	-	-

[0116] *Day 33*: Selected peptide/tumor reactive bulk cultures (post three stimulations) were cloned at 10 cells/well as described for Day 11 of Example 1.

[0117] *Days 45-48*: Growth positive wells were screened for peptide reactivity via IFN-γ secretion upon co-culture with the tumor cell lines set forth in Table 5. Tumor cells were treated with IFNγ (20 ng/ml) and tumor necrosis factor alpha (3 ng/ml) overnight prior to the assay.

[0118] The splenocytes stimulated with LPS-activated HLA-A2+ splenocytes (3,000 rads) pulsed with 1 μg/ml priming peptide and 10 μg/ml human β2-microgobulin on Day 0 produced 33 out of 960 growth positive wells. Data for the four most reactive clones (Nos. 2, 5, 6, and 8) are shown in Table 5 (post 3 bulk stimulations; IFN-γ (pg/ml)). The splenocytes

stimulated with T2 cells (17,000 rads) pulsed with 1 μg/ml peptide produced 104 out of 960 growth positive wells. Data for the four most reactive clones (Nos. 1, 50, 51, and 63) are shown in Table 5.

TABLE 5

	HLA-A2	NY-ESO-1	RNA copies per GAPDH (x100)	2	5	6	8	1	50	51	63
T2+HBV	+	-	nt	235	317	223	344	306	335	270	239
T2+ESO:157	+	+	nt	>14,000	>14,000	>14,000	>14,000	>14,000	>14,000	>14,000	>14,000
media	-	-	nt	221	314	231	563	266	232	258	222
888mel	-	-	0.02	210	316	208	288	234	241	244	208
Sk23mel	+	-	0.01	216	309	210	297	278	208	222	207
1359mel	-	+	5.68	243	383	206	422	347	271	212	229
1359-A2	+	+	nt	1,981	6,027	2,523	1,845	1,477	3,661	1,965	2,272
A375mel	+	+	59.08	523	388	232	1,455	556	557	556	737
624mel	+	+	4.14	7,879	1,931	2,527	8,595	4,629	4,487	2,978	7,139
1390mel	+	+	nt	1,124	17,567	352	900	517	379	914	716
1363mel	+	+	nt	-	-	-	-	-	-	-	-
COS-A2-CEA	+	-	nt	-	-	-	-	-	-	-	-
COS-A2-ESO	+	+	nt	-	-	-	-	-	-	-	-
293-A2-gp100	+	-	nt	-	-	-	-	-	-	-	-
293-A2-ESO	+	+	nt	-	-	-	-	-	-	-	-

[0119] *Days 46*-49: Peptide reactive clones were restimulated in 24-well plates as described for Day 21 of this example. Restimulated clones were flash-frozen for RNA preparation.

EXAMPLE 3

[0120] This example demonstrates the isolation of a murine anti-NY-ESO-1 TCR and the specific reactivity of the isolated TCR against NY-ESO-1.

[0121] The TCR from five clones, (namely, clones B, H, 5, 6, 1, 50, and 63) were isolated. The nucleotide sequence (RNA) encoding the TCR of each clone was isolated, sequenced, and transfected into human peripheral blood mononuclear cells (PBMC) from Patients 1 and 2. The transfected cells were stimulated with OKT3 and IL-2 and cultured alone (media) or co-cultured with T2 cells pulsed with control (HBV) peptide, T2 cells pulsed with NY-ESO-$1_{157-165}$ peptide, COA-A2-CEA (NY-ESO-1^-), COS-A2-ESO (NY-ESO-1^+), or one of various melanoma tumor cell lines 888mel (NY-ESO-1^-), Sk23mel (NY-ESO-1^-), A375mel (NY-ESO-1^+), 1363mel (NY-ESO-1^+), 1390 (NY-ESO-1^+), or 624 (NY-ESO-1^+). IFNγ secretion was measured. The results are shown in Table 6 (IFNγ (pg/ml)).

TABLE 6

	T2+HBV	T2+ESO: 157	media	888	Sk23	1363	1390	A375	624	COS-A2-CEA	COS-A2-ESO
HLA-A2	-	-	-	-	+	+	+	+	+	+	+
NY-ESO-1	-	+	-	-	-	+	+	+	+	-	+
Patient 1											
GFP	326	180	8	198	134	220	325	632	32	94	74
Avidex TCR	235	>10,000	7	188	81	>10,000	1637	5752	531	52	2320
TRAV7D-4/TRBV19[1]	664	>10,000	7	185	102	2262	489	893	39	72	449
TRAV13D-2/TRBV14[2]	197	>10,000	8	152	88	134	159	338	26	75	55
TRAV7D-3/TRBV14[3]	155	366	7	129	112	122	171	378	28	68	71
TRAV6D/TRBV26[4]	198	>10,000	11	255	156	>10,000	3859	9973	782	91	3872
TRAV7D-3/TRBV26[5]	190	1269	0	208	107	246	189	509	34	79	104
Patient 2											
GFP	26	30	2	47	27	22	62	98	8	16	19
Avidex TCR	50	>10,000	4	32	22	2484	208	192	150	11	588
TRAV7D-4/TRBV19[1]	183	>10,000	2	34	15	149	47	39	7	13	90
TRAV13D-2/TRBV14[2]	22	7898	9	27	13	20	42	58	11	22	17
TRAV7D-3/TRBV14[3]	24	23	11	28	13	21	30	39	5	7	13
TRAV6D/TRBV26[4]	63	>10,000	39	77	40	3597	777	344	133	32	683
TRAV7D-3/TRBV26[5]	10	77	0	28	17	27	33	51	5	16	40

[1]TRAV7D-4/TRBV19: Clone ESO (1 stim LPS) B (Table 2 above)
[2]TRAV13D-2/TRBV14: Clone ESO (1 stim LPS) H (Table 2 above)
[3]TRAV7D-3/TRBV14: Clone ESO (3 stim LPS) 5 (Table 5 above)
[4]TRAV6D/TRBV26: Clones ESO (3 stim LPS) 6; ESO (3 stim T2) 1; ESO (3 stim T2) 63 (Table 5 above)
[5]TRAV7D-3/TRBV26: Clone ESO (3 stim T2) 50 (Table 5 above)

[0122] As shown in Table 6, the TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12) TCR provided the highest specific anti-NY-ESO-1 reactivity and was chosen for further study.

[0123] The nucleotide sequence (RNA) encoding the TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12) TCR was transfected into human PBMC from Patients 3 and 4. The transfected cells were positively selected for CD8+ and CD4+ cells, stimulated with OKT3 and IL-2, and cultured alone (media) or co-cultured with T2 cells pulsed with control (HBV) peptide, T2 cells pulsed with various concentrations of NY-ESO-$1_{157-165}$ peptide, COS-A2-ESO (NY-ESO-1^+), COA-A2-CEA (NY-ESO-1^-), or one of various melanoma tumor cell lines 888mel (NY-ESO-1^-), Sk23mel (NY-ESO-1^-), A375mel (NY-ESO-1^+), 1363mel (NY-ESO-1^+), or 624 (NY-ESO-1^+). IFNγ secretion was measured and the results are shown in Table 7 (IFNγ (pg/ml)).

TABLE 7

											888	Sk23	A375	624	1363	COS-A2 CEA	COS-A2 ESO
		T2+HBV	---------T2+ESO:157-165----------								A2-	A2+	A2+	A2+	A2+	A2+	A2+
		10^{-6} g/ml	10^{-12} g/ml	10^{-11} g/ml	10^{-10} g/ml	10^{-9} g/ml	10^{-8} g/ml	10^{-7} g/ml	10^{-6} g/ml	media	ESO-	ESO-	ESO+	ESO+	ESO+	ESO-	ESO+
Patient 3																	
CD8+	TRAV6D/ TRBV26	243	238	1075	4257	6170	8996	5087	6142	122	90	70	419	125	1194	56	1041
	GFP	86	47	27	29	9	17	18	25	12	19	5	18	1	27	11	20
CD4+	TRAV6D/ TRBV26	127	67	69	1836	12835	19161	12495	14641	173	56	43	250	84	361	30	179
	Avidex	6	0	1	40	1147	2455	3538	5783	17	0	0	25	9	26	10	14
	GFP	10	0	0	0	0	0	0	0	10	5	0	43	18	47	4	7
Patient 4																	
CD8+	TRAV6D/ TRBV26	15	55	931	1713	2670	3721	2988	2878	0	0	0	48	15	262	0	380
	GFP	42	0	0	0	0	0	5	0	0	0	6	5	0	0	2	0
CD4+	TRAV6D/ TRBV26	38	1	58	5774	18051	19691	>20000	>20000	21	7	0	109	36	476	2	241
	Avidex	25	0	0	200	2923	15574	>20000	18293	8	0	0	37	0	60	0	23
	GFP	12	0	0	0	0	0	10	30	0	0	0	28	14	42	0	0

[0124] As shown in Table 7, the cells transfected with the TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12) TCR specifically recognized NY-ESO-1+ melanoma tumor cells, as measured by IFNγ secretion.

EXAMPLE 4

[0125] This example demonstrates the reactivity of human CD8+ and CD4+ T cells transfected with a murine anti-NY-ESO-1 TCR upon co-culture with dendritic cells pulsed with NY-ESO-1 peptide.

[0126] CD8+ (Figure 1A) or CD4+ (Figure 1B) human T cells were transfected with a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12)) or a human anti-NY-ESO-1 TCR. The transfected cells were co-cultured with dendritic cells pulsed with various concentrations of NY-ESO-$1_{157-165}$ peptide, and IFNγ secretion was measured.

[0127] As shown in Figures 1A and 1B, CD8+ and CD4+ human T cells transfected with a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12)) were reactive against dendritic cells pulsed with NY-ESO-$1_{157-165}$ peptide, as measured by IFNγ secretion. CD8+ human T cells transfected with a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12)) were more reactive against dendritic cells pulsed with NY-ESO-$1_{157-165}$ peptide, as measured by IFNγ secretion, as compared to CD8+ cells transfected with a human anti-NY-ESO-1 TCR.

