PROSTATE-ASSOCIATED ANTIGENS AND VACCINE-BASED IMMUNOTHERAPY REGIMENS

REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/642,844 filed on May 4, 2012, which is incorporated herein by reference in its entity.

REFERENCE TO SEQUENCE LISTING

This application is being filed along with a sequence listing in electronic format. The sequence listing is provided as a file in .txt format entitled "PC71854A SEQ LISTING_ST25.TXT", created on April 4, 2013 and having a size of 257KB. The sequence listing contained in the .txt file is part of the specification and is herein incorporated by reference in its entity.

FIELD OF THE INVENTION

The present invention relates generally to immunotherapy and specifically to vaccines and methods for treating or preventing neoplastic disorders.

BACKGROUND OF THE INVENTION

Cancer is a leading cause of mortality worldwide. Traditional regimens of cancer management have been successful in the management of a selective group of circulating and solid cancers. However, many tumors are resistant to traditional approaches. In recent years, immunotherapy for the treatment of cancers has been explored, which involves the generation of an active systemic tumor-specific immune response of host origin by administering a vaccine composition at a site distant from the tumor. Various types of vaccines have been proposed, including those containing isolated tumor-associated antigens.

Prostate cancer is the second most commonly diagnosed cancer and the fourth leading cause of cancer-related death in men in the developed countries worldwide. Various prostate-associated antigens (PAA), such as prostate-specific antigen (PSA), prostate-specific membrane antigen (PSMA), and prostate stem cell antigen (PSCA) have been shown to be overexpressed by prostate cancer cells as compared to normal counterparts. These antigens, therefore, represent possible targets for inducing specific immune responses against cancers expressing the antigens via the use of vaccine-based immunotherapy. (see e.g. Marrari, A., M. Iero, et al. (2007). "Vaccination therapy in prostate cancer." Cancer Immunol Immunother 56(4): 429-45.)

PSCA is a 123-amino acid membrane protein. The amino acid sequence of the full length human PSCA consists of amino acids 4-123 of SEQ ID NO:21. PSCA has

high tissue specificity and is expressed on more than 85% of prostate cancer specimens, with expression levels increasing with higher Gleason scores and androgen independence. It is expressed in 80-100% of bone metastasis of prostate cancer patients.

PSA is a kallikrein-like serine protease that is produced exclusively by the columnar epithelial cells lining the acini and ducts of the prostate gland. PSA mRNA is translated as an inactive 261-amino acid preproPSA precursor. PreproPSA has 24 additional residues that constitute the pre-region (the signal polypeptide) and the propolypeptide. Release of the propolypeptide results in the 237- amino acid, mature extracellular form, which is enzymatically active. The amino acid sequence of the human full length PSA is provided in SEQ ID NO: 15. PSA is organ-specific and, as a result, it is produced by the epithelial cells of benign prostatic hyperplastic (BPH) tissue, primary prostate cancer tissue, and metastatic prostate cancer tissue.

PSMA, also known as Folate hydrolase 1 (FOLH1), is composed of 750 amino acids. The amino acid sequence of the human full length PSMA is provided in SEQ ID NO:1. PSMA includes a cytoplasmic domain (amino acids 1-19), a transmembrane domain (amino acids 20 - 43), and an extracellular domain (amino acids 44-750). PSMA is a type II dimeric transmembrane protein expressed on the surface of prostate cancer cells and on neovasculature. It is also expressed on normal prostate cells, brain, salivary gland and biliary tree. However, in prostate cancer cells it was found to be expressed at 1000-fold higher levels than normal tissues. It is abundantly expressed on neovasculature of a variety of other solid tumors such as colon, breast, liver, bladder, pancreas, lung, renal cancers as well as melanoma and sarcomas. Thus, PSMA is considered a target not only specific for prostate cancer cells but also a pan-carcinoma target for other cancers. The expression of PSMA appears to be a universal feature of prostate carcinomas and its increased expression correlates with tumor aggressiveness. PSMA expression is highest in high-grade tumors, metastatic lesions and androgen-independent disease.

While a large number of tumor-associated antigens have been identified and many of these antigens have been explored as protein-based or DNA-based vaccines for the treatment or prevention of cancers, most clinical trials so far have failed to produce a therapeutic product. One of the challenges in developing cancer vaccines resides in the fact that the cancer antigens are usually self-derived and, therefore, poorly immunogenic because the immune system is self-regulated not to recognize self-

proteins. Accordingly, a need exists for a method to enhance the immunogenicity or therapeutic effect of cancer vaccines.

Numerous approaches have been explored for enhancing the immunogenicity or enhancing anti-tumor efficacy of cancer vaccines. One of such approach involves the use of various immune modulators, such as TLR agonists, TNFR agonists, CTLA-4 inhibitors, and protein kinase inhibitors.

Toll-like receptors (TLRs) are type 1 membrane receptors that are expressed on hematopoietic and non-hematopoietic cells. At least 11 members have been identified in the TLR family. These receptors are characterized by their capacity to recognize pathogen-associated molecular patterns (PAMP) expressed by pathogenic organisms. It has been found that triggering of TLR elicits profound inflammatory responses through enhanced cytokine production, chemokine receptor expression (CCR2, CCR5 and CCR7), and costimulatory molecule expression. As such, these receptors in the innate immune systems exert control over the polarity of the ensuing acquired immune response. Among the TLRs, TLR9 has been extensively investigated for its functions in immune responses. Stimulation of the TLR9 receptor directs antigen-presenting cells (APCs) towards priming potent, T_H1-dominated T-cell responses, by increasing the production of pro-inflammatory cytokines and the presentation of co-stimulatory molecules to T cells. CpG oligonucleotides, ligands for TLR9, were found to be a class of potent immunostimulatory factors. CpG therapy has been tested against a wide variety of tumor models in mice, and has consistently been shown to promote tumor inhibition or regression.

Cytotoxic T-Lymphocyte Antigen 4 (CTLA-4) is a member of the immunoglobulin superfamily and is expressed on the surface of Helper T cells. CTLA-4 is a negative regulator of CD28 dependent T cell activation, and acts as an inhibitory checkpoint for the adaptive immune response. Similar to the T-cell costimulatory protein CD28, CTLA-4 binds to CD80 and CD86 on antigen-presenting cells. CTLA-4 transmits an inhibitory signal to T cells, whereas CD28 transmits a stimulatory signal. Human antibodies against human CTLA-4 have been described as immunostimulation modulators in a number of disease conditions, such as treating or preventing viral and bacterial infection and for treating cancer (WO 01/14424 and WO 00/37504). Various preclinical studies have shown that CTLA-4 blockade by monoclonal antibodies enhances the host immune response against immunogenic tumors, and can even reject established tumors. Two fully human anti-human CTLA-4 monoclonal antibodies (mAbs), ipilimumab (MDX-

010) and Tremelimumab (also known as CP-675206), have been investigated in clinical trials in the treatment of various types of solid tumors.

The tumor necrosis factor (TNF) superfamily is a group of cytokines that engage specific cognate cell surface receptors, the TNF receptor (TNFR) superfamily. Members of the tumor necrosis factor superfamily act through ligand-mediated trimerization, causing recruitment of several intracellular adaptors to activate multiple signal transduction pathways, such as apoptosis, NF-kB pathway, JNK pathway, as well as immune and inflammatory responses. Examples of the TNF Superfamily include CD40 ligands, OX40 ligands, 4-1BB ligands, CD27, CD30 ligand (CD153), TNF- alpha, TNF-beta, RANK ligands, LT- alpha, LT- beta, GITR ligands, and LIGHT. The TNFR Superfamily includes, for example, CD40, OX40, 4-1BB, CD70 (CD27 ligand), CD30, TNFR2, RANK, LT- beta R, HVEM, GITR, TROY, and RELT. CD40 is found on the surface of B lymphocytes, dendritic cells, follicular dendritic cells, hematopoietic progenitor cells, epithelial cells, and carcinomas. CD40 binds to a ligand (CD40-L), which is a glycoprotein and expressed on activated T cells, mostly CD4+ but also some CD8+ as well as basophils/mast cells. Because of the role of CD40 in innate and adaptive immune responses, CD40 agonists, including various CD40 agonistic antibodies, such as the fully human agonist CD40 monoclonal antibody CP870893, have been explored for usage as vaccine adjuvants and in therapies.

Protein kinases are a family of enzymes that catalyze the phosphorylation of specific residues in proteins. Protein kinases are key elements in signal transduction pathways responsible for transducing extracellular signals, including the action of cytokines on their receptors, to the nuclei, triggering various biological events. The many roles of protein kinases in normal cell physiology include cell cycle control and cell growth, differentiation, apoptosis, cell mobility and mitogenesis. Kinases such as c-Src, c-Abl, mitogen activated protein (MAP) kinase, phosphotidylinositol-3-kinase (PI3K) AKT, and the epidermal growth factor (EGF) receptor are commonly activated in cancer cells, and are known to contribute to tumorigenesis. Logically, a number of kinase inhibitors are currently being developed for anti-cancer therapy, in particular tyrosine kinase inhibitors (TKIs): cyclin-dependent kinase inhibitors, aurora kinase inhibitors, cell cycle checkpoint inhibitors, epidermal growth factor receptor (EGFR) inhibitors, FMS-like tyrosine kinase inhibitors, platelet-derived growth factor receptor (PDGFR) inhibitors, kinase insert domain inhibitors, inhibitors targeting the PI3K/Akt/mTOR pathway, inhibitors targeting the Ras-Raf-MEK-ERK (ERK) pathway, vascular endothelial growth factor receptor (VEGFR) kinase inhibitors, c-kit inhibitors and serine/threonine kinase

inhibitors. A number of kinase inhibitors have been investigated in clinical investigation for use in anti-cancer therapies, which includes, for example, MK0457, VX-680, ZD6474, MLN8054, AZD2171, SNS-032, PTK787/ZK222584, Sorafenib (BAY43-9006), SU5416, SU6668 AMG706, Zactima (ZD6474), MP-412, Dasatinib, CEP-701, (Lestaurtinib), XL647, XL999, Tykerb, (Lapatinib), MLN518, (formerly known as CT53518), PKC412, ST1571, AMN107, AEE 788, OSI-930, OSI-817, Sunitinib malate (Sutent; SU11248), Vatalanib (PTK787/ZK 222584), SNS-032, SNS-314 and Axitinib (AG-013736). Gefitinib and Erlotinib are two orally available EGFR-TKIs.

The immune modulators that have been explored are typically administered systemically to the patients, for example, by oral administration, intravenous injection or infusion, or intramuscular injection. One major factor that limits the effective use of some of the immune modulators is toxicity caused by high systemic exposure to the administered agents. For example, with respect to CD40 agonists, it has been reported that 0.3 mg/kg is the maximum tolerated dose for an exemplified agonistic CD40 antibody and that higher doses may elicit side effects including venous thromboembolism, grade 3 headache, cytokine release resulting in toxic effects such as chills and the like, and transient liver toxicity. (Vanderheide et al., J Clin. Oncol. 25(7): 876-8833 (March 2007). In a clinical trial to investigate combinations of intravenous Tremelimumab (an anti-CTLA-4 antibody) plus oral sunitinib in patients with metastatic renal cell carcinoma, rapid onset of renal failure was observed and, as a result, further investigation of Tremelimumab at doses higher than 6 mg/kg plus sunitinib at 37.5 mg daily was not recommended. See: Brian I. Rini et al.: Phase 1 Dose-Escalation Trial of Tremelimumab Plus Sunitinib in Patients With Metastatic Renal Cell Carcinoma. Cancer 117(4):758-767 (2011)]. Therefore, there is a need for vaccine-based immunotherapy regimens where the immune modulators are administered at effective doses which do not elicit severe adverse side effects such as liver toxicity or renal failure.

SUMMARY OF THE INVENTION

In some aspects, the present disclosure provides isolated immunogenic PSMA polypeptides and immunogenic PSA polypeptides, which are useful, for example, for eliciting an immune response *in vivo* (e.g. in an animal, including humans) or *in vitro*, generating antibodies, or for use as a component in vaccines for treating cancers, including prostate cancer. In one aspect, the present disclosure provides isolated immunogenic PSMA polypeptides which have at least 90% identity to amino acids 15-750 of the human PSMA of SEQ ID NO:1 and comprise the amino acids of at least 10,

11, 12, 13 ,14, 15, 16, 17, 18, or 19 of the conserved T cell epitopes of the human PSMA at corresponding positions.

In other aspects, the present disclosure provides nucleic acid molecules that encode immunogenic PAA polypeptides. In some embodiments, the present disclosure provides isolated nucleic acid molecules, or degenerate variants thereof, which comprise a nucleotide sequence encoding an immunogenic PSMA polypeptide, or a functional variant of said polypeptide, provided by the present disclosure.

In some other aspects, the present disclosure provides multi-antigen nucleic acid constructs that each encode two or more immunogenic PAA polypeptides.

The disclosure also provides vectors containing one or more nucleic acid molecules of the invention. The vectors are useful for cloning or expressing the immunogenic PAA polypeptides encoded by the nucleic acid molecules, or for delivering the nucleic acid molecules in a composition, such as a vaccine, to a host cell or to a host animal, such as a human.

In some further aspects, the present disclosure provides compositions comprising one or more immunogenic PAA polypeptides, isolated nucleic acid molecules encoding immunogenic PAA polypeptides, or vectors or plasmids containing nucleic acid molecules encoding immunogenic PAA polypeptides. In some embodiments, the composition is an immunogenic composition useful for eliciting an immune response against a PAA in a mammal, such as a mouse, dog, monkey, or human. In some embodiments, the composition is a vaccine composition useful for immunization of a mammal, such as a human, for inhibiting abnormal cell proliferation, for providing protection against the development of cancer (used as a prophylactic), or for treatment of disorders (used as a therapeutic) associated with PAA over-expression, such as cancer, particularly prostate cancer.

In still other aspects, the present disclosure provides methods of using the immunogenic PAA polypeptides, isolated nucleic acid molecules, and compositions comprising an immunogenic PAA polypeptide or isolated nucleic acid molecules described herein above. In some embodiments, the present disclosure provides a method of eliciting an immune response against a PAA in a mammal, particularly a human, comprising administering to the mammal an effective amount of a polypeptide provided by the invention that is immunogenic against the target PAA, an effective amount of an isolated nucleic acid molecule encoding such an immunogenic polypeptide, or a composition comprising such an immunogenic PAA polypeptide or an isolated

nucleic acid molecule encoding such an immunogenic PAA polypeptide. The polypeptide or nucleic acid vaccines may be used together with one or more adjuvants.

In yet other aspects, the present disclosure provides vaccine-based immunotherapy regimens (or "VBIR") that involve co-administration of a vaccine delivering various tumor associated antigens (TAAs) for inducing TAA specific immune responses to treat a variety of cancers in combination with at least one immune-suppressive-cell inhibitor and at least one immune-effector-cell enhancer. Specifically, in some aspects, the disclosure provides a method of enhancing the immunogenicity or therapeutic effect of a vaccine for the treatment of a neoplastic disorder in a mammal, comprising administering to the mammal receiving the vaccine an effective amount of at least one immune-suppressive-cell inhibitor and at least one immune-effector-cell enhancer. In a further aspect, the disclosure provides a method of treating a neoplastic disorder in a mammal, comprising administering to the mammal a vaccine, at least one immune-suppressive-cell inhibitor, and at least one immune-effector-cell enhancer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1. Schematic illustration of PJV7563 vector.

FIG. 2. Amino acid alignment of five viral 2A cassettes. The skipped glycine-proline bonds are indicated by asterisks.

FIG. 3. Sequence of the preferred EMCV IRES. The translation initiation site is indicated by the asterisk. The minimal IRES element excludes the underlined first 5 codons of the EMCV L protein.

FIG. 4. Dot plots showing expression of the human PSMA modified antigen (amino acids 15-750) and full length human PSCA on the surface of HEK293 cells transfected with dual antigen vaccine constructs as measured by flow cytometry.

FIG. 5. Image of Western blots showing expression of the human PSMA modified antigen (amino acids 15-750) and full length human PSCA in HEK293 cells transfected with dual antigen vaccine constructs as measured by western blotting with PSMA and PSCA specific monoclonal antibodies.

FIG. 6. Image of Western blots showing expression of human PSA cytosolic antigen (amino acids 25-261) in HEK293 cells transfected with dual antigen vaccine constructs as measured by western blotting with a PSA specific monoclonal antibody. Lane 5300 exhibited a faint band about 2kD larger than PSA, consistent with a C-terminal fusion of the 2A peptide.

FIGS. 7A, 7B. Dot plots showing expression of human PSMA modified antigen (amino acids 15-750) and full length human PSCA on the surface of HEK293 cells

transfected with triple antigen vaccine constructs as measured by flow cytometry. (FIG. 7A. Single antigen controls and single promoter triple antigen constructs. FIG. 7B. Dual promoter triple antigen constructs.)

FIGS. 8A, 8B. Images of Western blots showing expression of human PSA in HEK293 cells transfected with triple antigen vaccine constructs as measured by western blotting with a PSA specific monoclonal antibody. The bands in lanes 5259 and 456 are spillover from lane 5297. Although not visible in the scanned gel, lanes 456, 457, and 458 exhibited a band about 2kD larger than PSA, consistent with a C-terminal fusion of the 2A peptide. (FIG. 8A. Single promoter triple antigen constructs. FIG. 8B. Dual promoter triple antigen constructs)

FIGS. 9A-9D. Graphs depicting results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by IFN-γ ELISPOT assay.