EXAMPLE 5

[0128] This example demonstrates the reactivity of human CD8+ and CD4+ T cells transfected with a murine anti-NY-ESO-1 TCR upon co-culture with melanoma tumor cells.

[0129] CD8+ (Figure 2A) or CD4+ (Figure 2B) human T cells were transfected with a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12)) or a human anti-NY-ESO-1 TCR. The transfected cells were cultured alone (media) or co-cultured with T2 cells pulsed with control peptide, T2 cells pulsed with NY-ESO-$1_{157-165}$ peptide, COA-A2-CEA (NY-ESO-1^-), COS-A2-ESO (NY-ESO-1^+), or one of various melanoma tumor cell lines 888mel (NY-ESO-1^-), Sk23mel (NY-ESO-1^-), A375mel (NY-ESO-1^+), or 1363mel (NY-ESO-1^+). IFNγ secretion was measured.

[0130] As shown in Figures 2A and 2B, CD8+ and CD4+ human T cells transfected with a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12)) specifically recognized NY-ESO-1+ melanoma tumor cells, as measured by IFNγ secretion. CD8+ and

CD4+ human T cells transfected with a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26 (SEQ ID NOs: 11 and 12)) were more reactive against NY-ESO-1+ tumor cell lines, as measured by IFNγ secretion, as compared to CD8+ and CD4+ cells transfected with a human anti-NY-ESO-1 TCR.

EXAMPLE 6

[0131] This example demonstrates the reactivity of human CD8+ and CD4+ T cells transfected with a wild-type or codon-optimized nucleotide sequence encoding a murine anti-NY-ESO-1 TCR upon co-culture with melanoma tumor cells.

[0132] A wild-type (SEQ ID NOs: 19 and 20) or codon-optimized (SEQ ID NOs: 15 and 16) nucleotide sequence (RNA) encoding the murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26) was transfected into CD8+ or CD4+ human PBMC from Patients 5 and 6. The transfected cells were positively selected for CD8+ and CD4+ cells, stimulated with OKT3 and IL-2, and cultured alone (media) or co-cultured with T2 cells pulsed with control (HBVc) peptide, T2 cells pulsed with various concentrations of NY-ESO-$_{1157\text{-}165}$ peptide, COA-A2-CEA (NY-ESO-1$^-$), COS-A2-ESO (NY-ESO-1$^+$), or one of various melanoma tumor cell lines 888mel (NY-ESO-1$^-$), Sk23mel (NY-ESO-1$^-$), A375mel (NY-ESO-1$^+$), 1363mel (NY-ESO-1$^+$), A375 (NY-ESO-1$^+$), or 624mel (NY-ESO-1$^+$). IFNγ secretion was measured. The results are shown in Table 8 (IFNγ (pg/ml)).

TABLE 8

	----------Patient 5 CD4----------			--------Patient 5 CD8----------			-------Patient 6 CD4----------			-------Patient 6 CD8----------			
	Codon optimized	wild type	GFP	Codon optimized	wild type	GFP	Codon optimized	wild type	GFP	Codon optimized	wild type	GFP	media
media	103	62	6	43	60	1	0	0	0	0	0	0	3
T2+HBVc	58	37	4	71	108	82	2	17	7	3	12	9	8
T2+10^{-12} M ESO	44	32	0	67	86	46	13	15	6	6	9	14	0
T2+10^{-11} M ESO	83	42	0	52	150	30	15	22	7	20	23	2	0
T2+10^{-10} M ESO	69	27	3	221	175	43	13	18	4	193	176	0	0
T2+10^{-9} M ESO	232	60	0	3149	2465	20	728	555	6	1979	3066	4	0
T2+10^{-8} M ESO	5158	2979	0	13308	13394	56	15468	12906	7	5382	11217	0	0
T2+10^{-7} M ESO	13987	9362	1	>20000	>20000	37	23981	21321	8	8914	13127	0	0
T2+10^{-6} M ESO	15345	9417	0	>20000	>20000	51	26802	25225	8	14734	19766	2	0
888mel (A2- ESO-)	54	30	8	55	98	37	22	9	8	36	58	37	17
Sk23mel (A2+ ESO-)	30	34	7	8	26	29	3	0	3	8	29	11	0
A375 (A2+ ESO+)	239	204	75	525	925	55	114	146	82	190	480	22	0
624mel (A2+ ESO+)	102	81	57	176	211	24	44	42	6	89	125	0	0
1363mel (A2+ ESO+)	605	443	176	964	1421	28	525	576	153	426	1079	20	nt
COS-A2-CEA	68	66	22	51	83	39	8	17	16	4	13	9	4
COS-A2-ESO	429	92	2	1322	1436	22	1213	431	17	872	1372	10	0

[0133] As shown in Table 8, CD8+ and CD4+ human T cells transfected with a wild-type or codon-optimized nucleotide sequence encoding a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26) specifically recognized NY-ESO-1+ melanoma tumor cells, as measured by IFNγ secretion.

EXAMPLE 7

[0134] This example demonstrates the reactivity of human CD8+ T cells transfected with a wild-type nucleotide sequence encoding a murine anti-NY-ESO-1 TCR upon co-culture with melanoma and non-melanoma tumor cells.

[0135] A nucleotide sequence (RNA) (SEQ ID NO: 19 and 20) encoding the murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26) was electroporated into CD8+ human T cells from Patients 7 and 8. Untransfected cells (mock) or transfected cells were positively selected for CD8+ T cells, stimulated with OKT3 and IL-2, and cultured alone (media) or co-cultured with T2 cells pulsed with control (HBVc) peptide; T2 cells pulsed with various concentrations of NY-ESO-$1_{157-165}$ peptide; COA-A2-CEA (NY-ESO-1$^-$); COS-A2-ESO (NY-ESO-1$^+$); one of various melanoma tumor cell lines 888mel (NY-ESO-1$^-$), Sk23mel (NY-ESO-1$^-$), A375mel (NY-ESO-1$^+$), 1363mel (NY-ESO-1$^+$), A375 (NY-ESO-1$^+$); osteogenic sarcoma cell line Saos2 (NY-ESO-1$^+$); glioma cell line LN-18 (NY-ESO-1$^+$); Ewing's sarcoma cell line TC-71 (NY-ESO-1$^+$); neuroblastoma cell lines SKN AS (NY-ESO-1$^+$) or SKN AS-A2 (NY-ESO-1$^+$); or breast cancer cell lines MDA 453S (NY-ESO-1$^+$) or MDA 453S-A2 (NY-ESO-1$^+$). IFNγ secretion was measured. The results are shown in Table 9 (IFNγ (pg/ml)).

TABLE 9

		--Patient 7 CD8---		--Patient 8 CD8---		
		ESO a/b	mock	ESO a/b	mock	media
media		21	0	0	6	0
T2+HBVc		64	60	88	50	0
T2+10-12 M ESO		50	58	107	59	0
T2+10-11 M ESO		66	51	209	71	0
T2+10-10 M ESO		332	66	1704	50	0
T2+10-9 M ESO		3142	51	10886	55	0
T2+10-8 M ESO		6505	52	>20000	58	0
T2+10-7 M ESO		6764	42	>20000	51	0
T2+10-6 M ESO		6550	55	>20000	58	0
888mel (A2- ESO -)	melanoma	59	45	142	133	0
Sk23mel (A2+ ESO-)	melanoma	79	54	31	59	0
A375mel (A2+ ESO+)	melanoma	2986	240	1984	93	0
1363mel (A2+ ESO+)	melanoma	1889	119	9858	137	0
Saos2 (A2+ ESO+)	osteogenic sarcoma	248	34	1253	28	0
LN-18 (A2+ ESO+)	glioma	123	21	224	34	0
TC-71 (A2+ ESO+)	Ewing's sarcoma	159	116	183	127	3
SKN AS (A2- ESO+)	neuroblastoma	542	328	199	207	2
SKN AS - A2 (A2+ ESO+)	neuroblastoma	148	38	1004	39	0
MDA 453S (A2- ESO+)	breast cancer	448	311	177	230	0
MDA 453S -A2 (A2+ ESO+)	breast cancer	111	50	610	39	0
COS-A2-CEA (A2+ ESO-)		45	51	50	63	7
COS-A2-ESO (A2+ ESO+)		588	34	4109	63	0

[0136] As shown in Table 9, CD8+ human T cells transfected with a nucleotide sequence encoding a murine anti-NY-ESO-1 TCR (TRAV6D/TRBV26) specifically recognized NY-ESO-1+ melanoma, osteogenic sarcoma, Ewing's sarcoma, neuroblastoma, and breast cancer tumor cells, as measured by IFNγ secretion.

EXAMPLE 8

[0137] This example demonstrates the preparation of recombinant expression vectors encoding a murine anti-NY-ESO-1 TCR.

[0138] A retroviral vector comprising DNA encoding wild-type human anti-NY-ESO-1 TCR (1G4), 1G4 TCR having a double substitution within the CDR3α chain in which leucine and tyrosine are substituted for threonine at position 95 (1G4-LY) (Robbins et al., *J. Clin. Oncol.*, 29: 917-924 (2011); Robbins et al., *J. Immunol.*, 180: 6116–6131 (2008)), or murine

anti-NY-ESO-1 TCR (TRAV6D/TRBV26) (SEQ ID NOs: 11 and 12) were cloned into a MSGVI retroviral backbone and transformed into TOP10 cells. A picornavirus 2A peptide (SEQ ID NO: 13) linked the alpha and beta chains. Two vectors encoding the murine TRAV6D/TRBV26 TCR were made: one contained the nucleotide sequence encoding the alpha chain located 5' of the nucleotide sequence encoding the beta chain (mESOαβ) (SEQ ID NO: 17), and one contained the nucleotide sequence encoding the beta chain located 5' of the nucleotide sequence encoding the alpha chain (mESOβα) (SEQ ID NO: 18). The presence of the inserts encoding the alpha and beta chains of the TCR was confirmed by digestion with *Nco* I and *Not* I restriction enzymes. DNA was generated from one clone for each of the human and murine TCRs by maxiprep.

[0139] DNA from the 1G4 TCR and 1G4-LY vectors was transfected into 293GP cells to collect supernatant and transduce PBL in subsequent transduction experiments. A vector encoding GFP was used as a control.

EXAMPLE 9

[0140] This example demonstrates the transduction efficiency of a murine anti-NY-ESO-1 TCR.

[0141] Peripheral blood lymphocytes (PBL) were stimulated with OKT3 on Day 0 (S1). The PBL were transduced with the 1G4, 1G4-LY, mESOαβ, or mESOβα TCR vector of Example 8 on Days 3 and 4. On Days 7-11, transduction efficiency was evaluated by fluorescence-activated cell sorting (FACS). An antibody recognizing the variable region of the murine TCR (VB13.1) and an antibody recognizing the constant region of the murine TCR (mB) were used for the FACS. The FACS was performed 7 to 11 days after first stimulation (S1D7-S1D11). The results are summarized in Table 10 below.

TABLE 10

	% VB13.1, mB+ cells pre-rapid expansion (REP) (for 5 donors) (S1D7-S1D11)
Untransduced (UT)	0-6
Green fluorescent protein (GFP)	67-90.5
1G4 TCR	62-85
1G4-LY TCR	37-85
mESOαβ TCR	56-90
mESOβα TCR	56-91

[0142] As shown in Table 10, PBL transduced with the mESOαβ or mESOβα TCR vector were transduced with similar efficiency as compared to the vectors encoding the 1G4 and 1G4-LY TCRs.

EXAMPLE 10

[0143] This example demonstrates the reactivity of cells transduced with a vector encoding a murine anti-NY-ESO-1 TCR.

[0144] PBL from five donors were stimulated and either untransduced or transduced with vectors encoding GFP or the 1G4-LY, mESOαβ, or mESOβα TCR as described in Example 9. Transduced PBL were co-cultured with one of the various tumor cell lines listed in Table 11A or 11B below or with T2 cells pulsed with SSX peptide, no peptide (T2), or one of the various concentrations of NY-ESO-$1_{157-165}$ peptide listed in Table 12 below. IFNγ secretion was measured by enzyme-linked immunosorbent assay (ELISA) of 24 hour supernatant from co-cultures. ELISA was performed 6, 7, or 10 days following first stimulation (S1D6, S1D7, and S1D10). The results are shown in Tables 11A, 11B, and 12 (IFNγ pg/ml). Transduction (Td) efficiency was based on FACS analysis of Vβ13.1 + mβ + cells.

TABLE 11A

	% td efficiency	888	938	COS-A2-gp100	624.38	H1299-A2	A375	COAS-A2-ESO	1300
Patient 1 (Dilution 1:10; S1D7)									
Untransduced (UT)	N/A	12	0	99	22	17	132	24	61
GFP	90	0	0	91	17	65	95	0	33
1G4-LY TCR	85	13	0	99	3316	8592	3059	1391	5732
mESOαβ TCR	83	239	284	156	5523	9616	4430	1872	6922
mESOβα TCR	83	329	326	42	6721	9898	4178	2270	7798
Patient 2 (Dilution 1:5; S1D7)									
Untransduced (UT)	N/A	44	43	46	44	42	53	46	42
GFP	67	42	42	43	44	40	50	41	41
1G4-LY TCR	63	53	43	44	346	1446	451	132	352
mESOαβ TCR	56	43	44	45	372	1259	415	108	323
mESOβα TCR	56	43	46	45	327	1236	412	136	625
Patient 3 (Dilution 1:5; S1D10)									
Untransduced (UT)	N/A	0	0	0	0	0	48	39	-
GFP	63	0	0	0	0	0	0	0	-

	% td efficiency	888	938	COS-A2-gp100	624.38	H1299-A2	A375	COAS-A2-ESO	1300
1G4-LY TCR	76	0	305	0	546	770	1020	332	-
mESOαβ TCR	63	0	0	0	111	38	292	13	-
mESOβα TCR	60	0	0	0	413	540	819	283	-

TABLE 11B

Patient 4 (Dilution 1:5; S1D6)									
	% Td efficiency	Media	888	938	COS-A2 gp100	624.38	H1299-A2	A375	COS-A2-ESO
Untransduced (UT)	NA	52	155	35	294	195	122	476	212
GFP	91%	34	91	22	78	106	62	306	50
1G4-LY TCR	75%	86	113	54	313	2172	7187	1671	2394
mESOαβ TCR	84%	41	131	98	185	1946	5744	1064	1490
mESOβα TCR	85%	52	130	110	164	2812	7163	1262	1676
Patient 5 (Dilution 1:5; S1D6)									
Untransduced (UT)	NA	42	23	12	88	9	8	107	64
GFP	87%	15	20	15	76	0	11	98	62
1G4-LY TCR	25%	63	16	10	20	1172	3156	918	430
mESOαβ TCR	74%	19	55	22	57	444	917	233	372
mESOβα TCR	74%	15	32	20	24	810	2417	603	380

TABLE 12

	% td efficiency	SSX	T2	1 µg/ml	100 ng/ml	10 ng/ml	1 ng/ml	0.1 ng/ml
Patient 1 (Dilution 1:5; S1D7)								
Untransduced (UT)	NA	0	0	0	0	0	0	0
GFP	90	0	0	0	0	0	0	0
1G4 TCR	85	0	0	2452	2475	1525	851	99
1G4-LY TCR	85	0	0	2173	1599	1087	677	0
mESOαβ TCR	83	0	0	2825	2210	1904	1060	278
mESOβα TCR	83	0	0	3018	2403	2020	1212	522
Patient 2 (Dilution 1:5; S1D7)								
Untransduced (UT)	NA	22	20	52	24	21	33	53
GFP	67	17	38	33	39	31	21	20
1G4 TCR	62	19	15	1,963	1,104	860	397	41
1G4-LY TCR	63	15	19	2441	1280	879	291	40
mESOαβ TCR	56	20	42	4645	1854	1529	535	92
mESOβα TCR	56	38	27	7091	2302	1336	348	262

[0145] Cells transduced with the mESOαβ or the mESOβα TCR vectors specifically recognized NY-ESO-1$^+$/HLA-A*0201$^+$ target tumor cell lines but not HLA-A*0201$^-$/NY-ESO-1$^+$ or HLA-A*0201$^+$/NY-ESO-1$^-$ cell lines as measured by IFNγ secretion (Tables 11A and 11B). Cells transduced with the mESOαβ or the mESOβα TCR vectors specifically recognized T2 cells pulsed with NY-ESO-1 peptide as measured by IFNγ secretion (Table 12). The NY-ESO-1 specific recognition was consistent among cells from five different donors. Functionality of the cells transduced with the murine anti-NY-ESO-1 TCR was comparable to that of cells transduced with human anti-NY-ESO-1 TCR. Functionality of the cells transduced with the mESOβα TCR vector was slightly higher as compared to that of the cells transduced with the mESOαβ TCR vector. PBL transduced with either mESOαβ or the mESOβα TCR vectors recognized T2 cells pulsed with as little as 1 ng/mL, indicating that both mTCRs are relatively high avidity receptors. Co-culture of PBL expressing mESOαβ or the mESOβα TCR vectors with control T2 cells that were not pulsed with any peptide produced background levels of IFN-γ. The cells of Patient 1 transduced with mESOβα TCR had higher levels of IFN-γ secretion when compared to the cells transduced with mESOαβ TCR for the same level of peptide. The cells of Patient 2 transduced with mESOβα TCR had higher levels of IFN-γ secretion when compared to the cells transduced with mESOαβ TCR for the same level of peptide for peptide concentrations 1 μg/ml, 100 ng/ml, and 0.1 ng/ml.

EXAMPLE 11

[0146] This example demonstrates that cells transduced with a vector encoding a murine anti-NY-ESO-1 TCR maintain expression of the murine anti-NY-ESO-1 TCR following expansion of the numbers of cells.

[0147] PBL from two donors were stimulated and either untransduced or transduced with vectors encoding GFP or the 1G4, 1G4-LY, mESOαβ, or mESOβα TCR as described in Example 9. The numbers of PBL were expanded as described in Riddell et al., *Science,* 257:238–241 (1992) and Dudley et al., *Cancer J. Sci. Am.,* 6:69–77 (2000). Generally, the numbers of PBL were expanded up to 3 logs using soluble OKT3, irradiated feeder cells, and high-dose IL-2. Expression of murine anti-NY-ESO-1 TCR by expanded numbers (expanded once) of cells was measured by FACS twice (on Days 10 and 20). The results are summarized in Table 13 (% VB13.1, mB+ cells following expansion).

TABLE 13

Donor	1		2	
	D10	D20	D10	D20
UT	0	<1	0	<1
GFP	88	87	42	70
1G4 TCR	59	80	50	59
1G4-LY TCR	76	88	37	60
mESOαβ TCR	82	76	62	46
mESOβα TCR	82	74	62	50

[0148] As shown in Table 13, PBL transduced with the mESOαβ or mESOβα TCR vector maintained expression of the murine anti-NY-ESO-1 TCR following expansion of the numbers of cells.

EXAMPLE 12

[0149] This example demonstrates that cells transduced with a vector encoding a murine anti-NY-ESO-1 TCR maintain functionality following expansion of the numbers of transduced cells.

[0150] PBL from two donors were stimulated and either untransduced or transduced with vectors encoding GFP or the 1G4-LY, mESOαβ, or mESOβα TCR as described in Example 9. The numbers of transduced cells were expanded as described in Example 11. Transduced expanded PBL were cultured alone (media) or co-cultured with one of the various tumor cell lines listed in Table 14 below or with T2 cells pulsed with SSX peptide, no peptide (T2), or one of the various concentrations of NY-ESO-$1_{157-165}$ peptide listed in Table 15 below. IFNγ secretion was measured by ELISA nine days after the second stimulation (S2D9). The results are shown in Tables 14 and 15 (IFNγ pg/ml; Dilution 1:10).