FIGS. 10A-10D. Graphs depicting results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by IFN-γ ELISPOT assay.

FIG. 11. Graph depicting results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSMA antibody titers.

FIG. 12. Graph depicting results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSCA antibody titers.

FIG. 13. Graph depicting results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSMA antibody cell-surface binding.

FIG. 14. Graph depicting results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSCA antibody cell-surface binding.

FIGS. 15A-15C. Graphs depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by IFN-γ ELISPOT assay.

FIGD. 16A-16C. Graphs depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by IFN-γ ELISPOT assay.

FIG. 17. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody titers.

FIG. 18. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody titers.

FIG. 19. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody cell-surface binding.

FIG. 20. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody cell-surface binding.

FIGS. 21A-21D. Graphs depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by IFN-γ ELISPOT assay.

FIG. 22. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody titers.

FIG. 23. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody titers.

FIG. 24. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody cell-surface binding.

FIG. 25. Graph depicting results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody cell-surface binding.

FIG. 26. Graph depicting results of a representative study to evaluate the T cell immune response elicited by human PSMA modified antigen (aa 15-750) versus full-length human PSMA (aa 1-750) in C57BL/6 mice.

FIGS. 27A, 27B. Graphs depicting results of a representative study to evaluate the T cell immune response of human PSMA modified antigen (aa 15-750) versus full-length human PSMA antigen (aa 1-750) in Pasteur (HLA-A2/DR1) transgenic mice by IFN-γ ELISPOT assay.

FIG. 28. Graph depicting results of a representative study that evaluates the immunogenicity of the human modified and full-length PSMA vaccines by anti-PSMA antibody titers.

FIG. 29. Graph depicting results of a representative study that evaluates the immunogenicity of the human modified and full-length PSMA vaccines by anti-PSMA antibody cell-surface binding.

FIG. 30. Graph depicting results of a representative study that evaluates the blood anti-CTLA-4 monoclonal antibody levels measured by competitive ELISA in Indian *Rhesus macaques* injected with anti-CTLA-4 (CP-675, 206) at 10 mg/kg.

FIGS. 31A and 31B. Graphs depicting results of a representative study that evaluates the immunomodulatory activity of anti-murine CTLA-4 monoclonal antibody (clone 9H10) on the quality of the vaccine induced immune responses by intracellular cytokine staining assay.

FIG. 32. Graph depicting results of a representative study that evaluates and compares the subcutaneous tumor growth rate upon treatment with sunitinib malate

(Sutent) as a monotherapy or in combination with a control (control) or a cancer vaccine (rHER2).

FIGS. 33A - 33D. Graphs showing Individual tumor growth rates of mice from a representative study that evaluates and compares the anti-tumor efficacy of sunitinib malate (Sutent) at 20mg/kg with control (control) or cancer vaccine (rHER2).

FIG. 34. Graph showing the Kaplan-Meier survival curves of the groups of mice from the study described in Figure 33 that evaluates the anti-tumor efficacy of sunitinib malate (Sutent) with the control (control) or cancer vaccine (rHER2) treated with sunitinib malate (Sutent) with control (control) or cancer vaccine (cancer).

FIGS. 35A, 35B. Graphs showing changes in myeloid derived suppressor cells (Gr1+CD11b+) and Treg containing CD25+CD4+ cells in the periphery blood from mice treated in Fig 33.

FIGS. 36A-36C. Graphs showing changes in total number of myeloid derived suppressor cells (Gr1+CD11b+), Tregs (CD4+CD25+Foxp3+), and PD-1+ CD8 T cells isolated from tumors of mice.

FIG. 37. Graph showing the Kaplan-Meier survival curves of the groups of mice from a representative study evaluating the anti-tumor efficacy of sunitinib malate (Sutent) and anti-murine CTLA-4 monoclonal antibody (clone 9D9) in combination with a control (control) or cancer vaccine (vaccine) in subcutaneous TUBO tumor bearing BALB/neuT mice.

FIG. 38. Graph showing Kinetics of the blood sunitinib levels of BALB/neuT mice with subcutaneous TUBO tumors.

FIG. 39. Graph showing the Kaplan-Meier survival curves of the groups of mice from a representative study that evaluates the anti-tumor efficacy of BALB/neuT mice with subcutaneous TUBO tumors dosed with sunitinib malate (Sutent) and a control or cancer vaccine.

FIG. 40. Graph depicting the IFNγ ELISPOT results from groups of mice from a representative study evaluating the magnitude of antigen specific T cell responses induced by the rHER2 vaccine when given with the immune modulators.

FIGS. 41A, 41B. Graphs depicting results of a representative study that evaluates the immunomodulatory activity of CpG7909 (PF-03512676) on the quality of the vaccine induced immune responses by intracellular cytokine staining assay.

FIGS. 42A, 42B. Graphs depicting results of a representative study that evaluates the immunomodulatory activity of an agonistic anti-murine CD40 monoclonal antibody

on the quality of the vaccine induced immune responses by intracellular cytokine staining assay.

FIG. 43. Graph showing the Kaplan-Meier survival curves of the groups of mice from a representative study that evaluates the anti-tumor efficacy of low dose sunitinib malate (Sutent) and a control or cancer vaccine in spontaneous mammary tumor bearing BALB/neuT mice.

DETAILED DESCRIPTION OF THE INVENTION

A. DEFINITIONS

The term "adjuvant" refers to a substance that is capable of enhancing, accelerating, or prolonging an immune response when given with a vaccine immunogen.

The term "agonist" refers to is a substance which promotes (induces, causes, enhances or increases) the activity of another molecule or a receptor. The term agonist encompasses substances which bind receptor (e.g., an antibody, a homolog of a natural ligand from another species) and substances which promote receptor function without binding thereto (e.g., by activating an associated protein).

The term "antagonist" or "inhibitor" refers to a substance that partially or fully blocks, inhibits, or neutralizes a biological activity of another molecule or receptor.

The term "co-administration" refers to administration of two or more agents to the same subject during a treatment period. The two or more agents may be encompassed in a single formulation and thus be administered simultaneously. Alternatively, the two or more agents may be in separate physical formulations and administered separately, either sequentially or simultaneously to the subject. The term "administered simultaneously" or "simultaneous administration" means that the administration of the first agent and that of a second agent overlap in time with each other, while the term "administered sequentially" or "sequential administration" means that the administration of the first agent and that of a second agent does not overlap in time with each other.

The term "conserved T cell epitope" refers to one of the following amino acid sequences of the human PSMA protein as set forth in SEQ ID NO. 1:

amino acids 168-176 (GMPEGDLVY),

amino acids 347-356 (HSTNGVTRIY),

amino acids 557-566 (ETYELVEKFY),

amino acids 207-215 (KVFRGNKVK),

amino acids 431-440 (STEWAEENSR),

amino acids 4-12 (LLHETDSAV),

amino acids 27-35 (VLAGGFFLL),

amino acids 168-177 (GMPEGDLVYV),
amino acids 441-450 (LLQERGVAYI),
amino acids 469-477 (LMYSLVHNL),
amino acids 711-719 (ALFDIESKV),
amino acids 663-671 (MNDQVMFL),
amino acids 178-186 (NYARTEDFF),
amino acids, 227-235 (LYSDPADYF),
amino acids 624-632 (TYSVSFDSL),
amino acids 334-348 (TGNFSTQKVKMHIHS),
amino acids 459-473 (NYTLRVDCTPLMYSL),
amino acids 687-701(YRHVIYAPSSHNKYA), and
amino acids 730-744 (RQIYVAAFTVQAAAE).

The term “cytosolic” means that after a nucleotide sequence encoding a particular polypeptide is expressed by a host cell, the expressed polypeptide is retained inside the host cell.

The terms "degenerate variant" refers to DNA sequences that have substitutions of bases but encode the same polypeptide.

The term “effective amount” refers to an amount administered to a mammal that is sufficient to cause a desired effect in the mammal.

The term “fragment” of a given polypeptide refers to a polypeptide that is shorter than the given polypeptide and shares 100% identity with the sequence of the given polypeptide.

The term "identical" or percent "identity," in the context of two or more nucleic acid or polypeptide sequences, refers to two or more sequences or subsequences that are the same or have a specified percentage of amino acid residues or nucleotides that are the same, when compared and aligned for maximum correspondence.

The term "immune-effector-cell enhancer” or “IEC enhancer” refers to a substance capable of increasing or enhancing the number, quality, or function of one or more types of immune effector cells of a mammal. Examples of immune effector cells include cytolytic CD8 T cells, CD40 T cells, NK cells, and B cells.

The term "immune modulator" refers to a substance capable of altering (e.g., inhibiting, decreasing, increasing, enhancing or stimulating) the working of any component of the innate, humoral or cellular immune system of a mammal. Thus, the term “immune modulator” encompasses the “immune-effector-cell enhancer” as defined

herein and the "immune-suppressive-cell inhibitor" as defined herein, as well as substance that affects other components of the immune system of a mammal.

The term "immune response" refers to any detectable response to a particular substance (such as an antigen or immunogen) by the immune system of a host vertebrate animal, including, but not limited to, innate immune responses (e.g., activation of Toll receptor signaling cascade), cell-mediated immune responses (e.g., responses mediated by T cells, such as antigen-specific T cells, and non-specific cells of the immune system), and humoral immune responses (e.g., responses mediated by B cells, such as generation and secretion of antibodies into the plasma, lymph, and/or tissue fluids). Examples of immune responses include an alteration (e.g., increase) in Toll-like receptor activation, lymphokine (e.g., cytokine (e.g., Th1, Th2 or Th17 type cytokines) or chemokine) expression or secretion, macrophage activation, dendritic cell activation, T cell (e.g., CD4+ or CD8+ T cell) activation, NK cell activation, B cell activation (e.g., antibody generation and/or secretion), binding of an immunogen (e.g., antigen (e.g., immunogenic polypolypeptide)) to an MHC molecule, induction of a cytotoxic T lymphocyte ("CTL") response, induction of a B cell response (e.g., antibody production), and, expansion (e.g., growth of a population of cells) of cells of the immune system (e.g., T cells and B cells), and increased processing and presentation of antigen by antigen presenting cells. The term "immune response" also encompasses any detectable response to a particular substance (such as an antigen or immunogen) by one or more components of the immune system of a vertebrate animal *in vitro*.

The term "immunogenic" refers to the ability of a substance to cause, elicit, stimulate, or induce an immune response, or to improve, enhance, increase or prolong a pre-existing immune response, against a particular antigen, whether alone or when linked to a carrier, in the presence or absence of an adjuvant.

The term "immunogenic PSA polypeptide" refers to a polypeptide that is immunogenic against human PSA protein or against cells expressing human PSA protein.

The term "immunogenic PSCA polypeptide" refers to a polypeptide that is immunogenic against human PSCA protein or against cells expressing human PSCA protein.

The term "immunogenic PSMA polypeptide" refers to a polypeptide that is immunogenic against human PSMA protein or against cells expressing human PSMA protein.

The term "immunogenic PAA polypeptide" refers to an "immunogenic PSA polypeptide," an "immunogenic PSCA polypeptide," or an "immunogenic PSMA polypeptide" as defined herein above.

The term "immunogenic PSA nucleic acid molecule" refers to a nucleic acid molecule that encodes an immunogenic PSA polypeptide as defined herein.

The term "immunogenic PSCA nucleic acid molecule" refers to a nucleic acid molecule that encodes an "immunogenic PSCA polypeptide" as defined herein.

The term "immunogenic PSMA nucleic acid molecule" refers to a nucleic acid molecule that encodes an "immunogenic PSMA polypeptide" as defined herein.

The term "immunogenic PAA nucleic acid molecule" refers to a nucleic acid molecule that encodes an "immunogenic PSA polypeptide," an "immunogenic PSCA polypeptide," or an "immunogenic PSMA polypeptide" as defined herein above.

The term "immune-suppressive-cell inhibitor" or "ISC inhibitor" refers to a substance capable of reducing or suppressing the number or function of immune suppressive cells of a mammal. Examples of immune suppressive cells include regulatory T cells ("T regs"), myeloid-derived suppressor cells, and tumor-associated macrophages.

The term "intradermal administration," or "administered intradermally," in the context of administering a substance, such as a therapeutic agent or an immune modulator, to a mammal including a human, refers to the delivery of the substance into the dermis layer of the skin of the mammal. The skin of a mammal is composed of three layers - the epidermis, dermis, and subcutaneous layer. The epidermis is the relatively thin, tough, outer layer of the skin. Most of the cells in the epidermis are keratinocytes. The dermis, the skin's next layer, is a thick layer of fibrous and elastic tissue (made mostly of collagen, elastin, and fibrillin) that gives the skin its flexibility and strength. The dermis contains nerve endings, sweat glands and oil (sebaceous) glands, hair follicles, and blood vessels. The dermis varies in thickness depending on the location of the skin. In humans it is about 0.3 mm on the eyelid and about 3.0 mm on the back. The subcutaneous layer is made up of fat and connective tissue that houses larger blood vessels and nerves. The thickness of this layer varies throughout the body and from person to person. The term "intradermal administration" refers to delivery of a substance to the inside of the dermis layer. In contrast, "subcutaneous administration" refers to the administration of a substance into the subcutaneous layer and "topical administration" refers to the administration of a substance onto the surface of the skin.

The term "local administration" or "administered locally" encompasses "topical administration," "intradermal administration," and "subcutaneous administration," each as defined herein above. This term also encompasses "intratumoral administration," which refers to administration of a substance to the inside of a tumor. Local administration is intended to allow for high local concentrations around the site of administration for a period of time until systemic biodistribution has been achieved with of the administered substance, while "systemic administration" is intended for the administered substance to be absorbed into the blood and attain systemic exposure rapidly by being distributed through the circulatory system to organs or tissues throughout the body.

The term "mammal" refers to any animal species of the Mammalia class. Examples of mammals include: humans; non-human primates such as monkeys; laboratory animals such as rats, mice, guinea pigs; domestic animals such as cats, dogs, rabbits, cattle, sheep, goats, horses, and pigs; and captive wild animals such as lions, tigers, elephants, and the like.

The term "membrane-bound" means that after a nucleotide sequence encoding a particular polypeptide is expressed by a host cell, the expressed polypeptide is bound to, attached to, or otherwise associated with, the membrane of the cell.

The term "neoplastic disorder" refers to a condition in which cells proliferate at an abnormally high and uncontrolled rate, the rate exceeding and uncoordinated with that of the surrounding normal tissues. It usually results in a solid lesion or lump known as "tumor." This term encompasses benign and malignant neoplastic disorders. The term "malignant neoplastic disorder", which is used interchangeably with the term "cancer" in the present disclosure, refers to a neoplastic disorder characterized by the ability of the tumor cells to spread to other locations in the body (known as "metastasis"). The term "benign neoplastic disorder" refers to a neoplastic disorder in which the tumor cells lack the ability to metastasize.

The term "operably linked" refers to a juxtaposition wherein the components so described are in a relationship permitting them to function in their intended manner. A control sequence "operably linked" to a transgene is ligated in such a way that expression of the transgene is achieved under conditions compatible with the control sequences.

The term "ortholog" refers to genes in different species that are similar to each other and originated from a common ancestor.

The term “pharmaceutically acceptable excipient” refers to a substance in an immunogenic or vaccine composition, other than the active ingredients (e.g., the antigen, antigen-coding nucleic acid, immune modulator, or adjuvant) that is compatible with the active ingredients and does not cause significant untoward effect in subjects to whom it is administered.

The terms "peptide," "polypeptide," and "protein" are used interchangeably herein, and refer to a polymeric form of amino acids of any length, which can include coded and non-coded amino acids, chemically, or biochemically modified or derivatized amino acids, and polypeptides having modified polypeptide backbones.

The term “preventing” or “prevent” refers to (a) keeping a disorder from occurring or (b) delaying the onset of a disorder or onset of symptoms of a disorder.

The term “prostate-associated-antigen” (or PAA) refers to the TAA (as defined herein) that is specifically expressed on prostate tumor cells or expressed at a higher frequency or density by tumor cells than by non-tumor cells of the same tissue type. Examples of PAA include PSA, PSCA, and PSMA.

The term “secreted” in the context of a polypeptide means that after a nucleotide sequence encoding the polypeptide is expressed by a host cell, the expressed polypeptide is secreted outside of the host cell.

The term "suboptimal dose" when used to describe the amount of an immune modulator, such as a protein kinase inhibitor, refers to a dose of the immune modulator that is below the minimum amount required to produce the desired therapeutic effect for the disease being treated when the immune modulator is administered alone to a patient.

The term “treating,” “treatment,” or “treat” refers to abrogating a disorder, reducing the severity of a disorder, or reducing the severity or occurrence frequency of a symptom of a disorder.

The term "tumor-associated antigen" or "TAA" refers to an antigen which is specifically expressed by tumor cells or expressed at a higher frequency or density by tumor cells than by non-tumor cells of the same tissue type. Tumor-associated antigens may be antigens not normally expressed by the host; they may be mutated, truncated, misfolded, or otherwise abnormal manifestations of molecules normally expressed by the host; they may be identical to molecules normally expressed but expressed at abnormally high levels; or they may be expressed in a context or milieu that is abnormal. Tumor-associated antigens may be, for example, proteins or protein fragments, complex carbohydrates, gangliosides, haptens, nucleic acids, or any combination of these or other biological molecules.

The term "vaccine" refers to an immunogenic composition for administration to a mammal for eliciting an immune response against a particular antigen.

The term "variant" of a given polypeptide refers to a polypeptide that shares less than 100% but more than 80% identity to the amino acid sequence of that given polypeptide and exhibits at least some of the immunogenic activity of that given polypeptide.

The term "vector" refers to a nucleic acid molecule capable of transporting or transferring a foreign nucleic acid molecule. The term encompasses both expression vectors and transcription vectors. The term "expression vector" refers to a vector capable of expressing the insert in the target cell, and generally contain control sequences, such as enhancer, promoter, and terminator sequences, that drive expression of the insert. The term "transcription vector" refers to a vector capable of being transcribed but not translated. Transcription vectors are used to amplify their insert. The foreign nucleic acid molecule is referred to as "insert" or "transgene." A vector generally consists of an insert and a larger sequence that serves as the backbone of the vector. Based on the structure or origin of vectors, major types of vectors include plasmid vectors, cosmid vectors, phage vectors such as lambda phage, viral vectors such as adenovirus (Ad) vectors, and artificial chromosomes.

B. IMMUNOGENIC PROSTATE-ASSOCIATED-ANTIGEN (PAA) POLYPEPTIDES

In some aspects, the present disclosure provides isolated immunogenic PSA polypeptides and PSMA polypeptides, which are useful, for example, for eliciting an immune response *in vivo* (e.g. in an animal, including humans) or *in vitro*, activating effector T cells, or generating antibodies specific for PSA and PSMA, respectively, or for use as a component in vaccines for treating cancer, particularly prostate cancer. These polypeptides can be prepared by methods known in the art in light of the present disclosure. The capability of the polypeptides to elicit an immune response can be measured in *in vitro* assays or *in vivo* assays. *In vitro* assays for determining the capability of a polypeptide or DNA construct to elicit immune responses are known in the art. One example of such *in vitro* assays is to measure the capability of the polypeptide or nucleic acid expressing an polypeptide to stimulate T cell response as described in US Patent 7,387,882, the disclosure of which is incorporated in this application. The assay method comprises the steps of: (1) contacting antigen presenting cells in culture with an antigen thereby the antigen can be taken up and processed by the antigen presenting cells, producing one or more processed antigens; (2) contacting

the antigen presenting cells with T cells under conditions sufficient for the T cells to respond to one or more of the processed antigens; (3) determining whether the T cells respond to one or more of the processed antigens. The T cells used may be $CD8^+$ T cells or $CD4^+$ T cells. T cell response may be determined by measuring the release of one of more of cytokines, such as interferon-gamma and interleukin-2, lysis of the antigen presenting cells (tumor cells), and production of antibodies by B cells.

B-1. Immunogenic PSMA Polypeptides

In one aspect, the present disclosure provides isolated immunogenic PSMA polypeptides which have at least 90% identity to amino acids 15-750 of the human PSMA of SEQ ID NO:1 and comprise the amino acids of at least 10, 11, 12, 13 ,14, 15, 16, 17, 18, or 19 of the conserved T cell epitopes of the human PSMA at corresponding positions.

In some embodiments, the immunogenic PSMA polypeptides comprise at least 15, 16, 17, 18, or 19 of the conserved T cell epitopes of the human PSMA.

In some embodiments, the present disclosure provides an immunogenic PSMA polypeptide consisting of the amino acid sequence of SEQ ID NO:9, or an immunogenic PSMA polypeptide having 93% - 99%, 94% - 98%, or 94% - 97% identity to the amino acid sequence of SEQ ID NO:9.

Examples of some particular immunogenic PSMA polypeptides include:

1) a polypeptide consisting of amino acids 15-750 of SEQ ID NO: 1;

2) a polypeptide comprising the amino acids 4 -739 of SEQ ID NO: 3;

3) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO:5;

4) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO:7;

2) a polypeptide comprising the amino acid sequence of SEQ ID NO:3;

3) a polypeptide comprising the amino acid sequence of SEQ ID NO:5; and

4) a polypeptide comprising the amino acid sequence of SEQ ID NO:7.

In other embodiments, the present disclosure provides an immunogenic PSMA polypeptide selected from the group consisting of:

1) a polypeptide consisting of the amino acid sequence of SEQ ID NO:11

2) a polypeptide consisting of the amino acid sequence of SEQ ID NO:13; and

3) a polypeptide comprising the amino acid sequence of SEQ ID NO:13.

In some other embodiments, the present disclosure provides isolated immunogenic PSMA polypeptides that are variants of any of the following polypeptides:

2) a polypeptide comprising the amino acids 4 – 739 of SEQ ID NO: 3;

3) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO: 5; and

4) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO: 7,

wherein the amino acid sequence of the variant has 93% - 99% identity to the sequence of SEQ ID NO:1 and share at least 80%, at least 85%, at least 90%, at least 95%, or at least 99% identity with the amino acid sequence of SEQ ID NO: 3, 5, or 7.

The variants of a given PAA polypeptide can be obtained by deleting, inserting, or substituting one or more amino acids in the parent immunogenic PAA polypeptide. An example for the production of such variants is the conservative substitution of individual amino acids of the polypeptides, that is, by substituting one amino acid for another having similar properties.

An immunogenic PSMA polypeptide of the invention may be constructed by conserving some or all of the conserved T cell epitopes of the human PSMA of SEQ ID NO:1 while substituting certain amino acids in the remaining regions of the human PSMA with amino acids found in one or more orthologs of human PSMA at corresponding positions. Sequences of various PSMA orthologs that may be utilized to make the immunogenic PSMA polypeptides are available from the GeneBank database. These orthologs along with their NCBI ID numbers are provided in Table 18. Substitutions of amino acids of human PSMA with amino acids from one or more of the orthologs may be conservative substitutions or non-conservative substitutions, or both, and may be selected based on a number of factors known in the art, including the divergence needed to be achieved, MHC binding, the presence of ortholog amino acids at the site of substitution, surface exposure, and maintaining the 3-D structure of the protein for optimal processing and presentation.

B-2. Immunogenic PSA Polypeptides

In another aspect, the present disclosure provides isolated immunogenic PSA polypeptides. In one embodiment, the isolated immunogenic PSA polypeptide is a polypeptide consisting of the amino acid sequence of SEQ ID NO:15 or amino acids 4 – 263 of SEQ ID NO: 15, or a variant thereof. In another embodiment, the isolated immunogenic PSA polypeptide is a polypeptide consisting of the amino acid sequence of SEQ ID NO:17 or amino acids 4 – 240 of SEQ ID NO: 17, or a variant thereof. In a further embodiment, the isolated immunogenic PSA polypeptide is a polypeptide consisting of the amino acid sequence of SEQ ID NO:19 or amino acids 4 – 281 of SEQ ID NO: 19, or a variant thereof.

C. NUCLEIC ACID MOLECULES ENCODING IMMUNOGENIC PAA POLYPEPTIDES

In some aspects, the present disclosure provides nucleic acid molecules that encode immunogenic PAA polypeptides. The nucleic acid molecules can be deoxyribonucleotides (DNA) or ribonucleotides (RNA). Thus, a nucleic acid molecule can comprise a nucleotide sequence disclosed herein wherein thymidine (T) can also be uracil (U), which reflects the differences between the chemical structures of DNA and RNA. The nucleic acid molecules can be modified forms, single or double stranded forms, or linear or circular forms. The nucleic acid molecules can be prepared using methods known in the art light of the present disclosure.

C-1. Nucleic Acid Molecules Encoding Immunogenic PSMA Polypeptides

In one aspect, the present disclosure provides isolated nucleic acid molecules, or degenerate variants thereof, which comprise a nucleotide sequence encoding an immunogenic PSMA polypeptide, including the immunogenic PSMA polypeptides provided by the present disclosure or a functional variant thereof

In some embodiments, the nucleotide sequence encodes a membrane-bound immunogenic PSMA polypeptide. In some particular embodiments, the isolated nucleic acid molecule comprises a nucleotide sequence, or a degenerate variant thereof, selected from the group consisting of:

1) a nucleotide sequence encoding the amino acid sequence of SEQ ID NO:9;

2) a nucleotide sequence encoding amino acids 4- 739 of SEQ ID NO:3;

3) a nucleotide sequence encoding amino acids 4 -739 of SEQ ID NO:5; and

4) a nucleotide sequence encoding amino acids 4 – 739 of SEQ ID NO:7.

In some other particular embodiments, the nucleotide sequence encodes a variant of an immunogenic PSMA polypeptide of SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, or SEQ ID NO:9, wherein the variant has an amino acid sequence that has (a) 93% to 99% identity with the amino acid sequence of SEQ ID NO:1 and (b) at least 80%, at least 85%, at least 90%, at least 95%, or at least 99% identity with the amino acid sequence of SEQ ID NO: 3, 5, or 7.

In still some other particular embodiments, the isolated nucleic acid molecule comprises a nucleotide sequence, or a degenerate variant thereof, selected from the group consisting of:

1) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:4;

2) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:6;

3) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:8; and

4) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:10.

C-2. Nucleic Acid Molecules Encoding Immunogenic PSA Polypeptides

In another aspect, the present disclosure provides isolated nucleic acid molecules, or degenerate variants thereof, which encode an immunogenic PSA polypeptide, including the immunogenic PSA polypeptides provided by the present disclosure.

In some embodiments, the isolated nucleic acid molecule comprises or consists of a nucleotide sequence encoding a cytosolic immunogenic PSA polypeptide. In one embodiment, the nucleotide sequence encodes a cytosolic immunogenic PSA polypeptide consisting of consecutive amino acid residues 4 - 240 of SEQ ID NO:17. In another embodiment, the nucleotide sequence encodes a cytosolic immunogenic PSA polypeptide comprising the amino acid sequence of SEQ ID NO:17. In still another embodiment, the nucleotide sequence encodes a cytosolic immunogenic PSA polypeptide consisting of the amino acid sequence of SEQ ID NO:17. In yet another embodiment, the nucleotide sequence encodes a functional variant of any of said cytosolic immunogenic polypeptides provided herein above.

In some other embodiments, the isolated nucleic acid molecule comprises a nucleotide sequence encoding a membrane-bound immunogenic PSA polypeptide. In one embodiment, the nucleotide sequence encodes a membrane-bound immunogenic PSA polypeptide comprising consecutive amino acid residues 4 - 281 of SEQ ID NO:19. In another embodiment, the nucleotide sequence encodes a membrane-bound immunogenic PSA polypeptide comprising the amino acid sequence of SEQ ID NO:19. In still another embodiment, the nucleotide sequence encodes a membrane-bound immunogenic PSA polypeptide consisting of the amino acid sequence of SEQ ID NO:19. In yet other embodiments, the nucleotide sequence encodes a functional variant of any of said membrane-bound immunogenic PSA polypeptides provided herein above.

Examples of particular nucleic acid molecules provided by the present disclosure include:

1) a nucleic acid molecule consisting of the nucleotide sequence of SEQ ID NO: 18;

2) a nucleic acid molecule comprising the nucleotide sequence of SEQ ID NO; 18;

3) a nucleic acid molecule consisting of the nucleotide sequence of SEQ ID NO; 20;

4) a nucleic acid molecule comprising the nucleotide sequence of SEQ ID NO: 20; and

5) a degenerate variant of any of the nucleic acid molecules 1) – 4) above.

C-3. Nucleic Acid Molecules Encoding Two or More Immunogenic PAA Polypeptides

In another aspect, the present disclosure provides a nucleic acid molecule that encodes more than one immunogenic PAA polypeptide, for example at least two, at least three, or at least four immunogenic PAA polypeptides. Such nucleic acid molecules are also be referred to as "multi-antigen constructs," "multi-antigen vaccine," "multi-antigen plasmid," and the like, in the present disclosure. Thus, in some aspects, one nucleic acid molecule carries two coding nucleotide sequences wherein each of the coding nucleotide sequences expresses an individual immunogenic PAA polypeptide. Such a nucleic acid molecule is also referred to as "dual antigen construct," "dual antigen vaccine," or "dual antigen plasmid," etc., in this disclosure. In some other aspects, one nucleic acid molecule carries three coding nucleotide sequences wherein each of the coding nucleotide sequences expresses an individual immunogenic PAA polypeptide. Such a nucleic acid molecule is also referred to as "triple antigen construct," "triple antigen vaccine," or "triple antigen plasmid" in this disclosure. The individual PAA polypeptides encoded by a multi-antigen construct may be immunogenic against the same antigen, such as PSMA, PSA, or PSCA. The individual PAA polypeptides encoded by a multi-antigen construct may be immunogenic against different antigens, for example, one PAA polypeptide being a PSMA polypeptide and another one a PSA polypeptide. Specifically, one multi-antigen construct may encode two or more immunogenic PAA polypeptides in any one of the following combinations:

1) at least one immunogenic PSMA polypeptide and at least one immunogenic PSA polypeptide;

2) at least one immunogenic PSMA polypeptide and at least one PSCA polypeptide ;

3) at least one immunogenic PSA polypeptide and at least one PSCA polypeptide; and

4) at least one immunogenic PSMA polypeptide, at least one immunogenic PSA polypeptide, and at least one PSCA polypeptide.

The immunogenic PSMA polypeptides encoded by a multi-antigen construct may be either cytosolic, secreted, or membrane-bound, but preferably membrane-bound. Similarly, the immunogenic PSA polypeptide encoded by a multi-antigen construct may be either cytosolic, secreted, or membrane-bound, but preferably cytosolic.

In some embodiments, the present disclosure provides a multi-antigen construct that encodes at least one membrane-bound immunogenic PSMA polypeptide and at least one membrane-bound PSA polypeptide.

In some other embodiments, the present disclosure provides a multi-antigen construct that encodes at least one membrane-bound immunogenic PSMA polypeptide, at least one a cytosolic PSA polypeptide, and at least one PSCA polypeptide, wherein the at least one cytosolic PSA polypeptide comprises amino acids 4 - 240 of SEQ ID NO:17 and wherein the at least one immunogenic PSMA polypeptide is selected from the group consisting of:

1) a polypeptide comprising amino acids 15-750 of SEQ ID NO: 1;
2) a polypeptide comprising the amino acid sequence of SEQ ID NO:3;
3) a polypeptide comprising the amino acid sequence of SEQ ID NO:5;
4) a polypeptide comprising the amino acid sequence of SEQ ID NO:7;
5) a polypeptide comprising the amino acids 4 – 739 of SEQ ID NO:9;
6) a polypeptide comprising the amino acids 4 – 739 of SEQ ID NO:3;
7) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO:5;
8) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO:7; and
9) polypeptide comprising the amino acid sequence of SEQ ID NO: 9..

In some particular embodiments, the present disclosure provides a multi-antigen construct comprising at least one nucleotide sequence encoding an immunogenic PSMA polypeptide, at least one nucleotide sequence encoding an immunogenic PSA polypeptide, and at least one nucleotide sequence encoding the human PSCA polypeptide, wherein the nucleotide sequence encodes an immunogenic PSA polypeptide of SEQ ID NO: 17 or amino acids 4- 240 of SEQ ID NO: 17, and wherein the nucleotide sequence encoding the immunogenic PSMA polypeptide is selected from the group consisting of:

1) the nucleotide sequence of SEQ ID NO: 2;
2) the nucleotide sequence of SEQ ID NO:4;
3) the nucleotide sequence of SEQ ID NO:6;
4) the nucleotide sequence of SEQ ID NO:8;
5) the nucleotide sequence of SEQ ID NO:10;
6) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:4;
7) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:6;
8) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:8; and
9) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:10.

Examples of specific multi-antigen constructs provided by the present disclosure include the nucleic acid molecules that comprise a nucleotide sequence set forth in SEQ ID NOs:23 – 36.

Multi-antigen constructs provided by the present disclosure can be prepared using various techniques known in the art in light of the disclosure. For example, a multi-antigen construct can be constructed by incorporating multiple independent promoters into a single plasmid (Huang, Y., Z. Chen, et al. (2008). "Design, construction, and characterization of a dual-promoter multigenic DNA vaccine directed against an HIV-1 subtype C/B' recombinant." J Acquir Immune Defic Syndr 47(4): 403-411; Xu, K., Z. Y. Ling, et al. (2011). "Broad humoral and cellular immunity elicited by a bivalent DNA vaccine encoding HA and NP genes from an H5N1 virus." Viral Immunol 24(1): 45-56). The plasmid can be engineered to carry multiple expression cassettes, each consisting of a) a eukaryotic promoter for initiating RNA polymerase dependent transcription, with or without an enhancer element, b) a gene encoding a target antigen, and c) a transcription terminator sequence. Upon delivery of the plasmid to the transfected cell nucleus, transcription will be initiated from each promoter, resulting in the production of separate mRNAs, each encoding one of the target antigens. The mRNAs will be independently translated, thereby producing the desired antigens.