TABLE 14

	% td efficiency	Media	888	938	COS-A2-gp100	624.38	H1299-A2	A375	COAS-A2-ESO	1300
Patient 1										
Untransduced (UT)	N/A	282	181	91	515	78	128	779	-	91
GFP	88	95	87	44	216	44	48	783	-	53
1G4-LY TCR	76	208	184	105	260	8233	12848	6454	-	2786
mESOαβ TCR	82	129	183	111	121	8132	11976	6152	-	3035
mESOβα TCR	82	92	194	130	148	9104	11381	6226	-	2654
Patient 2										
(UT)	N/A	297	276	195	231	151	144	353	-	167
GFP37	42	393	380	205	272	146	186	465	-	168
1G4-LY TCR	37	102	174	53	133	4571	5984	2420	-	2066
mESOαβ TCR	62	125	397	362	170	7382	9590	4681	-	3439
mESOβα TCR	62	137	323	370	130	6345	8250	4236	-	3054

TABLE 15

	% td efficiency	SSX	T2	1 μg/ml	100 ng/ml	10 ng/ml	1 ng/ml	0.1 ng/ml
Patient 1								
Untransduced (UT)	NA	365	479	123	113	168	168	231
GFP	88	0	30	0	0	0	0	0
1G4 TCR	59	179	275	26446	19424	13530	6988	1277
1G4-LY TCR	76	185	217	30639	21553	16246	7261	1328
mESOαβ TCR	82	511	516	26427	22062	16950	8601	1873
mESOβα TCR	82	399	384	27813	23052	16872	8076	2174
Patient 2								
Untransduced (UT)	NA	976	1281	886	616	680	782	764
GFP	42	660	912	505	697	726	591	763
1G4 TCR	50	279	364	19505	12698	7350	3553	747
1G4-LY TCR	37	150	110	19416	10632	6799	2495	662
mESOαβ TCR	62	386	460	19960	13887	9970	4488	1025
mESOβα TCR	62	379	611	16434	12708	9646	5266	1177

[0151] Functionality of expanded transduced cells was also evalulated by chromium release assay. Expanded transduced cells (effector cells) were co-cultured with target melanoma cells 624.38 cells (Table 16A) or A375 cells (Table 16B) at various effector:target (E:T) cell ratios, and the percentage of target cells lysed was measured. The results are shown in Tables 16A and 16B (percentage of target cells lysed).

TABLE 16A

E:T Ratio	1G4-LY TCR	mESOα/β TCR	mESOβ/α TCR	GFP
40 : 1	71.0	69.0	68	20.0
13 : 1	59.0	64.0	62	13.0
4 :1	54.0	73.0	46	23.0
1.5 :1	42.0	40.0	39	2.0

TABLE 16B

E:T Ratio	IG4-LY TCR	mESO α/β	mESO β/α	GFP
40 : 1	43.0	49.0	51	21.0
13 : 1	43.0	47.0	50	16.0
4 :1	36.0	28.0	32	8.0
1.5 :1	29.0	31.0	32	6.0

[0152] As shown in Tables 14, 15, 16A, and 16B, cells transduced with a vector encoding a murine anti-NY-ESO-1 TCR maintained functionality following expansion of the numbers of transduced cells.

EXAMPLE 13

[0153] This example demonstrates a method of producing packaging cell clones for the production of mESOβα TCR for potential clinical application.

[0154] DNA for the mESOβα TCR vector was used to produce retroviral vector packaging cell clones under conditions required for potential clinical application. Supernatant from six PG13 producer cell clones was used to transduce PBL. FACS analysis of transduced PBL using the anti-mouse TCR-β chain antibody revealed that each clone produced virus that mediated positive TCR transduction (Table 17). To assess the specific recognition of tumor cells, the mTCR engineered PBL from each PG13 producer cell clone were co-cultured with a panel of HLA-A*0201$^+$ and HLA-A*0201$^-$ melanoma and lung

tumor derived cell lines (Table 17). IFN-gamma was measured by ELISA. A comparison of the six mTCR PG13 producer clones showed that T cells transduced with Clone C1 released high levels of IFN-γ in response to HLA-A*0201$^+$/NY-ESO-1$^+$ tumor cell target H1299-A2 and demonstrated the highest transduction efficiency (Table 17). These responses were specific as background levels of IFN-γ were released in response to NY-ESO-1$^+$/HLA-A*0201$^-$ cell lines and NY-ESO-1$^-$/HLA-A*0201$^+$ cell lines by each clone (Figure 2). Based on this analysis, Clone C1 was selected for the production of a master cell bank for subsequent production of good manufacturing practice (GMP) retroviral supernatant.

TABLE 17

Clone	% mTCRβ	IFN-γ pg/ml				
		media	888	H1299A2	624.38	A375
UT	4	122	1	0	0	146
B2	30	39	46	2923	670	382
C1	63	0	0	7529	942	257
C12	42	10	0	3332	661	351
D8	36	64	90	5773	675	439
F2	47	31	38	5533	579	488
H4	44	34	38	7185	531	459

EXAMPLE 14

[0155] This example demonstrates the transduction efficiency of cells transduced with a mESOβα TCR using a retroviral supernatant from the packaging cell clone of Example 13.

[0156] To compare the respective NY-ESO-1 TCRs (murine, or mTCR, versus human, or hTCR (1G4-LY TCR)), FACS analysis of PBL transduced with retroviral supernatant from packaging cell clones using the anti-mouse TCR-Vβ chain and the anti- Vβ13.1 antibodies was performed after one stimulation with OKT3 and following a second large-scale expansion using the rapid expansion protocol (REP) (Table 18). Results demonstrated that both the mTCR and the hTCR had equivalent percentages of transduction after stimulation, with the mTCR having equal to or greater levels of transduction after REP (Table 18).

TABLE 18

	%TCR			
	Donor H		Donor E	
	After one stimulation with OKT3	After expanding numbers of cells twice	After one stimulation with OKT3	After expanding numbers of cells twice
UT	4	13	4	8
1G4-LY TCR	52	56	48	44
mESOβα TCR	56	61	46	66

EXAMPLE 15

[0157] This example demonstrates the reactivity of cells transduced with a mESOβα TCR using a retroviral supernatant from the packaging cell clone of Example 13.

[0158] The recognition of each TCR was evaluated by subjecting the mTCR and the hTCR transduced T cells to co-culture with NY-ESO-1 peptide-pulsed T2 cells. Both the mTCR and the hTCR specifically secreted IFN-γ upon encounter with the antigenic peptide in a dose-dependent manner after one stimulation with OKT3 and after REP (Table 19). After one stimulation, both the mTCR and the hTCR recognized T2 cells pulsed with as little as 0.1 ng/mL indicating that both mTCRs are relatively high avidity receptors. Following the expansion of the numbers of cells, the mTCR released higher levels of IFN-γ compared to the hTCR vector transduced T cells at each concentration of peptide (Table 19). Co-culture of PBL expressing NY-ESO-1 mTCR or NY-ESO-1 hTCR with control T2 cells that were not pulsed with any peptide produced background levels of IFN-γ.

TABLE 19

	IFN-γ pg/ml Donor H (after stimulation with OKT3)				
peptide concentration	T2 cells without peptide	0.1 ng/μl	1 ng/μl	10 ng/μl	100 ng/μl
UT	400	380	329	350	285
GFP	633	455	424	410	412
1G4-LY TCR	1259	1400	1710	3016	3775
mESOβα TCR	1070	1316	1660	3091	3744
	IFN-γ pg/ml Donor H (after expanding numbers of cells)				
peptide concentration	T2 cells without peptide	0.1 ng/μl	1 ng/μl	10 ng/μl	100 ng/μl
UT	34	47	57	22	28
GFP	34	47	57	22	28
1G4-LY TCR	24	89	512	2974	4341
mESOβα TCR	174	229	1456	6633	10683

[0159] To assess the specific recognition of tumor cells, the mTCR engineered PBL were co-cultured with a panel of HLA-A*0201$^+$ and HLA-A*0201$^-$ melanoma and lung tumor derived cell lines. Specific release of IFN-γ was observed when both the mTCR engineered PBL and the hTCR were co-cultured with HLA-A*0201$^+$/NY-ESO-1$^+$ cell lines but not HLA-A*0201$^-$/NY-ESO-1$^+$ or HLA-A*0201$^+$/NY-ESO-1$^-$ cell lines (Table 20 (representative experiments shown)).

TABLE 20

Patient H				
	H1299-A2	624.38	1300	938
Untransduced (UT)	86	93	118	0
GFP	83	81	91	0
1G4-LY TCR	14549	6171	1507	0
mESOβα TCR	8877	4248	1326	0
Patient E				
	H1299-A2	624.38	1300	938
Untransduced (UT)	64	72	81	0
GFP	70	72	63	0
1G4-LY TCR	7483	2149	452	0
mESOβα TCR	10646	3548	986	0

EXAMPLE 16

[0160] This example demonstrates specific lysis of melanoma cells by cells transduced with a mESOβα TCR using a retroviral supernatant from the packaging cell clone of Example 13.

[0161] The specific lysis of melanoma cell lines by the mTCR and the hTCR were also compared. The ability of the transduced PBL to lyse HLA-A*0201$^+$/NY-ESO-1$^+$ tumor cells was measured using a CYTOTOX-GLO bioluminescence assay (Promega, Madison, WI). This assay utilizes a luminogenic peptide substrate, the AAF-GLO substrate, to measure dead-cell protease activity, which is released from cells that have lost membrane integrity, resulting in the generation of a "glow-type" luminescent signal that is proportional to the number of dead cells in the sample. The AAF-GLO substrate cannot cross the intact membrane of live cells and does not generate any appreciable signal from the live-cell population. In these assays, TCR engineered PBL were co-incubated with increasing ratios of target cells (E:T) in AIM-V medium in 96-well U-bottom plates at 37°C for 4 hours (hr.) Lysis was measured by bioluminescence release in the medium: percent specific lysis = [specific release – (spontaneous effector release + spontaneous target release)]/total target release – spontaneous target release x 100%, average of quadruplicate samples. Little or no cell lysis is measured as a negative value.