Multi-antigen constructs provided by the present disclosure can also be constructed using a single vector through the use of viral 2A-like polypeptides (Szymczak, A. L. and D. A. Vignali (2005). "Development of 2A peptide-based strategies in the design of multicistronic vectors." Expert Opin Biol Ther 5(5): 627-638; de Felipe, P., G. A. Luke, et al. (2006). "E unum pluribus: multiple proteins from a self-processing polyprotein." Trends Biotechnol 24(2): 68-75; Luke, G. A., P. de Felipe, et al. (2008). "Occurrence, function and evolutionary origins of '2A-like' sequences in virus genomes." J Gen Virol 89(Pt 4): 1036-1042; Ibrahimi, A., G. Vande Velde, et al. (2009). "Highly efficient multicistronic lentiviral vectors with peptide 2A sequences." Hum Gene Ther 20(8): 845-860; Kim, J. H., S. R. Lee, et al. (2011). "High cleavage efficiency of a 2A peptide derived from porcine teschovirus-1 in human cell lines, zebrafish and mice." PLoS One 6(4): e18556). These polypeptides, also called cleavage cassettes or CHYSELs (cis-acting hydrolase elements), are approximately 20 amino acids long with a highly conserved carboxy terminal D-V/I-EXNPGP motif (Figure 2). The cassettes are rare in nature, most commonly found in viruses such as Foot-and-mouth disease virus (FMDV), Equine rhinitis A virus (ERAV), Encephalomyocarditis virus (EMCV), Porcine teschovirus (PTV), and Thosea asigna virus (TAV) (Luke, G. A., P. de Felipe, et al.

(2008). "Occurrence, function and evolutionary origins of '2A-like' sequences in virus genomes." J Gen Virol 89(Pt 4): 1036-1042). With a 2A-based multi-antigen expression strategy, genes encoding multiple target antigens can be linked together in a single open reading frame, separated by 2A cassettes. The entire open reading frame can be cloned into a vector with a single promoter and terminator. Upon delivery of the constructs to a host cell, mRNA encoding the multiple antigens will be transcribed and translated as a single polyprotein. During translation of the 2A cassettes, ribosomes skip the bond between the C-terminal glycine and proline. The ribosomal skipping acts like a cotranslational autocatalytic "cleavage" that releases upstream from downstream proteins. The incorporation of a 2A cassette between two protein antigens results in the addition of ~20 amino acids onto the C-terminus of the upstream polypeptide and 1 amino acid (proline) to the N-terminus of downstream protein. In an adaptation of this methodology, protease cleavage sites can be incorporated at the N terminus of the 2A cassette such that ubiquitous proteases will cleave the cassette from the upstream protein (Fang, J., S. Yi, et al. (2007). "An antibody delivery system for regulated expression of therapeutic levels of monoclonal antibodies in vivo." Mol Ther 15(6): 1153-1159).

Another strategy for constructing the multi-antigen constructs provided by the present disclosure involves the use of an internal ribosomal entry site, or IRES. Internal ribosomal entry sites are RNA elements (Figure 3) found in the 5' untranslated regions of certain RNA molecules (Bonnal, S., C. Boutonnet, et al. (2003). "IRESdb: the Internal Ribosome Entry Site database." Nucleic Acids Res 31(1): 427-428). They attract eukaryotic ribosomes to the RNA to facilitate translation of downstream open reading frames. Unlike normal cellular 7-methylguanosine cap-dependent translation, IRES-mediated translation can initiate at AUG codons far within an RNA molecule. The highly efficient process can be exploited for use in multi-cistronic expression vectors (Bochkov, Y. A. and A. C. Palmenberg (2006). "Translational efficiency of EMCV IRES in bicistronic vectors is dependent upon IRES sequence and gene location." Biotechniques 41(3): 283-284, 286, 288). Typically, two transgenes are inserted into a vector between a promoter and transcription terminator as two separate open reading frames separated by an IRES. Upon delivery of the constructs to a host cell, a single long transcript encoding both transgenes will be transcribed. The first ORF will be translated in the traditional cap-dependent manner, terminating at a stop codon upstream of the IRES. The second ORF will be translated in a cap-independent manner using the IRES. In this

way, two independent proteins can be produced from a single mRNA transcribed from a vector with a single expression cassette.

Although the multi-antigen expression strategies are described here in the context of a DNA vaccine construct, the principles apply similarly in the context of viral vector genetic vaccines.

D. VECTORS CONTAINING A NUCLEIC ACID MOLECULE ENCODING AN IMMUNOGENIC PAA POLYPEPTIDE

Another aspect of the invention relates to vectors containing one or more nucleic acid molecules of the invention. The vectors are useful for cloning or expressing the immunogenic PAA polypeptides encoded by the nucleic acid molecules, or for delivering the nucleic acid molecule in a composition, such as a vaccine, to a host cell or to a host animal, such as a human. A wide variety of vectors may be prepared to contain and express a nucleic acid molecule of the invention, such as plasmid vectors, cosmid vectors, phage vectors, and viral vectors.

In some embodiments, the disclosure provides a plasmid-based vector containing a nucleic acid molecule of the invention. Representative examples of suitable plasmid vectors include pBR325, pUC18, pSKF, pET23D, and pGB-2. Other representative examples of plasmid vectors, as well as method of constructing such vectors, are described in U.S. Pat. Nos. 5,580,859, 5,589,466, 5,688,688, 5,814,482 and 5,580,859.

In other embodiments, the present invention provides vectors that are constructed from viruses, such as retroviruses, alphaviruses, adenoviruses. Representative examples of retroviral vectors are described in more detail in EP 0,415,731; PCT Publication Nos. WO 90/07936; WO 91/0285, WO 9311230; WO 9310218, WO 9403622; WO 9325698; WO 9325234; and U.S. Pat. Nos. 5,219,740, 5,716,613, 5,851,529, 5,591,624, 5,716,826, 5,716,832, and 5,817,491. Representative examples of vectors that can be generated from alphaviruses are described in U.S. Pat. Nos. 5,091,309 and 5,217,879, 5,843,723, and 5,789,245. In some particular embodiments, the present disclosure provides adenoviral vectors derived from non-human primate adenoviruses, such as simian adenoviruses. Examples of such adenoviral vectors, as well as their preparation, are described in PCT application publication WO2005/071093 and WO 2010/086189, and include non-replicating vectors such as ChAd3, ChAd4, ChAd5, ChAd7, ChAd8, ChAd9, ChAd10, ChAd11, ChAd16, ChAd17, ChAd19, ChAd20, ChAd22, ChAd24, ChAd26, ChAd30, ChAd31, ChAd37, ChAd38, ChAd44, ChAd63, ChAd68, ChAd82, ChAd55, ChAd73, ChAd83, ChAd146, ChAd147, PanAd1, Pan Ad2, and Pan Ad3, and replication-competent

vectors such as Ad4 and Ad7 vectors. It is preferred that in constructing the adenoviral vectors from the simian adenoviruses one or more of the early genes from the genomic region of the virus selected from E1A, E1B, E2A, E2B, E3, and E4 are either deleted or rendered non-functional by deletion or mutation. In a particular embodiment, the vector is constructed from ChAd3 or ChAd68. Suitable vectors can also be generated from other viruses such as: pox viruses, such as canary pox virus or vaccinia virus (Fisher-Hoch et al., PNAS 86:317-321, 1989; Flexner et al., Ann. N.Y. Acad. Sci. 569:86-103, 1989; Flexner et al., Vaccine 8:17-21, 1990; U.S. Pat. Nos. 4,603,112, 4,769,330 and 5,017,487; WO 89/01973); adeno-associated vectors (see, e.g., U.S. Pat. No. 5,872,005); SV40 (Mulligan et al., Nature 277:108-114, 1979); herpes (Kit, Adv. Exp. Med. Biol. 215:219-236, 1989; U.S. Pat. No. 5,288,641); and lentivirus such as HIV (Poznansky, J. Virol. 65:532-536, 1991).

Methods of constructing vectors are well known in the art. Expression vectors typically include one or more control elements that are operatively linked to the nucleic acid sequence to be expressed. The term "control elements" refers collectively to promoter regions, polyadenylation signals, transcription termination sequences, upstream regulatory domains, origins of replication, internal ribosome entry sites ("IRES"), enhancers, and the like, which collectively provide for the replication, transcription, and translation of a coding sequence in a recipient cell. Not all of these control elements need always be present so long as the selected coding sequence is capable of being replicated, transcribed, and translated in an appropriate host cell. The control elements are selected based on a number of factors known to those skilled in that art, such as the specific host cells and source or structures of other vector components, For enhancing the expression of an immunogenic PAA polypeptide, a Kozak sequence can be provided upstream of the sequence encoding the immunogenic PAA polypeptide. For vertebrates, a known Kozak sequence is (GCC)NCCATGG, wherein N is A or G and GCC is less conserved. Exemplary Kozak sequences that can be used include ACCAUGG and ACCATGG.

E. COMPOSITIONS COMPRISING AN IMMUNOGENIC PAA POLYPEPTIDE (POLYPEPTIDE COMPOSITIONS)

In another aspect, the present disclosure provides compositions comprising one or more isolated immunogenic PAA polypeptides provided by the present disclosure (“polypeptide composition”). In some embodiments, the polypeptide composition is an immunogenic composition useful for eliciting an immune response against a PAA protein in a mammal, such as a mouse, dog, nonhuman primates or human. In some

other embodiments, the polypeptide composition is a vaccine composition useful for immunization of a mammal, such as a human, for inhibiting abnormal cell proliferation, for providing protection against the development of cancer (used as a prophylactic), or for treatment of disorders (used as a therapeutic) associated with PAA over expression, such as cancers, particularly prostate cancer.

A polypeptide composition provided by the present disclosure may contain a single type of immunogenic PAA polypeptide, such an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, or an immunogenic PSCA polypeptide. A composition may also contain a combination of two or more different types of immunogenic PAA polypeptides. For example, a polypeptide composition may contain immunogenic PAA polypeptides in any of the following combinations:

1) an immunogenic PSMA polypeptide and an immunogenic PSA polypeptide;

2) an immunogenic PSMA polypeptide and a PSCA polypeptide; or

3) an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and a PSCA polypeptide.

An immunogenic composition or vaccine composition provided by the present disclosure may further comprise a pharmaceutically acceptable excipient. Pharmaceutically acceptable excipients for immunogenic or vaccine compositions are known in the art. Examples of suitable excipients include biocompatible oils, such as rape seed oil, sunflower oil, peanut oil, cotton seed oil, jojoba oil, squalan, squalene, physiological saline solution, preservatives and osmotic pressure controlling agents, carrier gases, pH-controlling agents, organic solvents, hydrophobic agents, enzyme inhibitors, water absorbing polymers, surfactants, absorption promoters, pH modifiers, and anti-oxidative agents.

The immunogenic PAA polypeptide in a composition, particularly an immunogenic composition or a vaccine composition, may be linked to, conjugated to, or otherwise incorporated into a carrier for administration to a recipient. The term “carrier” refers to a substance or structure that an immunogenic polypeptide can be attached to or otherwise associated with for delivery of the immunogenic polypeptide to the recipient (e.g., patient). The carrier itself may be immunogenic. Examples of carriers include immunogenic polypeptides, immune CpG islands, limpet hemocyanin (KLH), tetanus toxoid (TT), cholera toxin subunit B (CTB), bacteria or bacterial ghosts, liposome, chitosome, virosomes, microspheres, dendritic cells, or their like. One or more immunogenic PAA polypeptide molecules may be linked to a single carrier molecule. Methods for linking an immunogenic polypeptide to a carrier are known in the art,

A vaccine composition or immunogenic composition provided by the present disclosure may be used in conjunction with one or more immune modulators or adjuvants. The immune modulators or adjuvants may be formulated separately from the vaccine composition, or they may be part of the same vaccine composition formulation. Thus, in one embodiment, the vaccine composition further comprises one or more immune modulators or adjuvants. Examples of immune modulators and adjuvants are provided herein below.

The polypeptide compositions, including the immunogenic and vaccine compositions, can be prepared in any suitable dosage forms, such as liquid forms (e.g., solutions, suspensions, or emulsions) and solid forms (e.g., capsules, tablets, or powder), and by methods known to one skilled in the art.

F. COMPOSITIONS COMPRISING AN IMMUNOGENIC PAA NUCLEIC ACID MOLECULE (NUCLEIC ACID COMPOSITIONS)

The present disclosure also provides a composition comprising an isolated nucleic acid molecule or vector provided by the present disclosure (herein "nucleic acid composition'). The nucleic acid compositions are useful for eliciting an immune response against a PAA protein *in vitro* or *in vivo* in a mammal, including a human.

In some particular embodiments, the nucleic acid composition is a DNA vaccine composition for administration to humans for inhibiting abnormal cell proliferation, providing protection against the development of cancer (used as a prophylactic), or for treatment of cancer (used as a therapeutic) associated with PAA over–expression, or for eliciting an immune response to a particular human PAA, such as PSMA, PSA, and PSCA. The nucleic acid molecule in the composition may be a "naked" nucleic acid molecule, i.e. simply in the form of an isolated DNA free from elements that promote transfection or expression. Alternatively, the nucleic acid molecule in the composition can be incorporated into a vector.

A nucleic acid composition provided by the present disclosure may comprise individual isolated nucleic acid molecules that each encode only one type of immunogenic PAA polypeptide, such as an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, or an immunogenic PSCA polypeptide.

A nucleic acid composition may comprise a multi-antigen construct provided by the present disclosure that encodes two or more types of immunogenic PAA polypeptides. A multi-antigen construct may encode two or more immunogenic PAA polypeptides in any of the following combinations:

1) an immunogenic PSMA polypeptide and an immunogenic PSA polypeptide;

2) an immunogenic PSMA polypeptide and an immunogenic PSCA polypeptide;

3) an immunogenic PSA polypeptide and an immunogenic PSCA polypeptide; and

4) an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and an immunogenic PSCA polypeptide.

The nucleic acid compositions, including the DNA vaccine compositions, may further comprise a pharmaceutically acceptable excipient. Examples of suitable pharmaceutically acceptable excipients for nucleic acid compositions, including DNA vaccine compositions, are well known to those skilled in the art and include sugars, etc. Such excipients may be aqueous or non aqueous solutions, suspensions, and emulsions. Examples of non-aqueous excipients include propylene glycol, polyethylene glycol, vegetable oils such as olive oil, and injectable organic esters such as ethyl oleate. Examples of aqueous excipient include water, alcoholic/aqueous solutions, emulsions or suspensions, including saline and buffered media. Suitable excipients also include agents that assist in cellular uptake of the polynucleotide molecule. Examples of such agents are (i) chemicals that modify cellular permeability, such as bupivacaine, (ii) liposomes or viral particles for encapsulation of the polynucleotide, or (iii) cationic lipids or silica, gold, or tungsten microparticles which associate themselves with the polynucleotides. Anionic and neutral liposomes are well-known in the art (see, e.g., Liposomes: A Practical Approach, RPC New Ed, IRL press (1990), for a detailed description of methods for making liposomes) and are useful for delivering a large range of products, including polynucleotides. Cationic lipids are also known in the art and are commonly used for gene delivery. Such lipids include Lipofectin.TM. also known as DOTMA (N-[l-(2,3-dioleyloxy) propyls N,N, N-trimethylammonium chloride), DOTAP (1,2-bis (oleyloxy)-3 (trimethylammonio) propane), DDAB (dimethyldioctadecyl-ammonium bromide), DOGS (dioctadecylamidologlycyl spermine) and cholesterol derivatives such as DCChol (3 beta-(N-(N',N'-dimethyl aminomethane)-carbamoyl) cholesterol). A description of these cationic lipids can be found in EP 187,702, WO 90/11092, U.S. Pat. No. 5,283,185, WO 91/15501, WO 95/26356, and U.S. Pat. No. 5,527,928. A particular useful cationic lipid formulation that may be used with the nucleic vaccine provided by the disclosure is VAXFECTIN, which is a commixture of a cationic lipid (GAP-DMORIE) and a neutral phospholipid (DPyPE) which, when combined in an aqueous vehicle, self-assemble to form liposomes.

Cationic lipids for gene delivery are preferably used in association with a neutral lipid such as DOPE (dioleyl phosphatidylethanolamine), as described in WO 90/11092 as an

example. In addition, a DNA vaccine can also be formulated with a nonionic block copolymer such as CRL1005.

G. USES OF THE IMMUNOGENIC PAA POLYPEPTIDES, NUCLEIC ACID MOLECULES, AND COMPOSITIONS

In other aspects, the present disclosure provides methods of using the immunogenic PAA polypeptides, isolated nucleic acid molecules, and compositions comprising an immunogenic PAA polypeptide or isolated nucleic acid molecule described herein above.

In one aspect, the present disclosure provides a method of eliciting an immune response against a PAA in a mammal, particularly a human, comprising administering to the mammal an effective amount of (1) an immunogenic PAA polypeptide provided by the disclosure that is immunogenic against the target PAA, (2) an isolated nucleic acid molecule encoding such an immunogenic PAA polypeptide, (3) a composition comprising such an immunogenic PAA polypeptide, or (4) a composition comprising an isolated nucleic acid molecule encoding such an immunogenic PAA polypeptide.

In some embodiments, the disclosure provides a method of eliciting an immune response against PSMA in a human, comprising administering to the human an effective amount of an immunogenic PSMA composition provided by the present disclosure, wherein the immunogenic PSMA composition is selected from: (1) an immunogenic PSMA polypeptide, (2) an isolated nucleic acid molecule encoding an immunogenic PSMA polypeptide, (3) a composition comprising an immunogenic PSMA polypeptide, or (4) a composition comprising an isolated nucleic acid molecule encoding an immunogenic PSMA polypeptide.

In some other embodiments, the disclosure provides a method of eliciting an immune response against PSA in a human, comprising administering to the human an effective amount of an immunogenic PSA composition provided by the present disclosure, wherein the immunogenic PSA composition is selected from: (1) an immunogenic PSA polypeptide, (2) an isolated nucleic acid molecule encoding an immunogenic PSA polypeptide, (3) a composition comprising an immunogenic PSA polypeptide, or (4) a composition comprising an isolated nucleic acid molecule encoding an immunogenic PSA polypeptide.

In another aspect, the present disclosure provides a method of inhibiting abnormal cell proliferation in a human, wherein the abnormal cell proliferation is associated with over-expression of a PAA. The method comprises administering to the human an effective amount of immunogenic PAA composition provided by the present

disclosure that is immunogenic against the over-expressed PAA. The immunogenic PAA composition may be (1) an immunogenic PAA polypeptide, (2) an isolated nucleic acid molecule encoding one or more immunogenic PAA polypeptides, (3) a composition comprising an immunogenic PAA polypeptide, or (4) a composition comprising an isolated nucleic acid molecule encoding one or more immunogenic PAA polypeptides. In some embodiments, the method is for inhibiting abnormal cell proliferation in prostate in a human. In a particular embodiment, the present disclosure provide a method of inhibiting abnormal cell proliferation in prostate over-expressing PSMA, comprising administering to the human effective amount of (1) an immunogenic PSMA polypeptide, (2) an isolated nucleic acid molecule encoding one or more immunogenic PSMA polypeptides, (3) a composition comprising an immunogenic PSMA polypeptide, or (4) a composition comprising an isolated nucleic acid molecule encoding one or more immunogenic PSMA polypeptide.

In another aspect, the present disclosure provides a method of treating cancer in a human wherein cancer is associated with over-expression of a PAA. The method comprises administering to the human an effective amount of immunogenic PAA composition capable of eliciting an immune response against the over-expressed PAA. The immunogenic PAA composition may be (1) an immunogenic PAA polypeptide, (2) an isolated nucleic acid molecule encoding one or more immunogenic PAA polypeptides, (3) a composition comprising an immunogenic PAA polypeptide, or (4) a composition comprising an isolated nucleic acid molecule encoding one or more immunogenic PAA polypeptides. Examples of cancers that may be treated with the method include breast cancer, stomach cancer, ovarian cancer, lung cancer, bladder cancer, colorectal cancer, renal cancer, pancreatic cancer and prostate cancer.

In some embodiments, the disclosure provides a method of treating prostate cancer in a human, comprising administering to the human an effective amount of a nucleic acid composition provided herein above. The nucleic acids in the composition may encode only one particular immunogenic PAA polypeptide, such an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, or an immunogenic PSCA polypeptide. The nucleic acids in the composition may also encode two or more different immunogenic PAA polypeptides, such as: (1) an immunogenic PSMA polypeptide and an immunogenic PSA polypeptide; (2) an immunogenic PSMA polypeptide and an immunogenic PSCA polypeptide; (3) an immunogenic PSA polypeptide and an immunogenic PSCA polypeptide; (4) an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and an immunogenic PSCA polypeptide. Each

individual nucleic acid molecule in the composition may encode only one particular immunogenic PAA polypeptide, such as a PSMA polypeptide, a PSA polypeptide, or a PSCA polypeptide. Alternatively, an individual nucleic acid molecule in the composition may be a multi-antigen constructs encoding two different types of immunogenic PAA polypeptides, such as: (1) an immunogenic PSMA polypeptide and an immunogenic PSA polypeptide; (2) an immunogenic PSMA polypeptide and an immunogenic PSCA polypeptide; (3) an immunogenic PSCA polypeptide and an immunogenic PSA polypeptide; or (4) an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and an immunogenic PSCA polypeptide. In some particular embodiments, the nucleic acid composition comprises a multi-antigen construct that encode at least (4) an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and an immunogenic PSCA polypeptide. The immunogenic PSCA polypeptide contained in vaccine compositions or expressed by a nucleic acid in vaccine compositions for the treatment of prostate cancer in human is preferably the human full length PSCA protein.

The polypeptide and nucleic acid compositions can be administered to an animal, including human, by a number of methods known in the art. Examples of suitable methods include: (1) intramuscular, intradermal, intraepidermal, intravenous, intraarterial, subcutaneous, or intraperitoneal administration, (2) oral administration, and (3) topical application (such as ocular, intranasal, and intravaginal application). One particular method of intradermal or intraepidermal administration of a nucleic acid vaccine composition that may be used is gene gun delivery using the Particle Mediated Epidermal Delivery (PMED^{TM}) vaccine delivery device marketed by PowderMed. PMED is a needle-free method of administering vaccines to animals or humans. The PMED system involves the precipitation of DNA onto microscopic gold particles that are then propelled by helium gas into the epidermis. The DNA-coated gold particles are delivered to the APCs and keratinocytes of the epidermis, and once inside the nuclei of these cells , the DNA elutes off the gold and becomes transcriptionally active, producing encoded protein. This protein is then presented by the APCs to the lymphocytes to induce a T-cell-mediated immune response. Another particular method for intramuscular administration of a nucleic acid vaccine provided by the present disclosure is electroporation. Electroporation uses controlled electrical pulses to create temporary pores in the cell membrane, which facilitates cellular uptake of the nucleic acid vaccine injected into the muscle. Where a CpG is used in combination with a nucleic acid vaccine, it is preferred that the CpG and nucleic acid vaccine are co-formulated in one formulation and the formulation is administered intramuscularly by electroporation.

The effective amount of the immunogenic PAA polypeptide or nucleic acid encoding an immunogenic PAA polypeptide in the composition to be administered in a given method provided by the present disclosure can be readily determined by a person skilled in the art and will depend on a number of factors. In a method of treating cancer, such as prostate cancer, factors that may be considered in determining the effective amount of the immunogenic PAA polypeptide or nucleic acid include, but not limited: (1) the subject to be treated, including the subject's immune status and health, (2) the severity or stage of the cancer to be treated, (3) the specific immunogenic PAA polypeptides used or expressed, (4) the degree of protection or treatment desired, (5) the administration method and schedule, and (6) other therapeutic agents (such as adjuvants or immune modulators) used. In the case of nucleic acid vaccine compositions, including the multi-antigen vaccine compositions, the method of formulation and delivery are among the key factors for determining the dose of the nucleic acid required to elicit an effective immune response. For example, the effective amounts of the nucleic acid may be in the range of 2 μg/dose – 10 mg/dose when the nucleic acid vaccine composition is formulated as an aqueous solution and administered by hypodermic needle injection or pneumatic injection, whereas only 16 ng/dose – 16 μg/dose may be required when the nucleic acid is prepared as coated gold beads and delivered using a gene gun technology. The dose range for a nucleic acid vaccine by electroporation is generally in the range of 0.5 – 10 mg/dose. In the case where the nucleic acid vaccine is administered together with a CpG by electroporation in a co-formulation, the dose of the nucleic acid vaccine may be in the range of 0.5 – 5 mg/dose and the dose of CpG is typically in the range of 0.05 mg – 5 mg/dose, such as 0.05, 0.2, 0.6, or 1.2 mg/dose per person.

The nucleic acid or polypeptide vaccine composition of the present invention can be used in a prime-boost strategy to induce robust and long-lasting immune response. Priming and boosting vaccination protocols based on repeated injections of the same immunogenic construct are well known. In general, the first dose may not produce protective immunity, but only "primes" the immune system. A protective immune response develops after the second or third dose (the "boosts). The boosts are performed according to conventional techniques, and can be further optimized empirically in terms of schedule of administration, route of administration, choice of adjuvant, dose, and potential sequence when administered with another vaccine. In one embodiment, the nucleic acid or polypeptide vaccines of the present invention are used in a conventional homologous prime-boost strategy, in which the same vaccine is

administered to the animal in multiple doses. In another embodiment, the nucleic acid or polypeptide vaccine compositions are used in a heterologous prime-boost vaccination, in which different types of vaccines containing the same antigens are administered at predetermined time intervals. For example, a nucleic acid construct may be administered in the form of a plasmid in the initial dose ("prime") and as part of a vector in the subsequent doses ("boosts"), or vice versa.

For the treatment of prostate cancer, the polypeptide or nucleic acid vaccines of the present invention may be used together with prostate cancer vaccines based on other antigens, such as prostatic acid phosphatase-based antigens and androgen receptor.

The polypeptide or nucleic acid vaccine composition of the present invention may be used together with one or more adjuvants. Examples of suitable adjuvants include: (1) oil-in-water emulsion formulations (with or without other specific immunostimulating agents such as muramyl polypeptides or bacterial cell wall components), such as for example (a) MF59™ (PCT Publication No. WO 90/14837; Chapter 10 in *Vaccine design: the subunit and adjuvant approach,* eds. Powell & Newman, Plenum Press 1995), containing 5% Squalene, 0.5% Tween 80 (polyoxyethylene sorbitan mono-oleate), and 0.5% Span 85 (sorbitan trioleate) formulated into submicron particles using a microfluidizer, (b) SAF, containing 10% Squalene, 0.4% Tween 80, 5% pluronic-blocked polymer L121, and thr-MDP either microfluidized into a submicron emulsion or vortexed to generate a larger particle size emulsion, and (c) RIBI™ adjuvant system (RAS) (Ribi Immunochem, Hamilton, MT) containing 2% Squalene, 0.2% Tween 80, and one or more bacterial cell wall components such as monophosphorylipid A (MPL), trehalose dimycolate (TDM), and cell wall skeleton (CWS); (2) saponin adjuvants, such as QS21, STIMULON™ (Cambridge Bioscience, Worcester, MA), Abisco® (Isconova, Sweden), or Iscomatrix® (Commonwealth Serum Laboratories, Australia); (3) Complete Freund's Adjuvant (CFA) and Incomplete Freund's Adjuvant (IFA); (4) cytokines, such as interleukins *(e.g.* IL-1, IL-2, IL-4, IL-5, IL-6, IL-7, IL-12 (PCT Publication No. WO 99/44636), *etc.),* interferons *(e.g.* gamma interferon), macrophage colony stimulating factor (M-CSF), tumor necrosis factor (TNF), *etc.;* (5) monophosphoryl lipid A (MPL) or 3-O-deacylated MPL (3dMPL), optionally in the substantial absence of alum when used with pneumococcal saccharides (*e.g.* GB-2220221, EP-A-0689454, WO 00/56358); (6) combinations of 3dMPL with, for example, QS21 and/or oil-in-water emulsions (*e.g.* EP-A-0835318, EP-A-0735898, EP-A-0761231); (7) oligonucleotides comprising CpG motifs , *i.e.* containing at least one CG dinucleotide, where the cytosine is unmethylated

(e.g., Krieg, *Vaccine* (2000) 19:618-622; Krieg, *Curr Opin Mol Ther* (2001) 3:15-24; WO 98/40100, WO 98/55495, WO 98/37919 and WO 98/52581); (8) a polyoxyethylene ether or a polyoxyethylene ester (*e.g.* WO 99/52549); (9) a polyoxyethylene sorbitan ester surfactant in combination with an octoxynol (e.g., WO 01/21207) or a polyoxyethylene alkyl ether or ester surfactant in combination with at least one additional non-ionic surfactant such as an octoxynol (e.g., WO 01/21152); (10) a saponin and an immunostimulatory oligonucleotide *(e.g.* a CpG oligonucleotide) (e.g., WO 00/62800); (11) metal salt including aluminum salts (such as alum, aluminum phosphate, aluminum hydroxide); (12) a saponin and an oil-in-water emulsion (*e.g.* WO 99/11241); (13) a saponin *(e.g.* QS21) + 3dMPL + IM2 (optionally + a sterol)(*e.g.* WO 98/57659); (14) other substances that act as immunostimulating agents to enhance the efficacy of the composition, such as Muramyl polypeptides including N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP), N-25 acetyl-normuramyl-L-alanyl-D-isoglutamine (nor-MDP), N-acetylmuramyl-L-alanyl-D-isoglutarninyl-L-alanine-2-(1'-2'-dipalmitoyl-*sn*-glycero-3-hydroxyphosphoryloxy)-ethylamine MTP-PE), (15) ligands for toll-like receptors (TLR), natural or synthesized (e.g. Kanzler et al., *Nature Med.* 13:1552-1559 (2007)), including TLR3 ligands such as polyl:C and similar compounds such as Hiltonol and Ampligen.

The polypeptide or nucleic acid vaccine compositions of the present invention may be used together with one or more immune modulators. Examples of suitable immune modulators include protein tyrosine kinase inhibitors (such as afatinib, axitinib, cediranib, erlotinib, gefitinib, grandinin, lapatinib, lestaurtinib, neratinib, pazopanib, quizartinib, regorafenib, semaxanib, sorafenib, sunitinib, tivozanib, toceranib, bosutinib and vandetanib), CD40 agonists (such as CD40 agonist antibody), OX40 agonists (such as OX40 agonist antibody), CTLA-4 inhibitors (such as antiCTLA-4 antibody Ipilimumab and Tremelimumab), TLR agonists, 4-1BB agonists, Tim-1 antagonists, LAGE-3 antagonists and PD-L1 & PD-1 antagonists.

H. VACCINE-BASED IMMUNOTHERAPY REGIMENS (VBIR)

In a further aspect, the present disclosure provides a method of enhancing the immunogenicity or therapeutic effect of a vaccine for the treatment of a neoplastic disorder in a mammal, particularly a human. The method comprises administering to the mammal receiving the vaccine for the treatment of a neoplastic disorder (1) an effective amount of at least one immune-suppressive-cell inhibitor (ISC inhibitor) and (2) an effective amount of at least one immune-effector-cell enhancer (IEC enhancer). The method may be used in combination with a vaccine in any form or formulation, for example, a subunit vaccine, a protein-based vaccine, a peptide-based vaccine, or a

nucleic acid-based vaccines such as a DNA-based vaccine, a RNA-based vaccine, a plasmid-based vaccine, or a vector-based vaccine. In addition, the method is not limited to any particular types of vaccines or any particular types of cancer. Rather, the method may be used in combination with any vaccine intended for the treatment of neoplastic disorder, including benign, pre-malignant, and malignant neoplastic disorders. For example, the method may be used in combination a vaccine that is intended for the treatment of any of the following neoplastic disorders: carcinoma including that of the bladder (including accelerated and metastatic bladder cancer), breast, colon (including colorectal cancer), kidney, liver, lung (including small and non-small cell lung cancer and lung adenocarcinoma), ovary, prostate, testes, genitourinary tract, lymphatic system, rectum, larynx, pancreas (including exocrine pancreatic carcinoma), esophagus, stomach, gall bladder, cervix, thyroid, and skin (including squamous cell carcinoma); hematopoietic tumors of lymphoid lineage including leukemia, acute lymphocytic leukemia, acute lymphoblastic leukemia, B-cell lymphoma, T-cell lymphoma, Hodgkins lymphoma, non-Hodgkins lymphoma, hairy cell lymphoma, histiocytic lymphoma, and Burketts lymphoma; hematopoietic tumors of myeloid lineage including acute and chronic myelogenous leukemias, myelodysplastic syndrome, myeloid leukemia, and promyelocytic leukemia; tumors of the central and peripheral nervous system including astrocytoma, neuroblastoma, glioma, and schwannomas; tumors of mesenchymal origin including fibrosarcoma, rhabdomyosarcoma, and osteosarcoma; other tumors including melanoma, xenoderma pigmentosum, keratoactanthoma, seminoma, thyroid follicular cancer, and teratocarcinoma; melanoma, unresectable stage III or IV malignant melanoma, squamous cell carcinoma, small-cell lung cancer, non-small cell lung cancer, glioma, gastrointestinal cancer, renal cancer, ovarian cancer, liver cancer, colorectal cancer, endometrial cancer, kidney cancer, prostate cancer, thyroid cancer, neuroblastoma, pancreatic cancer, glioblastoma multiforme, cervical cancer, stomach cancer, bladder cancer, hepatoma, breast cancer, colon carcinoma, and head and neck cancer, gastric cancer, germ cell tumor, bone cancer, bone tumors, adult malignant fibrous histiocytoma of bone; childhood malignant fibrous histiocytoma of bone, sarcoma, pediatric sarcoma, sinonasal natural killer, neoplasms, plasma cell neoplasm; myelodysplastic syndromes; neuroblastoma; testicular germ cell tumor, intraocular melanoma, myelodysplastic syndromes; myelodysplastic/myeloproliferative diseases, synovial sarcoma, chronic myeloid leukemia, acute lymphoblastic leukemia, philadelphia chromosome positive acute lymphoblastic leukemia (Ph+ ALL), multiple myeloma, acute myelogenous leukemia, chronic lymphocytic leukemia, and mastocytosis.

In some embodiments, present disclosure provides a method of enhancing the immunogenicity or therapeutic effect of a vaccine for the treatment of prostate cancer in a human. The vaccine administered may be capable of eliciting an immune response against any human PAA, such as PSMA, PSA, or PSCA. In some particular embodiments, the vaccine administered comprises a nucleic acid molecule encoding an antigen capable of eliciting immunogenicity against a human PAA, such as PSMA, PSA, or PSCA. Examples of specific nucleic acid molecules that may be contained in the vaccine include the following provided by the present disclosure:

1) a nucleic acid molecule encoding an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, or an immunogenic PSCA polypeptide;

2) a nucleic acid molecule encoding two immunogenic PAA polypeptides provided by the present disclosure, such as a) an immunogenic PSMA polypeptide and an immunogenic PSA polypeptide; b) an immunogenic PSMA polypeptide and an immunogenic PSCA polypeptide; or c) an immunogenic PSA polypeptide and an immunogenic PSCA polypeptide; and

3) a nucleic acid molecule encoding three immunogenic PAA polypeptides, which are an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and an immunogenic PSCA polypeptide.