[0162] As shown in Table 21, both mTCR and hTCR transduced PBL demonstrated similar lytic activity against melanoma NY-ESO-1$^+$/HLA-A*0201$^+$ tumor cell line 624.38mel. There was little or no lysis of HLA-A*0201$^-$ cell line 938 mel, and the GFP transduced PBL showed no reactivity against any of the target cells (Table 21).

TABLE 21

	Positive Target: 624.38 cells		
Effector:target ratio	10:1	30:1	60:1
GFP	-9	-3	-2
1G4-LY TCR	29	59	58
mESOβα TCR	31	59	60
	Negative Target:938 cells		
Effector:target ratio	10:1	30:1	60:1
GFP	-19	-22	-34
1G4-LY TCR	-13	-11	-10
mESOβα TCR	-13	-10	-10

EXAMPLE 17

[0163] This example demonstrates the anti-tumor activity of cells transduced with a mESOβα TCR or human TCR using a retroviral supernatant from the packaging cell clone of Example 13.

[0164] The anti-tumor activity of CD4+ T lymphocytes transduced with the mTCR and the hTCR was also investigated. NY-ESO-1 hTCR and NY-ESO-1 mTCR transduced PBL were enriched with CD4+ magnetic beads, then co-cultured for 16 hours with a panel of HLA-A*0201$^+$ and HLA-A*0201$^-$ melanoma and lung tumor derived cell lines. CD4+ T lymphocytes transduced with both the mTCR and the hTCR had specific release of IFN-γ when co-cultured with HLA-A*0201$^+$/NY-ESO-1$^+$ cell lines but not HLA-A*0201$^-$/NY-ESO-1$^+$ cell lines (Table 22).

TABLE 22

	IFN-γ pg/ml (Donor I)		
	H1299A2	624.38	938
Untransduced	0	31	0
1G4-LY TCR	22684	7020	0
mESOβα TCR	21376	3754	41
	IFN-γ pg/ml (Donor J)		
	H1299A2	624.38	938
Untransduced	1158	0	0
1G4-LY TCR	22786	2594	0
mESOβα TCR	22331	481	14

EXAMPLE 18

[0165] This example demonstrates the specific recognition of different tumor histologies by cells transduced with a mESOβα TCR using a retroviral supernatant from the packaging cell clone of Example 13.

[0166] To assess the specific recognition of various tumor histologies, NY-ESO-1 mTCR transduced PBL were co-cultured with different HLA-A*0201$^+$/NY-ESO-1$^+$ cell lines derived from melanoma (A375), non-small cell lung cancer (H1299-A2), neuroblastoma (SKN AS-A2), breast cancer (MDA-435S-A2), and osteosarcoma (Saos2). Specific release of IFN-γ was observed (Table 23).

TABLE 23

	IFN-γ pg/ml	
	Untransduced	mESOβα TCR
A375	0	5710
H1299-A2	132	21222
MDA-435S-A2	1181	3057
SKN AS-A2	1417	5097
Saos2	117	12092

EXAMPLE 19

[0167] This example demonstrates the recognition of DAC-treated tumor cells by PBL transduced with a mESOβα TCR.

[0168] Increasing concentrations of the DNA-demethylating agent 5-aza-2'-deoxycytidine (decitabine; DAC) induces expression of various cancer testis antigens in lung cancer cells (Rao et al., *Ther. Tar. and Chem. Bio.*, 71: 4192-4204 (2011)). Without being bound to a particular theory or mechanism, it is believed that DAC may, potentially, up-regulate NY-ESO-1 expression in cancer cells, which may enhance the ability of the TCRs to recognize NY-ESO-1.

[0169] NY-ESO-1 mTCR transduced or untransduced PBL were co-cultured for 16 hours with the tumor target cell lines of different histologies (shown in Tables 24A-24B) that had been exposed to DAC at the concentrations shown in Tables 24A-24B for 72 hours. Interferon-gamma levels were measured. The results are shown in Table 24A-24B.

TABLE 24A

Prostate Cancer (pC3A2 cells)		
DAC concentration (mM/L)	IFN-γ (pg/ml)	
	Untransduced	mESOβα TCR from Clone C1
Untreated	159	336
0.1	289	1566
0.5	188	1766
1.0	282	1912
10	361	1520

TABLE 24B

Colorectal Cancer (SW480 cells)		
DAC concentration (mM/L)	IFN-γ (pg/ml)	
	Untransduced	mESOβα TCR from Clone C1
Untreated	118	135
0.1	141	196
0.5	169	239
1.0	98	255
10	80	388

[0170] As shown in Tables 24A and 24B, the PBL transduced with mESOβα TCR demonstrated higher reactivity toward DAC-treated target prostate cancer and colorectal cancer, respectively, as compared to untreated target cells.

EXAMPLE 20

[0171] This example demonstrates the recognition of T2 cells pulsed with alanine-substituted NY-ESO-1 peptides by PBL transduced with the mESOβα TCR or human TCR.

[0172] Untransduced human PBL or human PBL transduced with mTCR (mESOβα from clone C1), hTCR (1G4-LY TCR), or green fluorescent protein (GFP) were co-cultured for 16 hours with untreated T2 cells or T2 cells that were previously pulsed with different concentrations of peptide as shown in Tables 25A and 25B. Interferon gamma was measured. The results are shown in Table 25A and 25B. As shown in Tables 25A and 25B, the mTCR recognizes SEQ ID NO: 24 while the hTCR does not. In addition, the hTCR recognizes SEQ ID NO: 27 but the mTCR does not.

TABLE 25A (Donor K)

		IFN-γ (pg/ml)			
	pulsed peptide (ng/μL)	Untransduced	GFP	1G4-LY TCR	mESOβα
untreated T2 Cells	-	943	358	641	443
SLLMWITQC (SEQ ID NO: 2)	10	0	0	3759	5741
SLLMWITQC (SEQ ID NO: 2)	1	0	0	678	2111
MART	10	0	0	0	0
MART	1	0	0	0	0
SL**A**MWITQC (SEQ ID NO: 23)	10	0	0	3271	6287
SL**A**MWITQC (SEQ ID NO: 23)	1	0	0	1785	2421
SLL**A**WITQC (SEQ ID NO: 24)	10	0	0	0	2701
SLL**A**WITQC (SEQ ID NO: 24)	1	0	0	0	3172
SLLM**A**ITQC (SEQ ID NO: 25)	10	0	0	0	0
SLLM**A**ITQC (SEQ ID NO: 25)	1	0	0	0	0
SLLMW**A**TQC (SEQ ID NO: 26)	10	0	0	1114	1194
SLLMW**A**TQC (SEQ ID NO: 26)	1	0	0	884	921
SLLMWI**A**QC (SEQ ID NO: 27)	10	0	0	5672	0
SLLMWI**A**QC (SEQ ID NO: 27)	1	0	0	457	0
SLLMWIT**A**C (SEQ ID NO: 28)	10	0	0	0	0
SLLMWIT**A**C (SEQ ID NO: 28)	1	0	0	0	0

TABLE 25B (Donor L)

		IFN-γ (pg/ml)			
	pulsed peptide (ng/μL)	Untransduced	GFP	1G4-LY TCR	mESOβα
untreated T2 Cells	-	162	126	131	188
SLLMWITQC (SEQ ID NO: 2)	10	124	120	754	1168
SLLMWITQC (SEQ ID NO: 2)	1	199	112	184	273
MART	10	230	136	123	102
MART	1	155	152	112	108
SL**A**MWITQC (SEQ ID NO: 23)	10	145	168	1383	1541
SL**A**MWITQC (SEQ ID NO: 23)	1	120	139	370	505
SLL**A**WITQC (SEQ ID NO: 24)	10	128	121	185	616
SLL**A**WITQC (SEQ ID NO: 24)	1	123	111	225	1000
SLLM**A**ITQC (SEQ ID NO: 25)	10	183	163	294	137
SLLM**A**ITQC (SEQ ID NO: 25)	1	119	112	148	214
SLLMW**A**TQC (SEQ ID NO: 26)	10	96	80	297	375
SLLMW**A**TQC (SEQ ID NO: 26)	1	74	70	220	280
SLLMWI**A**QC (SEQ ID NO: 27)	10	78	95	1026	76
SLLMWI**A**QC (SEQ ID NO: 27)	1	123	72	208	86
SLLMWIT**A**C (SEQ ID NO: 28)	10	78	83	97	76
SLLMWIT**A**C (SEQ ID NO: 28)	1	85	75	82	74

[0173] [Blank]

[0174] The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0175] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

WE CLAIM:

1. An isolated or purified T-cell receptor (TCR) having antigenic specificity for NY-ESO-1 (SEQ ID NO: 1) and comprising the alpha chain complementarity determining region (CDR) 1 amino acid sequence of SEQ ID NO: 3, the alpha chain CDR2 amino acid sequence of SEQ ID NO: 4, the alpha chain CDR3 amino acid sequence of SEQ ID NO: 5, the beta chain CDR1 amino acid sequence of SEQ ID NO: 6, the beta chain CDR2 amino acid sequence of SEQ ID NO: 7, and the beta chain CDR3 amino acid sequence of SEQ ID NO: 8.
2. The isolated or purified TCR according to claim 1, wherein the TCR has antigenic specificity for NY-ESO-$1_{157\text{-}165}$ (SEQ ID NO: 2).
3. The isolated or purified TCR according to claim 1 or 2, comprising the alpha chain variable region amino acid sequence of SEQ ID NO: 9 and the beta chain variable region amino acid sequence of SEQ ID NO: 10.
4. The isolated or purified TCR according to any one of claims 1-3, comprising the alpha chain amino acid sequence of SEQ ID NO: 11 and the beta chain amino acid sequence of SEQ ID NO: 12.
5. An isolated or purified polypeptide comprising a functional portion of the TCR according to any one of claims 1-4, wherein the functional portion comprises the alpha chain CDR1 amino acid sequence of SEQ ID NO: 3, the alpha chain CDR2 amino acid sequence of SEQ ID NO: 4, the alpha chain CDR3 amino acid sequence of SEQ ID NO: 5, the beta chain CDR1 amino acid sequence of SEQ ID NO: 6, the beta chain CDR2 amino acid sequence of SEQ ID NO: 7, and the beta chain CDR3 amino acid sequence of SEQ ID NO: 8.
6. An isolated or purified polypeptide comprising a functional portion of the TCR according to any one of claims 1-4, wherein the portion comprises the alpha chain variable region amino acid sequence of SEQ ID NO: 9 and the beta chain variable region amino acid sequence of SEQ ID NO: 10.