In another further aspect, the present disclosure provides a method of treating a neoplastic disorder in a mammal, particularly a human. The method comprises administering to the mammal (1) an effective amount of a vaccine capable of eliciting an immune response against a TAA associated with the neoplastic disorder, (2) an effective amount of at least one immune-suppressive-cell inhibitor (ISC inhibitor), and (3) an effective amount of at least one immune-effector-cell enhancer (IEC enhancer). Any vaccine that is capable of eliciting an immune response against a particular TAA may be used in the method. Many TAAs are known in the art. In addition to the prostate-associated antigens, the following are examples of TAAs that are known in the art: CEA, MUC-1, Ep-CAM, 5T4, hCG-b, K-ras, and TERT for colorectal cancer; CEA, Muc-1, p53, mesothelin, Survivin, and NY-ESO-1 for ovarian cancer; Muc-1, 5T4, WT-1, TERT, CEA, EGF-R and MAGE-A3 for non-small cell lung cancer; 5T4 for renal cell carcinoma; and Muc-1, mesothelin, K-Ras, Annexin A2, TERT, and CEA for pancreatic cancer. New TAAs continue to be identified. A vaccine that is capable of eliciting an immune response against any of the known or new TAAs can be used in the method. In addition, the vaccine administered may be in any form or formulation, for example, subunit vaccines, protein-based vaccine, peptide based vaccines, or nucleic acid-based

vaccines such DNA-based vaccines, RNA-based vaccines, plasmid-based vaccines, or vector-based vaccines.

In some embodiments, the present disclosure provides a method of treating a prostate cancer in a human, the method comprising administering to the human a vaccine capable of eliciting an immune response against any human PAA, such as PSMA, PSA, or PSCA. In some particular embodiments, the vaccine administered comprises a nucleic acid molecule encoding an antigen capable of eliciting immunogenicity against a human PAA, such as PSMA, PSA, or PSCA. Examples of specific nucleic acid molecules that may be contained in the vaccine include the following provided by the present disclosure:

1) a nucleic acid molecule encoding an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, or an immunogenic PSCA polypeptide;

2) a nucleic acid molecule encoding two immunogenic PAA polypeptides provided by the present disclosure, such as a) an immunogenic PSMA polypeptide and an immunogenic PSA polypeptide; b) an immunogenic PSMA polypeptide and an immunogenic PSCA polypeptide; or c) an immunogenic PSA polypeptide and an immunogenic PSCA polypeptide; and

3) a nucleic acid molecule encoding three immunogenic PAA polypeptides, which are an immunogenic PSMA polypeptide, an immunogenic PSA polypeptide, and an immunogenic PSMA polypeptide.

The method of treating a neoplastic disorder in a mammal and the method of enhancing the immunogenicity or therapeutic effect of a vaccine for the treatment of a neoplastic disorder in a mammal described herein above are alternatively referred to as "vaccine-based immunotherapy regimens" (or "VBIR").

In the vaccine-based immunotherapy regimens, the IEC enhancers and ISC inhibitors may be administered by any suitable methods and routes, including (1) systemic administration such as intravenous, intramuscular, or oral administration, and (2) local administration such intradermal and subcutaneous administration. Where appropriate or suitable, local administration is generally preferred over systemic administration. Local administration of any IEC enhancer and ISC inhibitor can be carried out at any location of the body of the mammal that is suitable for local administration of pharmaceuticals; however, it is more preferable that these immune modulators are administered locally at close proximity to the vaccine draining lymph node.

Two or more specific IEC enhancers from a single class of IEC enhancers (for examples, two CTLA-agonists) may be administered in combination with the ISC inhibitors. In addition, two or more specific IEC enhancers from two or more different classes of IEC enhancers (for example, one CTLA-4 antagonist and one TLR agonist) may be administered together. Similarly, two or more specific ISC inhibitors from a single class of ISC inhibitors (for examples, two or more protein kinase inhibitors) may be administered in combination with the IEC enhancers. In addition, two or more specific ISC inhibitors from two or more different classes of ISC inhibitors (for example, one protein kinase inhibitor and one COX-2 inhibitor) may be administered together.

In the vaccine-based immunotherapy regimens the vaccine may be administered simultaneously or sequentially with any or all of the immune modulators (i.e., ISC inhibitors and IEC enhancers) used. Similarly, when two or more immune modulators are used, they may be administered simultaneously or sequentially with respect to each other. In some embodiments, a vaccine is administered simultaneously (e.g., in a mixture) with respect to one immune modulator, but sequentially with respect to one or more additional immune modulators. Co-administration of the vaccine and the immune modulators in the vaccine-based immunotherapy regimen can include cases in which the vaccine and at least one immune modulator are administered so that each is present at the administration site, such as vaccine draining lymph node, at the same time, even though the antigen and the immune modulators are not administered simultaneously. Co-administration of the vaccine and the immune modulators also can include cases in which the vaccine or the immune modulator is cleared from the administration site, but at least one cellular effect of the cleared vaccine or immune modulator persists at the administration site, such as vaccine draining lymph node, at least until one or more additional immune modulators are administered to the administration site. In cases where a nucleic acid vaccine is administered in combination with a CpG, the vaccine and CpG may be contained in a single formulation and administered together by any suitable method. In some embodiments, the nucleic acid vaccine and CpG in a co-formulation (mixture) is administered by intramuscular injection in combination with electroporation.

Any ISC inhibitors may be used in the vaccine-based immunotherapy regimens. Examples of classes of SIC inhibitors include protein kinase inhibitors, cyclooxygenase-2 (COX-2) inhibitors, phosphodiesterase type 5 (PDE5) inhibitors, and DNA crosslinkers. Examples COX-2 inhibitors include celecoxib and rofecoxib. Examples of PDE5 inhibitors include avanafil, lodenafil, mirodenafil, sildenafil, tadalafil, vardenafil, udenafil,

and zaprinast. An example of DNA crosslinkers is cyclophosphamide. Examples of specific protein kinase inhibitors are described in details below.

The term "protein kinase inhibitor" refers to any substance that acts as a selective or non-selective inhibitor of a protein kinase. The term “protein kinases” refers to the enzymes that catalyze the transfer of the terminal phosphate of adenosine triphosphate to tyrosine, serine or threonine residues in protein substrates. Protein kinases include receptor tyrosine kinases and non-receptor tyrosine kinases. Examples of receptor tyrosine kinases include EGFR (e.g., EGFR/HER1/ErbB1, HER2/Neu/ErbB2, HER3/ErbB3, HER4/ErbB4), INSR (insulin receptor), IGF-IR, IGF-II1R, IRR (insulin receptor-related receptor), PDGFR (e.g., PDGFRA, PDGFRB), c-KIT/SCFR, VEGFR-1/FLT-1, VEGFR-2/FLK-1/KDR, VEGFR-3/FLT-4, FLT-3/FLK-2, CSF-1R, FGFR 1-4, CCK4, TRK A-C, MET, RON, EPHA 1-8, EPHB 1-6, AXL, MER, TYRO3, TIE, TEK, RYK, DDR 1-2, RET, c-ROS, LTK (leukocyte tyrosine kinase), ALK (anaplastic lymphoma kinase), ROR 1-2, MUSK, AATYK 1-3, and RTK 106. Examples of non-receptor tyrosine kinases include BCR-ABL, Src, Frk, Btk, Csk, Abl, Zap70, Fes/Fps, Fak, Jak, Ack, and LIMK. In the vaccine-based immunotherapy regimen provided by the present disclosure, the protein kinase inhibitors are administered to the mammal at a suboptimal dose. The term “suboptimal dose” refers to the dose amount that is below the minimum effective dose when the tyrosine kinase inhibitor is administered in a monotherapy (i.e., where the protein kinase inhibitor is administered alone without any other therapeutic agents) for the target neoplastic disorder.

Examples of specific protein kinase inhibitors suitable for use in the vaccine-based immunotherapy regimen include Lapatinib, AZD 2171, ET18OCH 3, Indirubin-3'-oxime, NSC-154020, PD 169316, Quercetin, Roscovitine, Triciribine, ZD 1839, 5-Iodotubercidin, Adaphostin, Aloisine, Alsterpaullone, Aminogenistein, API-2, Apigenin, Arctigenin, ARRY-334543, Axitinib (AG-013736), AY-22989, AZD 2171, Bisindolylmaleimide IX, CCI-779, Chelerythrine, DMPQ, DRB, Edelfosine, ENMD-981693, Erbstatin analog, Erlotinib, Fasudil, Gefitinib (ZD1839), H-7, H-8, H-89, HA-100, HA-1004, HA-1077, HA-1100, Hydroxyfasudil, Kenpaullone, KN-62, KY12420, LFM-A13, Luteolin, LY294002, LY-294002, Mallotoxin, ML-9, MLN608, NSC-226080, NSC-231634, NSC-664704, NSC-680410, NU6102, Olomoucine, Oxindole I, PD 153035, PD 98059, Phloridzin, Piceatannol, Picropodophyllin, PKI, PP1, PP2, PTK787/ZK222584, PTK787/ZK-222584, Purvalanol A, Rapamune, Rapamycin, Ro 31-8220, Rottlerin, SB202190, SB203580, Sirolimus, SL327, SP600125, Staurosporine, STI-571, SU1498, SU4312, SU5416, SU5416 (Semaxanib), SU6656, SU6668, syk inhibitor, TBB, TCN,

Tyrphostin AG 1024, Tyrphostin AG 490, Tyrphostin AG 825, Tyrphostin AG 957, U0126, W-7, Wortmannin, Y-27632, Zactima (ZD6474), ZM 252868. gefitinib (Iressa.RTM.), sunitinib malate (Sutent.RTM.; SU11248), erlotinib (Tarceva.RTM.; OSI-1774), lapatinib (GW572016; GW2016), canertinib (CI 1033), semaxinib (SU5416), vatalanib (PTK787/ZK222584), sorafenib (BAY 43-9006), imatinib (Gleevec.RTM.; STI571), dasatinib (BMS-354825), leflunomide (SU101), vandetanib (Zactima.RTM.; ZD6474), and nilotinib. Additional protein kinase inhibitors suitable for use in the present invention are described in, e.g., U.S. Pat. Nos. 5,618,829, 5,639,757, 5,728,868, 5,804,396, 6,100,254, 6,127,374, 6,245,759, 6,306,874, 6,313,138, 6,316,444, 6,329,380, 6,344,459, 6,420,382, 6,479,512, 6,498,165, 6,544,988, 6,562,818, 6,586,423, 6,586,424, 6,740,665, 6,794,393, 6,875,767, 6,927,293, and 6,958,340.

In some embodiments, the protein kinase inhibitor is a multi-kinase inhibitor, which is an inhibitor that acts on more than one specific kinase. Examples of multi-kinase inhibitors include imatinib, sorafenib, lapatinib, BIRB-796, and AZD-1152, AMG706, Zactima (ZD6474), MP-412, sorafenib (BAY 43-9006), dasatinib, CEP-701 (lestaurtinib), XL647, XL999, Tykerb (lapatinib), MLN518, (formerly known as CT53518), PKC412, ST1571, AEE 788, OSI-930, OSI-817, sunitinib malate (Sutent), axitinib (AG-013736), erlotinib, gefitinib, axitinib, bosutinib, temsirolismus and nilotinib (AMN107). In some particular embodiments, the tyrosine kinase inhibitor is sunitinib, sorafenib, or a pharmaceutically acceptable salt or derivative (such as a malate or a tosylate) of sunitinib or sorafenib.

Sunitinib malate, which is marketed by Pfizer Inc. under the trade name SUTENT, is described chemically as butanedioic acid, hydroxy-, (2S)-, compound with *N*-[2-(diethylamino)ethyl]-5-[(*Z*)-(5-fluoro-1,2-dihydro-2-oxo-*3H*-indol-3-ylidine)methyl]-2,4-dimethyl-*1H*-pyrrole-3-carboxamide (1:1). The compound, its synthesis, and particular polymorphs are described in U.S. Pat. No. 6,573,293, U.S. Patent Publication Nos. 2003-0229229, 2003-0069298 and 2005-0059824, and in J. M. Manley, M. J. Kalman, B. G. Conway, C. C. Ball, J. L Havens and R. Vaidyanathan, "Early Amidation Approach to 3-[(4-amido)pyrrol-2-yl]-2-indolinones," J. Org. Chew. 68, 6447-6450 (2003). Formulations of sunitinib and its L-malate salt are described in PCT Publication No. WO 2004/024127. Sunitinib malate has been approved in the U.S. for the treatment of gastrointestinal stromal tumor, advanced renal cell carcinoma, and progressive, well-differentiated pancreatic neuroendocrine tumors in patients with unresectable locally advanced or metastatic disease. The recommended dose of sunitinib malate for gastrointestinal stromal tumor (GIST) and advanced renal cell carcinoma (RCC) for

humans is 50 mg taken orally once daily, on a schedule of 4 weeks on treatment followed by 2 weeks off (Schedule 4/2). The recommended dose of sunitinib malate for pancreatic neuroendocrine tumors (pNET) is 37.5 mg taken orally once daily.

In the vaccine-based immunotherapy regimen, sunitinib malate may be administered orally in a single dose or multiple doses. Typically, sunitinib malate is delivered for two, three, four or more consecutive weekly doses followed by a "off" period of about 1 or 2 weeks, or more where no sunitinib malate is delivered. In one embodiment, the doses are delivered for about 4 weeks, with 2 weeks off. In another embodiment, the sunitinib malate is delivered for two weeks, with 1 week off. However, it may also be delivered without a "off' period for the entire treatment period. The effective amount of sunitinib malate administered orally to a human in the vaccine-based immunotherapy regimen is typically below 40 mg per person per dose. For example, it may be administered orally at 37.5, 31.25, 25, 18.75, 12.5, 6.25 mg per person per day. In some embodiments, sunitinib malate is administered orally in the range of 1 – 25 mg per person per dose. In some other embodiments, sunitinib malate is administered orally in the range of 6.25, 12.5, or 18.75 mg per person per dose. Other dosage regimens and variations are foreseeable, and will be determined through physician guidance.

Sorafenib tosylate, which is marketed under the trade name NEXAVAR, is also a multi-kinase inhibitor. Its chemical name is 4-(4-{3-[4-Chloro-3-(trifluoromethyl) phenyl]ureido}phenoxy)-N-methylpyrid-ine-2-carboxamide. It is approved in the U.S. for the treatment of primary kidney cancer (advanced renal cell carcinoma) and advanced primary liver cancer (hepatocellular carcinoma). The recommended daily dose is 400 mg taken orally twice daily. In the vaccine-based immunotherapy regimen provided by the present disclosure, the effective amount of sorafenib tosylate administered orally is typically below 400 mg per person per day. In some embodiments, the effective amount of sorafenib tosylate administered orally is in the range of 10 - 300 mg per person per day. In some other embodiments, the effective amount of sorafenib tosylate administered orally is between 10 - 200 mg per person per day, such as 10, 20, 60, 80, 100, 120, 140, 160, 180, or 200 mg per person per day.

Axitinib, which is marketed under the trade name INLYTA, is a selective inhibitor of VEGF receptors 1, 2, and 3. Its chemical name is (*N*-Methyl-2-[3-((E)-2-pyridin-2-yl-vinyl)-1*H*-indazol-6-ylsulfanyl]-benzamide. It is approved for the treatment of advanced renal cell carcinoma after failure of one prior systemic therapy. The starting dose is 5 mg orally twice daily. Dose adjustments can be made based on individual safety and

tolerability. In the vaccine-based immunotherapy regimen provided by the present disclosure, the effective amount of axitinib administered orally is typically below 5 mg twice daily. In some other embodiments, the effective amount of axitinib administered orally is between 1-5 mg twice daily. In some other embodiments, the effective amount of axitinib administered orally is between 1, 2, 3, 4, or 5 mg twice daily.

In the vaccine-based immunotherapy regimens any IEC enhancers may be used. They may be small molecules or large molecules (such as protein, polypeptide, DNA, RNA, and antibody). Examples of IEC enhancers that may be used include TNFR agonists, CTLA-4 antagonists, TLR agonists, programmed cell death protein 1 (PD-1) antagonists (such as BMS-936558), anti-PD-1 antibody CT-011), and programmed cell death protein 1 ligand 1 (PD-L1) antagonists (such as BMS-936559), lymphocyte-activation gene 3 (LAG3) antagonists, and T cell Immunoglobulin- and mucin-domain-containing molecule -3 (TIM-3) antagonists. Examples of specific TNFR agonists, CTLA-4 antagonists, and TLR agonists are provided in details herein below.

TNFR Agonists.

Examples of TNFR agonists include agonists of OX40, 4-1BB (such as BMS-663513), GITR (such as TRX518), and CD40. Examples of specific CD40 agonists are described in details herein below.

CD40 agonists are substances that bind to a CD40 receptor on a cell and is capable of increasing one or more CD40 or CD40L associated activities. Thus, CD40 "agonists" encompass CD40 "ligands".

Examples of CD40 agonists include CD40 agonistic antibodies, fragments CD40 agonistic antibodies, CD40 ligands (CD40L), and fragments and derivatives of CD40L such as oligomeric (e.g., bivalent, trimeric CD40L), fusion proteins containing and variants thereof.

CD40 ligands for use in the present invention include any peptide, polypeptide or protein, or a nucleic acid encoding a peptide, polypeptide or protein that can bind to and activate one or more CD40 receptors on a cell. Suitable CD40 ligands are described, for example, in U.S. Pat. No. 6,482,411, 6,410,711; U.S. Pat. No. 6,391,637; and U.S. Pat. No. 5,981,724, all of which patents and application and the CD40L sequences disclosed therein are incorporated by reference in their entirety herein. Although human CD40 ligands will be preferred for use in human therapy, CD40 ligands from any species may be used in the invention. For use in other animal species, such as in veterinary embodiments, a species of CD40 ligand matched to the animal being treated will be preferred. In certain embodiments, the CD40 ligand is a gp39 peptide or protein

oligomer, including naturally forming gp39 peptide, polypeptide or protein oligomers, as well as gp39 peptides, polypeptides, proteins (and encoding nucleic acids) that comprise an oligomerization sequence. While oligomers such as dimers, trimers and tetramers are preferred in certain aspects of the invention, in other aspects of the invention larger oligomeric structures are contemplated for use, so long as the oligomeric structure retains the ability to bind to and activate one or more CD40 receptor(s).

In certain other embodiments, the CD40 agonist is an anti-CD40 antibody, or antigen-binding fragment thereof. The antibody can be a human, humanized or part-human chimeric anti-CD40 antibody. Examples of specific anti-CD40 monoclonal antibodies include the G28-5, mAb89, EA-5 or S2C6 monoclonal antibody, and CP870893. In a particular embodiment, the anti-CD40 agonist antibody is CP870893 or dacetuzumab (SGN-40).

CP-870,893 is a fully human agonistic CD40 monoclonal antibody (mAb) that has been investigated clinically as an anti-tumor therapy. The structure and preparation of CP870,893 is disclosed in WO2003041070 (where the antibody is identified by the internal identified "21.4.1"). The amino acid sequences of the heavy chain and light chain of CP-870,893 are set forth in SEQ ID NO: 40 and SEQ ID NO: 41, respectively. In clinical trials, CP870,893 was administered by intravenous infusion at doses generally in the ranges of 0.05 - 0.25 mg/kg per infusion. In a phase I clinical study, the maximum tolerated dose (MTD) of CP-870893 was estimated to be 0.2 mg/kg and the dose-limiting toxicities included grade 3 CRS and grade 3 urticaria. [Jens Ruter et al.: Immune modulation with weekly dosing of an agonist CD40 antibody in a phase I study of patients with advanced solid tumors. Cancer Biology & Therapy 10:10, 983-993; November 15, 2010.]. In the vaccine-based immunotherapy regimen provided by the present disclosure, CP-870,893 can be administered intradermally, subcutaneously, or topically. It is preferred that it is administered intradermally. The effective amount of CP870893 to be administered in the regimen is generally below 0.2 mg/kg, typically in the range of 0.01 mg – 0.15 mg/kg, or 0.05 – 0.1 mg/kg.

Dacetuzumab (also known as SGN-40 or huS2C6; CAS number 88-486-59-9) is another anti-CD40 agonist antibody that has been investigated in clinical trials for indolent lymphomas, diffuse large B cell lymphomas and Multiple Myeloma. In the clinical trials, dacetuzumab was administered intravenously at weekly doses ranging from 2 mg/kg to 16 mg/kg. In the vaccine-based immunotherapy regimen provided by the present disclosure, dacetuzumab can be administered intradermally,

subcutaneously, or topically. It is preferred that it is administered intradermally. The effective amount of dacetuzumab to be administered in the vaccine-based immunotherapy regimen is generally below 16 mg/kg, typically in the range of 0.2 mg – 14 mg/kg, or 0.5 –8 mg/kg, or 1 - 5 mg/kg.

CTLA-4 Inhibitors.

Suitable anti-CTLA-4 antagonist agents for use in the vaccine-based immunotherapy regimen provided by the disclosure include, without limitation, anti-CTLA-4 antibodies (such as human anti-CTLA-4 antibodies, mouse anti-CTLA-4 antibodies, mammalian anti-CTLA-4 antibodies, humanized anti-CTLA-4 antibodies, monoclonal anti-CTLA-4 antibodies, polyclonal anti-CTLA-4 antibodies, chimeric anti-CTLA-4 antibodies, anti-CTLA-4 domain antibodies), fragments of anti-CTLA-4 antibodies (such as (single chain anti-CTLA-4 fragments, heavy chain anti-CTLA-4 fragments, and light chain anti-CTLA-4 fragments), and inhibitors of CTLA-4 that agonize the co-stimulatory pathway. In some embodiments, the CTLA-4 inhibitor is Ipilimumab or Tremelimumab.

Ipilimumab (also known as MEX-010 or MDX-101), marketed as YERVOY, is a human anti-human CTLA-4 antibody. Ipilimumab can also be referred to by its CAS Registry No. 477202-00-9, and is disclosed as antibody 10DI in PCT Publication No. WO 01/14424, incorporated herein by reference in its entirety and for all purposes. Examples of pharmaceutical composition comprising Ipilimumab are provided in PCT Publication No. WO 2007/67959. Ipilimumab is approved in the U.S. for the treatment of unresectable or metastatic melanoma. The recommended dose of Ipilimumab as monotherapy is 3 mg/kg by intravenous administration every 3 weeks for a total of 4 doses. In the methods provided by the present invention, Ipilimumab is administered locally, particularly intradermally or subcutaneously. The effective amount of Ipilimumab administered locally is typically in the range of 5 – 200 mg/dose per person. In some embodiments, the effective amount of Ipilimumab is in the range of 10 – 150 mg/dose per person per dose. In some particular embodiments, the effective amount of Ipilimumab is about 10, 25, 50, 75, 100, 125, 150, 175, or 200 mg/dose per person.

Tremelimumab (also known as CP-675,206) is a fully human IgG2 monoclonal antibody and has the CAS number 745013-59-6. Tremelimumab is disclosed as antibody 11.2.1 in U.S. Patent No: 6,682,736, incorporated herein by reference in its entirety and for all purposes. The amino acid sequences of the heavy chain and light chain of Tremelimumab are set forth in SEQ IND NOs:42 and 43, respectively. Tremelimumab has been investigated in clinical trials for the treatment of various tumors,

including melanoma and breast cancer; in which Tremelimumab was administered intravenously either as single dose or multiple doses every 4 or 12 weeks at the dose range of 0.01 and 15 mg/kg. In the regimens provided by the present invention, Tremelimumab is administered locally, particularly intradermally or subcutaneously. The effective amount of Tremelimumab administered intradermally or subcutaneously is typically in the range of 5 – 200 mg/dose per person. In some embodiments, the effective amount of Tremelimumab is in the range of 10 – 150 mg/dose per person per dose. In some particular embodiments, the effective amount of Tremelimumab is about 10, 25, 50, 75, 100, 125, 150, 175, or 200 mg/dose per person.

Toll-like Receptor (TLR) Agonists.

The term “toll-like receptor agonist” or "TLR agonist" refers to a compound that acts as an agonist of a toll-like receptor (TLR). This includes agonists of TLR1, TLR2, TLR3, TLR4, TLR5, TLR6, TLR7, TLR8, TLR9, TLR10, and TLR11 or a combination thereof. Unless otherwise indicated, reference to a TLR agonist compound can include the compound in any pharmaceutically acceptable form, including any isomer (e.g., diastereomer or enantiomer), salt, solvate, polymorph, and the like. In particular, if a compound is optically active, reference to the compound can include each of the compound's enantiomers as well as racemic mixtures of the enantiomers. Also, a compound may be identified as an agonist of one or more particular TLRs (e.g., a TLR7 agonist, a TLR8 agonist, or a TLR7/8 agonist).

The TLR agonism for a particular compound may be assessed in any suitable manner known in the art. Regardless of the particular assay employed, a compound can be identified as an agonist of a particular TLR if performing the assay with a compound results in at least a threshold increase of some biological activity mediated by the particular TLR. Conversely, a compound may be identified as not acting as an agonist of a specified TLR if, when used to perform an assay designed to detect biological activity mediated by the specified TLR, the compound fails to elicit a threshold increase in the biological activity. Unless otherwise indicated, an increase in biological activity refers to an increase in the same biological activity over that observed in an appropriate control. An assay may or may not be performed in conjunction with the appropriate control. With experience, one skilled in the art may develop sufficient familiarity with a particular assay (e.g., the range of values observed in an appropriate control under specific assay conditions) that performing a control may not always be necessary to determine the TLR agonism of a compound in a particular assay.

Certain TLR agonists useful in the method of the present invention are small organic molecules, as opposed to large biological molecules such as proteins, peptides, and the like. Examples of small molecule TLR agonists include those disclosed in, for example, U.S. Pat. Nos. 4,689,338; 4,929,624; 4,988,815; 5,037,986; 5,175,296; 5,238,944; 5,266,575; 5,268,376; 5,346,905; 5,352,784; 5,367,076; 5,389,640; 5,395,937; 5,446,153; 5,482,936; 5,693,811; 5,741,908; 5,756,747; 5,939,090; 6,039,969; 6,083,505; 6,110,929; 6,194,425; 6,245,776; 6,331,539; 6,376,669; 6,451,810; 6,525,064; 6,545,016; 6,545,017; 6,558,951; and 6,573,273. Examples of specific small molecule TLR agonists useful in the methods provided by the present invention include 4-amino-alpha, alpha,2- trimethyl-lH-imidazo[4,5-c]qumolin-l-ethanol, N-(2-{2-[4-amino-2-(2-methoxyethyl)-lH-imidazo[4,5-c]quinolin-l-yl]ethoxy-}ethyl)-N-methylmorpholine-4-carboxamide, l~(2~amino-2-methylpropyl)-2-(ethoxymethyl-)-lH-imidazo[4,5-c]quinolin-4-arnine, N-[4-(4-amino-2-ethyl-lH-imidazo[4,5- c]quinolin-l-yl)butyl]methanesulfonamide, N-[4-(4-amino-2-propyl-lH-imidazo[4,5-c]quinolin-l-yl)butyl]me- thanesulfonamide, and imiquimod. Some TLR agonists particularly useful in the methods or regimen provided by the present disclosure are discussed in review article: Folkert Steinhagen, et al.: TLR-based immune adjuvants. Vaccine 29 (2011): 3341-3355.

In some embodiments, the TLR agonists are TLR9 agonists, particularly CpG oligonucleotides (or CpG.ODN). A CpG oligonucleotide is a short nucleic acid molecule containing a cytosine followed by a guanine linked by a phosphate bond in which the pyrimidine ring of the cytosine is unmethylated. A CpG motif is a pattern of bases that include an unmethylated central CpG surrounded by at least one base flanking (on the 3' and the 5' side of) the central CpG. CpG oligonucleotides include both D and K oligonucleotides. The entire CpG oligonucleotide can be unmethylated or portions may be unmethylated. Examples of CpG oligonucleotides useful in the methods provided by the present disclosure include those disclosed in U.S. Patent Nos. 6194388, 6207646, 6214806, 628371, 6239116, and 6339068.

The CpG oligonucleotides can encompass various chemical modifications and substitutions, in comparison to natural RNA and DNA, involving a phosphodiester internucleoside bridge, a beta -D-ribose (deoxyhbose) unit and/or a natural nucleoside base (adenine, guanine, cytosine, thymine, uracil). Examples of chemical modifications are known to the skilled person and are described, for example in Uhlmann E. et al. (1990), Chem. Rev. 90:543; "Protocols for Oligonucleotides and Analogs", Synthesis and Properties and Synthesis and Analytical Techniques, S. Agrawal, Ed., Humana

Press, Totowa, USA 1993; Crooke, ST. et al. (1996) Annu. Rev. Pharmacol. Toxicol. 36:107-129; and Hunziker J. et al., (1995), Mod. Synth. Methods 7:331 -417. Specifically, a CpG oligonucleotide can contain a modified cytosine. A modified cytosine is a naturally occurring or non-naturally occurring pyrimidine base analog of cytosine which can replace this base without impairing the immunostimulatory activity of the oligonucleotide. Modified cytosines include but are not limited to 5-substituted cytosines (e.g. 5-methyl-cytosine, 5-fluorocytosine, 5-chloro-cytosine, 5-bromo-cytosine, 5-iodo-cytosine, 5-hydroxy-cytosine, 5- hydroxymethyl-cytosine, 5-difluoromethyl-cytosine, and unsubstituted or substituted 5- alkynyl-cytosine), 6-substituted cytosines, N4-substituted cytosines (e.g. N4-ethyl- cytosine), 5-aza-cytosine, 2-mercapto-cytosine, isocytosine, pseudo-isocytosine, cytosine analogs with condensed ring systems (e.g. N,N'-propylene cytosine or phenoxazine), and uracil and its derivatives (e.g. 5-fluoro-uracil, 5-bromo-uracil, 5- bromovinyl-uracil, 4-thio-uracil, 5-hydroxy-uracil, 5-propynyl-uracil). Some of the preferred cytosines include 5-methyl-cytosine, 5-fluoro-cytosine, 5-hydroxy-cytosine, 5- hydroxymethyl-cytosine, and N4-ethyl-cytosine.

A CpG oligonucleotide can also contain a modified guanine. A modified guanine is a naturally occurring or non-naturally occurring purine base analog of guanine which can replace this base without impairing the immunostimulatory activity of the oligonucleotide. Modified guanines include but are not limited to 7-deeazaguanine, 7-deaza-7-substituted guanine, hypoxanthine, N2- substituted guanines (e.g. N2-methyl-guanine), 5-amino-3-methyl-3H,6H-thiazolo[4,5- d]pyhmidine-2,7-dione, 2,6-diaminopuhne, 2-aminopuhne, purine, indole, adenine, substituted adenines (e.g. N6-methyl-adenine, 8-oxo-adenine), 8-substituted guanine (e.g. 8-hydroxyguanine and 8-bromoguanine), and 6-thioguanine. In some embodiments of the disclosure, the guanine base is substituted by a universal base (e.g. 4-methyl-indole, 5-nitro-indole, and K-base), an aromatic ring system (e.g. benzimidazole or dichloro-benzimidazole, 1 -methyl-1 H-[1,2,4]triazole-3-carboxylic acid amide) or a hydrogen atom.

In certain aspects, the CpG oligonucleotides include modified backbones. It has been demonstrated that modification of the nucleic acid backbone provides enhanced activity of nucleic acids when administered in vivo. Secondary structures, such as stem loops, can stabilize nucleic acids against degradation. Alternatively, nucleic acid stabilization can be accomplished via phosphate backbone modifications. A preferred stabilized nucleic acid has at least a partial phosphorothioate modified backbone. Phosphorothioates may be synthesized using automated techniques employing either phosphoramidate or H-phosphonate chemistries. Aryl- and alkyl-phosphonates can be

made, e.g. as described in U.S. Patent No. 4,469,863; and alkylphosphotriesters (in which the charged oxygen moiety is alkylated as described in U.S. Pat. No. 5,023,243 and European Patent No. 092,574) can be prepared by automated solid phase synthesis using commercially available reagents. Methods for making other DNA backbone modifications and substitutions have been described (Uhlmann, E. and Peyman, A. (1990) Chem. Rev. 90:544; Goodchild, J. (1990) Bioconjugate Chem. 1:165). 2'-O-methyl nucleic acids with CpG motifs also cause immune activation, as do ethoxy-modified CpG nucleic acids. In fact, no backbone modifications have been found that completely abolish the CpG effect, although it is greatly reduced by replacing the C with a 5-methyl C. Constructs having phosphorothioate linkages provide maximal activity and protect the nucleic acid from degradation by intracellular exo- and endo-nucleases. Other modified oligonucleotides include phosphodiester modified oligonucleotides, combinations of phosphodiester and phosphorothioate oligonucleotides, methylphosphonate, methylphosphorothioate, phosphorordithioate, p-ethoxy, and combinations thereof. Each of these combinations and their particular effects on immune cells is discussed in more detail with respect to CpG nucleic acids in PCT Publication Nos. WO 96/02555 and WO 98/18810 and in U.S. Pat. Nos. 6,194,388 and 6,239,116.

The CpG oligonucleotides may have one or two accessible 5' ends. It is possible to create modified oligonucleotides having two such 5' ends, for instance, by attaching two oligonucleotides through a 3'-3' linkage to generate an oligonucleotide having one or two accessible 5' ends. The 3'-3'-linkage may be a phosphodiester, phosphorothioate or any other modified internucleoside bridge. Methods for accomplishing such linkages are known in the art. For instance, such linkages have been described in Seliger, H. et al., Oligonucleotide analogs with terminal 3'-3'- and 5'-5'-internucleotidic linkages as antisense inhibitors of viral gene expression, Nucleosides and Nucleotides (1991), 10(1-3), 469-77 and Jiang, et al., Pseudo-cyclic oligonucleotides: in vitro and in vivo properties, Bioorganic and Medicinal Chemistry (1999), 7(12), 2727-2735.