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7. An isolated or purified polypeptide comprising a functional portion of the TCR according to any one of claims 1-4, wherein the portion comprises the alpha chain amino acid sequence of SEQ ID NO: 11 and the beta chain amino acid sequence of SEQ ID NO: 12.

8. An isolated or purified protein comprising a first polypeptide chain comprising the alpha chain CDR1 amino acid sequence of SEQ ID NO: 3, the alpha chain CDR2 amino acid sequence of SEQ ID NO: 4, and the alpha chain CDR3 amino acid sequence of SEQ ID NO: 5 and a second polypeptide chain comprising the beta chain CDR1 amino acid sequence of SEQ ID NO: 6, the beta chain CDR2 amino acid sequence of SEQ ID NO: 7, and the beta chain CDR3 amino acid sequence of SEQ ID NO: 8.

9. The isolated or purified protein according to claim 8, comprising a first polypeptide chain comprising the alpha chain variable region amino acid sequence of SEQ ID NO: 9 and a second polypeptide chain comprising the beta chain variable region amino acid sequence of SEQ ID NO: 10.

10. The isolated or purified protein according to claim 8 or 9, comprising a first polypeptide chain comprising the alpha chain amino acid sequence of SEQ ID NO: 11 and a second polypeptide chain comprising the beta chain amino acid sequence of SEQ ID NO: 12.

11. The isolated or purified protein according to any one of claims 8-10, wherein the protein is a fusion protein.

12. The isolated or purified protein according to any one of claims 8-11, wherein the protein is a recombinant antibody.

13. An isolated or purified nucleic acid comprising a nucleotide sequence encoding the TCR according to any one of claims 1-4, the polypeptide according to any one of claims 5-7, or the protein according to any one of claims 8-12.

14. The isolated or purified nucleic acid according to claim 13, wherein the nucleotide sequence is codon-optimized.

15. The isolated or purified nucleic acid according to claim 13 or 14, wherein the nucleotide sequence comprises:

(i) the alpha chain-encoding sequence of SEQ ID NO: 15 and the beta chain-encoding sequence of SEQ ID NO: 16, or

(ii) the alpha chain-encoding sequence of SEQ ID NO: 19 and the beta chain-encoding sequence of SEQ ID NO: 20.

16. A recombinant expression vector comprising the nucleic acid according to any one of claims 13-15.

17. The recombinant expression vector according to claim 16, wherein the nucleotide sequence comprises a nucleotide sequence encoding a complementarity determining region (CDR) 1α, CDR2α, CDR3α, CDR1β, CDR2β, and CDR3β, and the nucleotide sequence encoding the CDR1α, CDR2α, and CDR3α is 5' of the nucleotide sequence encoding the CDR1β, CDR2β, and CDR3β.

18. The recombinant expression vector according to claim 16, wherein the nucleotide sequence comprises a nucleotide sequence encoding a CDR 1α, CDR2α, CDR3α, CDR1β, CDR2β, and CDR3β, and the nucleotide sequence encoding the CDR1α, CDR2α, and CDR3α is 3' of the nucleotide sequence encoding the CDR1β, CDR2β, and CDR3β.

19. The recombinant expression vector according to claim 17, comprising the nucleotide sequence of SEQ ID NO: 17.

20. The recombinant expression vector according to claim 18, comprising the nucleotide sequence of SEQ ID NO: 18.

21. An isolated host cell comprising the recombinant expression vector according to any one of claims 16-20.

22. The host cell according to claim 21, wherein the cell is human.

23. An isolated population of cells comprising at least one host cell according to claim 21 or 22, wherein the population of cells does not comprise a multicellular organism or single cells that are capable of growing into a multicellular organism.

24. A pharmaceutical composition comprising the TCR according to any one of claims 1-4, the polypeptide according to any one of claims 5-7, the protein according to any one of claims 8-12, the nucleic acid according to any one of claims 13-15, the recombinant expression vector according to any one of claims 16-20, the host cell according to claim 21 or 22, or the population of cells according to claim 23, and a pharmaceutically acceptable carrier.

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25. An *in vitro* method of detecting the presence of cancer in a mammal, comprising:

(a) contacting a sample comprising one or more cells from the mammal with the TCR according to any one of claims 1-4, the polypeptide according to any one of claims 5-7, the protein according to any one of claims 8-12, the nucleic acid according to any one of claims 13-15, the recombinant expression vector according to any one of claims 16-20, the host cell according to claim 21 or 22, the population of cells according to claim 23, or the pharmaceutical composition according to claim 24, thereby forming a complex, and

(b) detecting the complex, wherein detection of the complex is indicative of the presence of cancer in the mammal,

wherein the cancer is an NY-ESO-1 positive cancer.

26. The method of claim 25, wherein the cancer is melanoma, breast cancer, lung cancer, prostate cancer, thyroid cancer, ovarian cancer, or synovial cell sarcoma.

27. The TCR according to any one of claims 1-4, the polypeptide according to any one of claims 5-7, the protein according to any one of claims 8-12, the nucleic acid according to any one of claims 13-15, the recombinant expression vector according to any one of claims 16-20, the host cell according to claim 21 or 22, the population of cells according to claim 23, or the pharmaceutical composition according to claim 24, for use in the treatment or prevention of cancer in a mammal, wherein the cancer is an NY-ESO-1 positive cancer.

28. The TCR, polypeptide, protein, nucleic acid, recombinant expression vector, host cell, population of cells, antibody, or antigen binding portion thereof, or pharmaceutical composition for the use according to claim 27, wherein the cancer is melanoma, breast cancer, lung cancer, prostate cancer, thyroid cancer, ovarian cancer, or synovial cell sarcoma.

29. Use of the TCR according to any one of claims 1-4, the polypeptide according to any one of claims 5-7, the protein according to any one of claims 8-12, the nucleic acid according to any one of claims 13-15, the recombinant expression vector according to any one of claims 16-20, the host cell according to claim 21 or 22, the population of cells according

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to claim 23, or the pharmaceutical composition according to claim 24, in the manufacture of a medicament for the treatment or prevention of cancer in a mammal, wherein the cancer is an NY-ESO-1 positive cancer.

30. The use according to claim 29, wherein the cancer is melanoma, breast cancer, lung cancer, prostate cancer, thyroid cancer, ovarian cancer, or synovial cell sarcoma.

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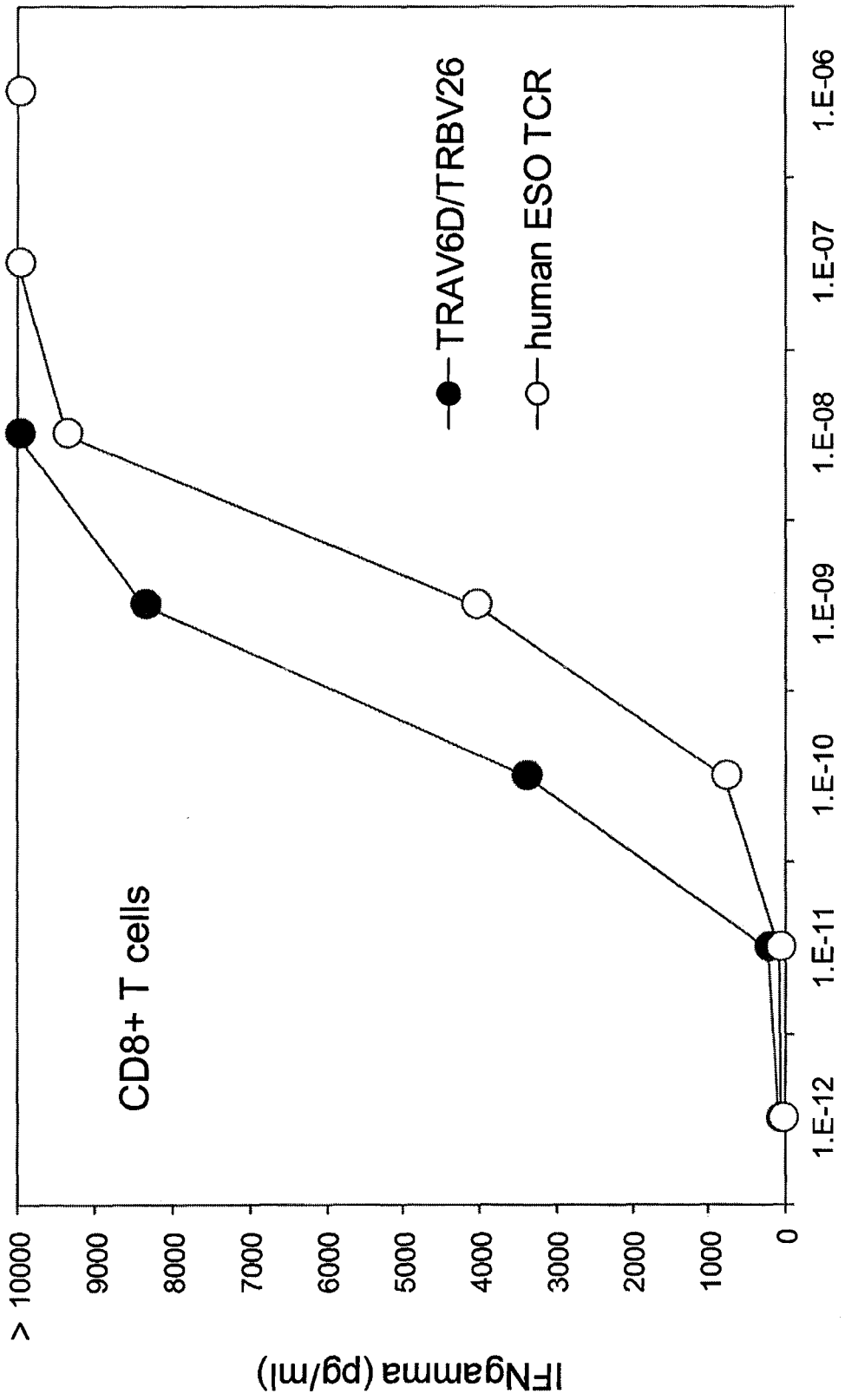
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8000
7000
6000
5000
4000
3000
2000
1000
0
CD8+ T cells
TRAV6D/TRBV26
human ESO TCR
1.E-12
1.E-11
1.E-10
1.E-09
1.E-08
1.E-07
1.E-06
Peptide concentration (mg/ml)

Fig. 1A

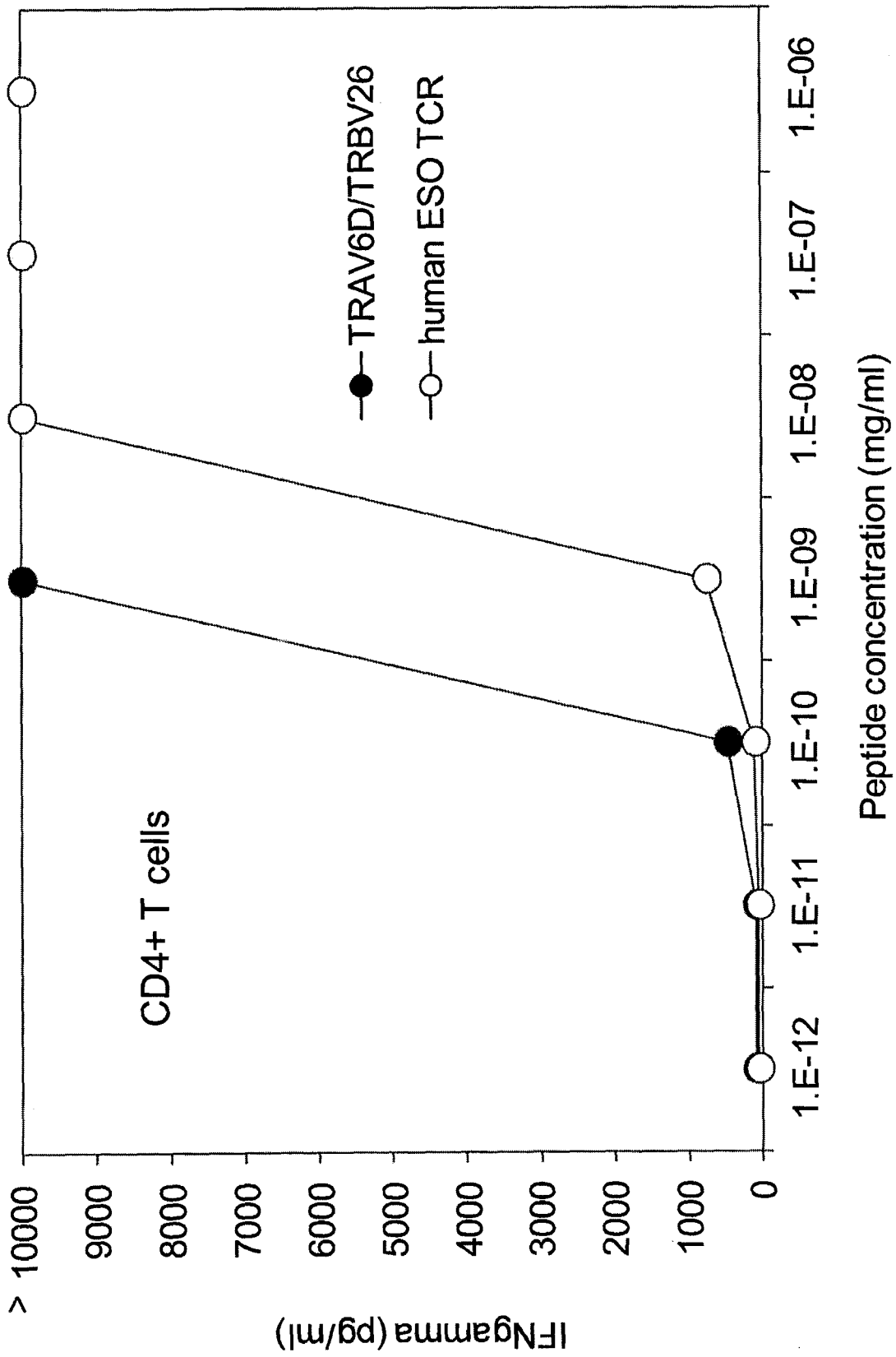
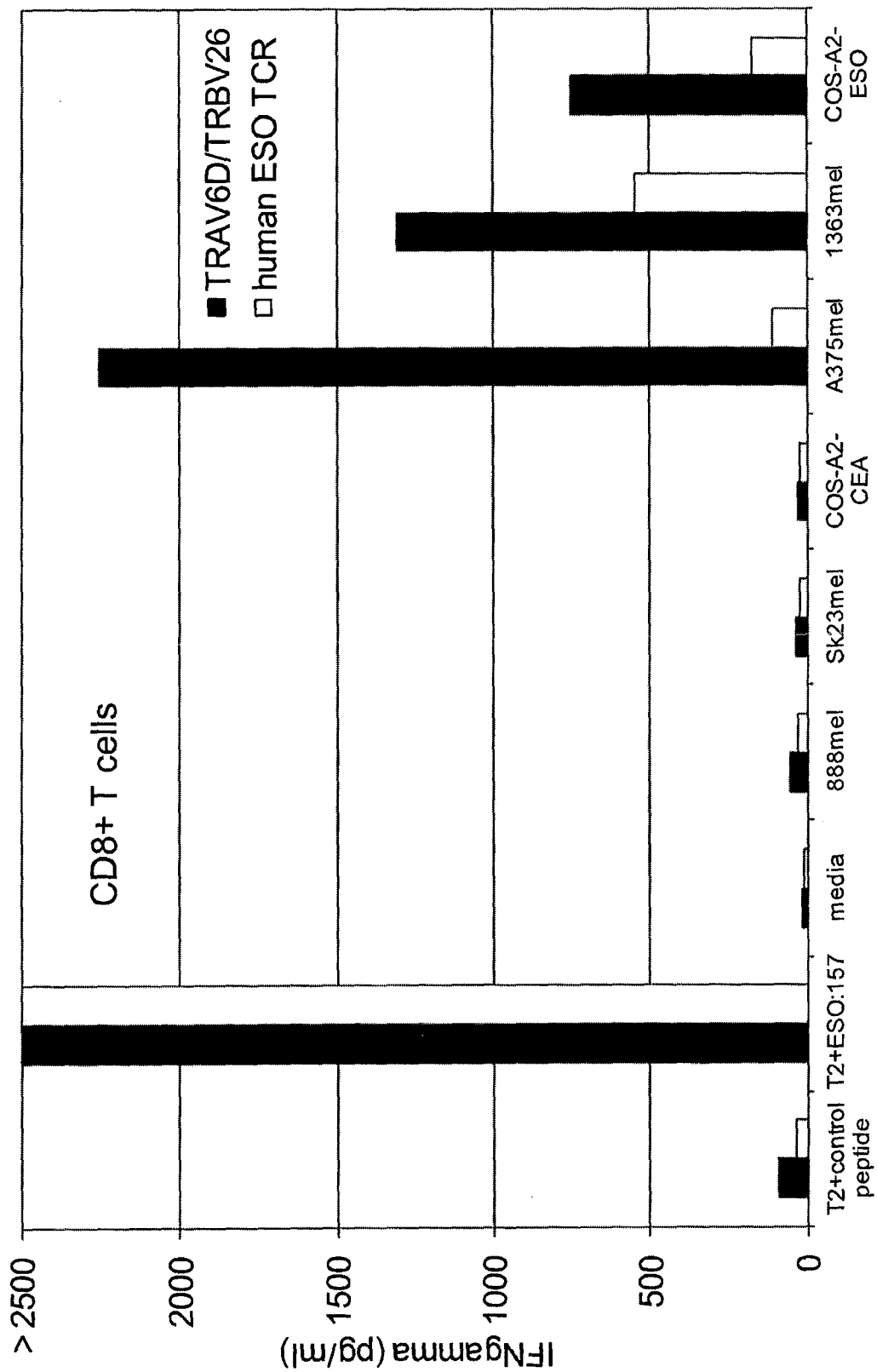

IFNgamma (pg/ml)
> 10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
CD4+ T cells
TRAV6D/TRBV26
human ESO TCR
1.E-12
1.E-11
1.E-10
1.E-09
1.E-08
1.E-07
1.E-06
Peptide concentration (mg/ml)

Fig. 1B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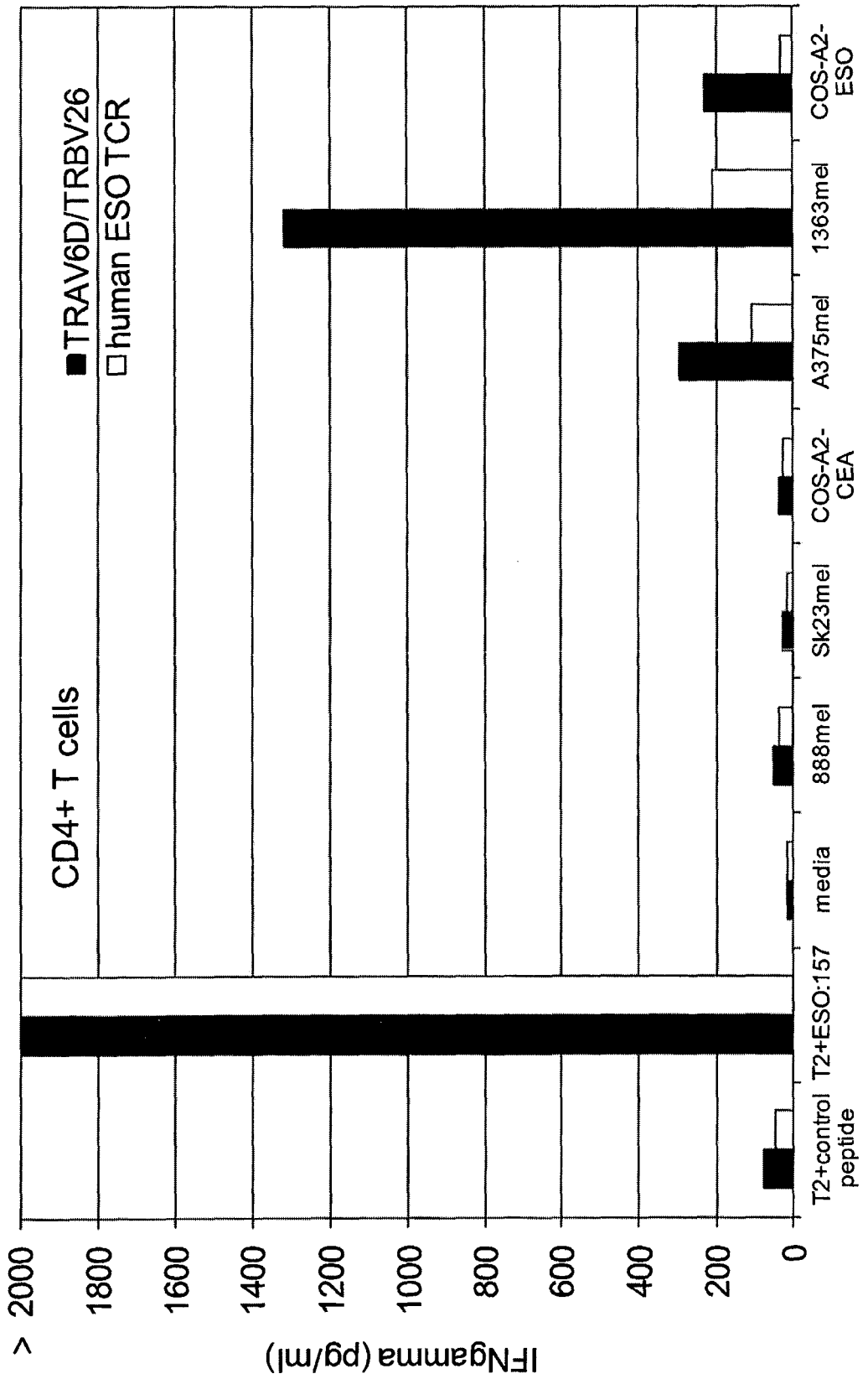
TRAV6D/TRBV26
human ESO TCR
IFNgamma (pg/ml)
> 2500
2000
1500
1000
500
0
T2+control peptide
T2+ESO:157
media
888mel
Sk23mel
COS-A2-CEA
A375mel
1363mel
COS-A2-ESO

Fig. 2A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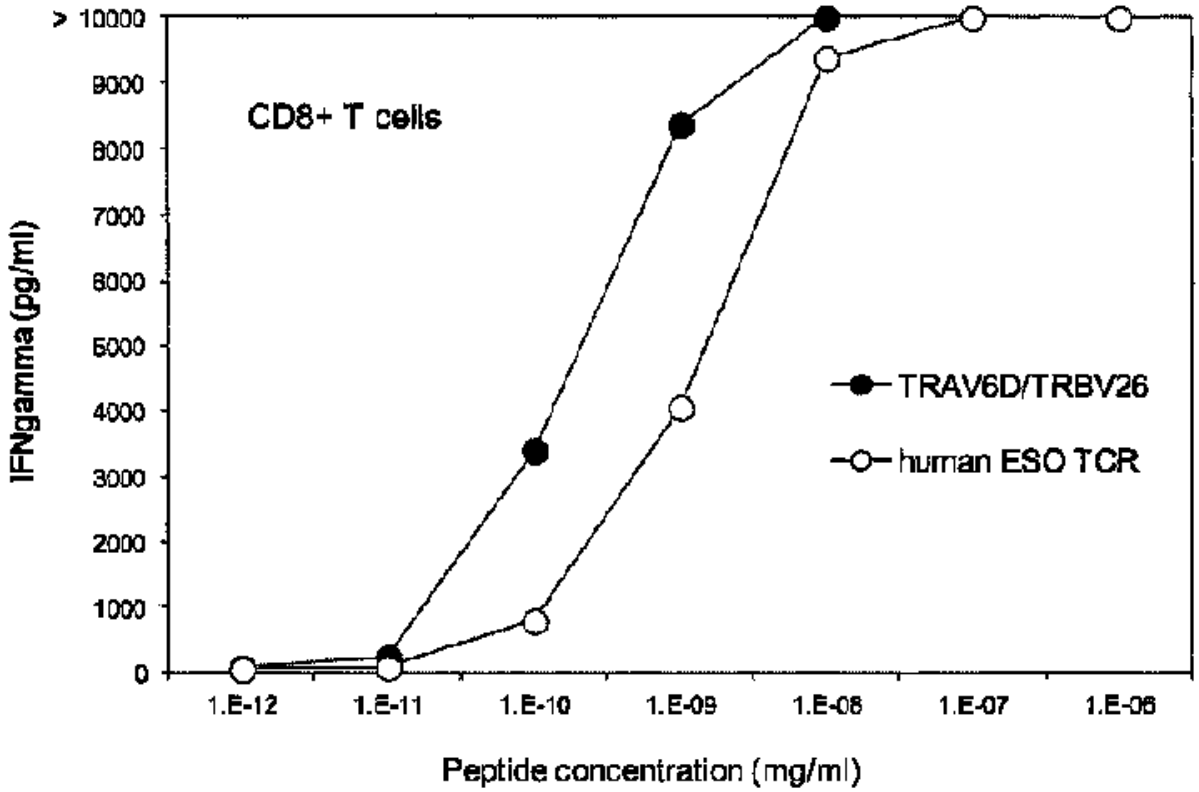
TRAV6D/TRBV26
human ESO TCR
IFNgamma (pg/ml)
> 2000
1800
1600
1400
1200
1000
800
600
400
200
0
T2+control peptide
T2+ESO:157
media
888mel
Sk23mel
COS-A2-CEA
A375mel
1363mel
COS-A2-ESO

Fig. 2B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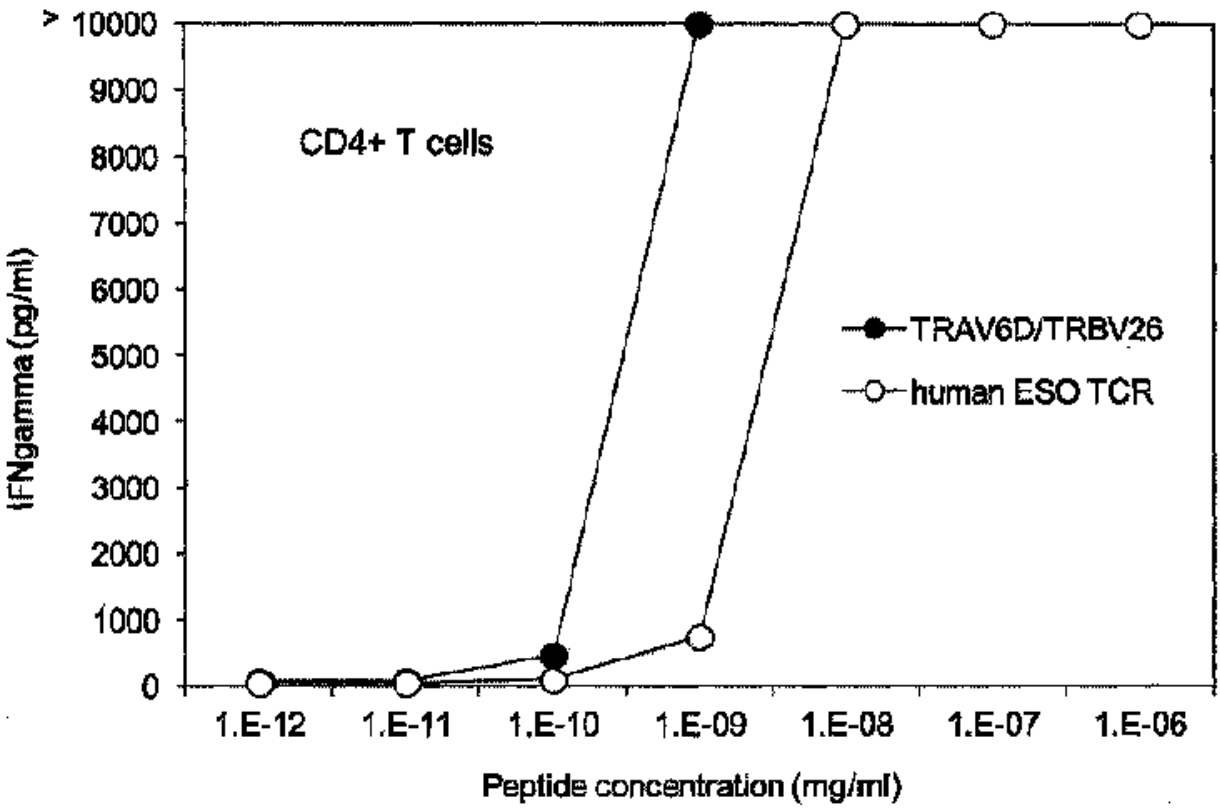
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
IFNgamma (pg/ml)
CD8+ T cells
TRAV6D/TRBV26
human ESO TCR
1.E-12
1.E-11
1.E-10
1.E-09
1.E-08
1.E-07
1.E-06
Peptide concentration (mg/ml)

A


> 10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
IFNgamma (pg/ml)
CD4+ T cells
TRAV6D/TRBV26
human ESO TCR
1.E-12
1.E-11
1.E-10
1.E-09
1.E-08
1.E-07
1.E-06
Peptide concentration (mg/ml)

B