Additionally, 3'-3'-linked oligonucleotides where the linkage between the 3'-terminal nucleosides is not a phosphodiester, phosphorothioate or other modified bridge, can be prepared using an additional spacer, such as tri- or tetra-ethyleneglycol phosphate moiety (Durand, M. et al., Triple-helix formation by an oligonucleotide containing one (dA)12 and two (dT)12 sequences bridged by two hexaethylene glycol chains, Biochemistry (1992), 31 (38), 9197-204, US Pat. Nos. 5,658,738 and 5,668,265). Alternatively, the non-nucleotidic linker may be derived from ethanediol, propanediol, or

from an abasic deoxyhbose (dSpacer) unit (Fontanel, Marie Laurence et al., Nucleic Acids Research (1994), 22(11), 2022-7) using standard phosphoramidite chemistry. The non-nucleotidic linkers can be incorporated once or multiple times, or combined with each other allowing for any desirable distance between the 3'-ends of the two oligonucleotides to be linked.

A phosphodiester internucleoside bridge located at the 3' and/or the 5' end of a nucleoside can be replaced by a modified internucleoside bridge, wherein the modified internucleoside bridge is for example selected from phosphorothioate, phosphorodithioate, $NRiR_2$-phosphoramidate, boranophosphate, a-hydroxybenzyl phosphonate, phosphate-(C_1-C_{21})-O-alkyl ester, phosphate-[(C_6-C_{21})aryl-(C_1-C_{21})-O-alkyl]ester, (C1-C_8)alkylphosphonate and/or (C_6-$C1_2$)arylphosphonate bridges, (C_7-C_{12})-a-hydroxymethyl-aryl (e.g. disclosed in PCT Publication No. WO 95/01363), wherein (C_6-C_{12})aryl, (C_6-C_{20})aryl and (C_6-C_{14})aryl are optionally substituted by halogen, alkyl, alkoxy, nitro, cyano, and where Ri and R_2 are, independently of each other, hydrogen, (C_1-$C1_8$)-alkyl, (C_6-C_{20})-aryl, (C_6-C_{14})-aryl, (C_1-C_8)-alkyl, preferably hydrogen, (C_1-C_8)-alkyl, preferably (C_1-C_4)-alkyl and/or methoxyethyl, or R_1 and R_2 form, together with the nitrogen atom carrying them, a 5 to 6-membered heterocyclic ring which can additionally contain a further heteroatom selected from the group O, S and N.

The replacement of a phosphodiester bridge located at the 3' and/or the 5' end of a nucleoside by a dephospho bridge (dephospho bridges are described, for example, in Uhlmann E. and Peyman A. in "Methods in Molecular Biology", Vol. 20, "Protocols for Oligonucleotides and Analogs", S. Agrawal, Ed., Humana Press, Totowa 1993, Chapter 16, pp. 355 ff), wherein a dephospho bridge is for example selected from the dephospho bridges formacetal, 3'-thioformacetal, methylhydroxylamine, oxime, methylenedimethyl-hydrazo, dimethylenesulfone and/or silyl groups.

The CpG oligonucleotides for use in the methods or regimen provided by the disclosure may optionally have chimeric backbones. A chimeric backbone is one that comprises more than one type of linkage. In one embodiment, the chimeric backbone can be represented by the formula: 5' Y1 N1ZN2Y2 3'. Y1 and Y2 are nucleic acid molecules having between 1 and 10 nucleotides. Y1 and Y2 each include at least one modified internucleotide linkage. Since at least 2 nucleotides of the chimeric oligonucleotides include backbone modifications these nucleic acids are an example of one type of "stabilized immunostimulatory nucleic acids".

With respect to the chimeric oligonucleotides, Y1 and Y2 are considered independent of one another. This means that each of Y1 and Y2 may or may not have

different sequences and different backbone linkages from one another in the same molecule. In some embodiments, Y1 and/or Y2 have between 3 and 8 nucleotides. N1 and N2 are nucleic acid molecules having between 0 and 5 nucleotides as long as N1ZN2 has at least 6 nucleotides in total. The nucleotides of N1ZN2 have a phosphodiester backbone and do not include nucleic acids having a modified backbone. Z is an immunostimulatory nucleic acid motif, preferably selected from those recited herein.

The center nucleotides (N1ZN2) of the formula Y1 N1ZN2Y2 have phosphodiester internucleotide linkages and Y1 and Y2 have at least one, but may have more than one or even may have all modified internucleotide linkages. In preferred embodiments, Y1 and/or Y2 have at least two or between two and five modified internucleotide linkages or Y1 has five modified internucleotide linkages and Y2 has two modified internucleotide linkages. The modified internucleotide linkage, in some embodiments, is a phosphorothioate modified linkage, a phosphorodithioate linkage or a p-ethoxy modified linkage.

Examples of particular CpG oligonucleotides useful in the methods provided by the present disclosure include:

5' TCGTCGTTTTGTCGTTTTGTCGTT3' (CpG 7909);

5' TCGTCGTTTTTCGGTGCTTTT3' (CpG 24555); and

5' TCGTCGTTTTTCGGTCGTTTT3' (CpG 10103).

CpG7909, a synthetic 24mer single stranded, has been extensively investigated for the treatment of cancer as a monotherapy and in combination with chemotherapeutic agents, as well as adjuvant as an adjuvant for vaccines against cancer and infectious diseases. It was reported that a single intravenous dose of CpG 7909 was well tolerated with no clinical effects and no significant toxicity up to 1.05 mg/kg, while a single dose subcutaneous CpG 7909 had a maximum tolerated dose (MTD) of 0.45 mg/kg with dose limiting toxicity of myalgia and constitutional effects. [See Zent, Clive S, et al: Phase I clinical trial of CpG oligonucleotide 7909 (PF-03512676) in patients with previously treated chronic lymphocytic leukemia. Leukemia and Lymphoma, 53(2):211-217(7)(2012). In the regimens provided by the present disclosure, CpG7909 may be administered by injection into the muscle or any other suitable methods. It is preferred that it is administered locally in proximity to the vaccine draining lymph node, particularly by intradermal or subcutaneous administration. For use with a nucleic acid vaccine, such as a DNA vaccine, a CpG may be preferably co-formulated with the vaccine in a single formulation and administered by intramuscular injection coupled with

electroporation. The effective amount of CpG7909 by intramuscular, intradermal, or subcutaneous administration is typically in the range of 10 µg/dose - 10 mg/dose. In some embodiments, the effective amount of CpG7909 is in the range of 0.05 mg – 14 mg/dose. In some particular embodiments, the effective amount of CpG7909 is about 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 05 1 mg/dose. Other CpG oligonucleotides, including CpG 24555 and CpG 10103, may be administered in similar manner and dose levels.

In some particular embodiments, the present disclosure provides a method of enhancing the immunogenicity or therapeutic effect of a vaccine for the treatment of a neoplastic disorder in a human, comprising administering the human (1) an effective amount of at least one ISC inhibitor and (2) an effective amount of at least one IEC enhancer, wherein the at least one ISC inhibitor is protein kinase inhibitor selected from sorafenib tosylate, sunitinib malate, axitinib, erlotinib, gefitinib, axitinib, bosutinib, temsirolismus, or nilotinib and wherein the at least one IEC enhancer is selected from a CTLA-4 inhibitor, a TLR agonist, or a CD40 agonist. In some preferred embodiments, regimen comprises administering to the human (1) an effective amount of at least one ISC inhibitor and (2) effective amount of at least one IEC enhancer, wherein the at least one ISC inhibitor is a protein kinase inhibitor selected from axitinib, sorafenib tosylate, or sunitinib malate and wherein the wherein the at least one IEC enhancer is a CTLA-4 inhibitor selected from Ipilimumab or Tremelimumab. In some further preferred embodiments, the regimen comprises administering to the human (1) an effective amount of at least one ISC inhibitor and (2) an effective amount of at least two IEC enhancers, wherein the at least one ISC inhibitor is a protein kinase inhibitor selected from sunitinib or axitinib and wherein the at least two IEC enhancers are Tremelimumab and a TLR agonist selected from CpG7909, CpG2455, or CpG10103.

In some other embodiments, the present disclosure provides a method of treating prostate cancer in a human, comprising administering to the human (1) an effective amount of a vaccine capable of eliciting an immune response against a human PAA, (2) an effective amount of at least one ISC inhibitor, and (3) an effective amount of at least one IEC enhancer, wherein the at least one ISC inhibitor is a protein kinase inhibitor selected from sorafenib tosylate, sunitinib malate, axitinib, erlotinib, gefitinib, axitinib, bosutinib, temsirolismus, or nilotinib, and wherein the at least one IEC enhancer is selected from a CTLA-4 inhibitor, a TLR agonist, or a CD40 agonist. In some preferred embodiments, the method comprises administering to the human (1) an effective amount of a vaccine capable of eliciting an immune response against a human PAA, (2) an effective amount of at least one ISC inhibitor, and (3) an effective amount of at least

one IEC enhancer, wherein the at least one ISC inhibitor is a protein kinase inhibitor selected from sorafenib tosylate, sunitinib malate, or axitinib and wherein the at least one IEC enhancer is a CTLA-4 inhibitor selected from Ipilimumab or Tremelimumab.

In some further specific embodiments, the method comprises administering to the human (1) an effective amount of at least one ISC inhibitor and (2) an effective amount of at least two IEC enhancers, wherein the at least one ISC inhibitor is a protein kinase inhibitor selected from sunitinib or axitinib and wherein the at least two IEC enhancers are Tremelimumab and a TLR agonist selected from CpG7909, CpG2455, or CpG10103.

Additional therapeutic agents.

The vaccine-based immunotherapy regimen provided by the present disclosure may further comprise an additional therapeutic agent. A wide variety of cancer therapeutic agents may be used, including chemotherapeutic agents and hormone therapeutic agents. One of ordinary skill in the art will recognize the presence and development of other cancer therapies which can be used in VBIR provided by the present disclosure, and will not be restricted to those forms of therapy set forth herein.

The term "chemotherapeutic agent" refers to a chemical or biological substance that can cause death of cancer cells, or interfere with growth, division, repair, and/or function of cancer cells. Examples of chemotherapeutic agents include those that are disclosed in WO2006/088639, WO2006/129163, and US 20060153808, the disclosures of which are incorporated herein by reference. Examples of particular chemotherapeutic agents include: (1) alkylating agents, such as chlorambucil (LEUKERAN), cyclophosphamide (CYTOXAN), ifosfamide (IFEX), mechlorethamine hydrochloride (MUSTARGEN), thiotepa (THIOPLEX), streptozotocin (ZANOSAR), carmustine (BICNU, GLIADEL WAFER), lomustine (CEENU), and dacarbazine (DTIC-DOME); (2) alkaloids or plant vinca alkaloids, including cytotoxic antibiotics, such as doxorubicin (ADRIAMYCIN), epirubicin (ELLENCE, PHARMORUBICIN), daunorubicin (CERUBIDINE, DAUNOXOME), nemorubicin, idarubicin (IDAMYCIN PFS, ZAVEDOS), mitoxantrone (DHAD, NOVANTRONE). dactinomycin (actinomycin D, COSMEGEN), plicamycin (MITHRACIN), mitomycin (MUTAMYCIN), and bleomycin (BLENOXANE), vinorelbine tartrate (NAVELBINE)), vinblastine (VELBAN), vincristine (ONCOVIN), and vindesine (ELDISINE); (3) antimetabolites, such as capecitabine (XELODA), cytarabine (CYTOSAR-U), fludarabine (FLUDARA), gemcitabine (GEMZAR), hydroxyurea (HYDRA), methotrexate (FOLEX, MEXATE, TREXALL), nelarabine (ARRANON), trimetrexate (NEUTREXIN), and pemetrexed (ALIMTA); (4) Pyrimidine antagonists,

such as 5-fluorouracil (5-FU); capecitabine (XELODA), raltitrexed (TOMUDEX), tegafur-uracil (UFTORAL), and gemcitabine (GEMZAR); (5) taxanes, such as docetaxel (TAXOTERE), paclitaxel (TAXOL); (6) platinum drugs, such as cisplatin (PLATINOL) and carboplatin (PARAPLATIN), and oxaliplatin (ELOXATIN); (7) topoisomerase inhibitors, such as irinotecan (CAMPTOSAR), topotecan (HYCAMTIN), etoposide (ETOPOPHOS, VEPESSID, TOPOSAR), and teniposide (VUMON); (8) epipodophyllotoxins (podophyllotoxin derivatives), such as etoposide (ETOPOPHOS, VEPESSID, TOPOSAR); (9) folic acid derivatives, such as leucovorin (WELLCOVORIN); (10) nitrosoureas, such as carmustine (BiCNU), lomustine (CeeNU); (11) inhibitors of receptor tyrosine kinase, including epidermal growth factor receptor (EGFR), vascular endothelial growth factor (VEGF), insulin receptor, insulin-like growth factor receptor (IGFR), hepatocyte growth factor receptor (HGFR), and platelet-derived growth factor receptor (PDGFR), such as gefitinib (IRESSA), erlotinib (TARCEVA), bortezomib (VELCADE), imatinib mesylate (GLEEVEC), genefitinib, lapatinib, sorafenib, thalidomide, sunitinib (SUTENT), axitinib, rituximab (RITUXAN, MABTHERA),, trastuzumab (HERCEPTIN), cetuximab (ERBITUX), bevacizumab (AVASTIN), and ranibizumab (LUCENTIS), lym-1 (ONCOLYM), antibodies to insulin-like growth factor -1 receptor (IGF-1R) that are disclosed in WO2002/053596); (12) angiogenesis inhibitors, such as bevacizumab (AVASTIN), suramin (GERMANIN), angiostatin, SU5416, thalidomide, and matrix metalloproteinase inhibitors (such as batimastat and marimastat), and those that are disclosed in WO2002055106; and (13) proteasome inhibitors, such as bortezomib (VELCADE).

The term "hormone therapeutic agent" refers to a chemical or biological substance that inhibits or eliminates the production of a hormone, or inhibits or counteracts the effect of a hormone on the growth and/or survival of cancer cells. Examples of such agents suitable for the VBIR include those disclosed in US20070117809. Examples of particular hormone therapeutic agents include tamoxifen (NOLVADEX), toremifene (Fareston), fulvestrant (FASLODEX), anastrozole (ARIMIDEX), exemestane (AROMASIN), letrozole (FEMARA), megestrol acetate (MEGACE), goserelin (ZOLADEX), leuprolide (LUPRON), abiraterone, and MDV3100.

The VBIR provided by this disclosure may also be used in combination with other therapies, including (1) surgical methods that remove all or part of the organs or glands which participate in the production of the hormone, such as the ovaries, the testicles, the adrenal gland, and the pituitary gland, and (2) radiation treatment, in which the organs

or glands of the patient are subjected to radiation in an amount sufficient to inhibit or eliminate the production of the targeted hormone.

I. EXAMPLES

The following examples are provided to illustrate certain embodiments of the invention. They should not be construed to limit the scope of the invention in any way. From the above discussion and these examples, one skilled in the art can ascertain the essential characteristics of the invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usage and conditions.

EXAMPLE 1. ANTIGENS IN CYTOSOLIC, SECRETED, AND MEMBRANE-BOUND FORMATS DERIVED FROM THE HUMAN PSMA PROTEIN

Example 1 illustrates the construction of three immunogenic PSMA polypeptides referred to an "human PSMA cytosolic antigen," "human PSMA secreted antigen," and "human PSMA membrane-bound antigen," respectively, and biological properties of these polypeptides.

1A. Design of Immunogenic PSMA Polypeptides

DNA constructs encoding immunogenic PSMA polypeptides in cytosolic, secreted, and modified formats were constructed based on the native human PSMA protein sequence and tested for their ability to induce anti-tumor effector immune responses. The structure and preparation of each of the human PSMA antigen formats are provided as follows.

1A1. Human PSMA cytosolic antigen. An immunogenic PSMA polypeptide in cytosolic form was designed to retain the immunogenic polypeptide inside the cell once it is expressed. The cytoplasmic domain (amino acids 1-19) and the transmembrane domain (amino acids 20-43) of the human PSMA were removed, resulting in a cytosolic PSMA polypeptide that consists of amino acids 44-750 (extracellular domain or ECD) of the human PSMA of SEQ ID NO: 1. The optimal Kozak sequence "MAS" may be added to the N-terminus of the polypeptide for enhancing the expression.

1A2. Human PSMA secreted antigen. An immunogenic PSMA polypeptide in secreted form was designed to secret the polypeptide outside of the cell once it is expressed. The secreted polypeptide is made with amino acids 44-750 (ECD) of the human PSMA of SEQ ID NO:1 and the Ig Kappa secretory element that has the amino acid sequence ETDTLLLWVLLLWVPGSTGD and a two-amino acid linker (AA) in the N-terminal in order to maximize the secretion of the PSMA antigen once it is expressed.

1A3. Human PSMA membrane-bound antigen. An immunogenic PSMA membrane-bound polypeptide was designed to stabilize the polypeptide on the cell surface. The first 14 amino acids of the human PSMA protein were removed and the resultant immunogenic polypeptide consists of amino acids 15 – 750 of the human PSMA protein of SEQ ID NO:1. The immunogenic polypeptide that consists of amino acids 15 – 750 of the native human PSMA protein of SES ID NO: 1 and share 100% sequence identity with the native human PSMA protein is also referred to as "human PSMA modified," "hPSMA modified," or "hPSMAmod" antigen in the present disclosure.

1B. Preparation of DNA Plasmids for Expressing the PSMA antigens

DNA constructs encoding the PSMA cytosolic, PSMA secreted, and PSMA modified antigens were cloned individually into PJV7563 vector that was suitable for in vivo testing in animals (Figure 1). Both strands of the DNA in the PJV7563 vectors were sequenced to confirm the design integrity.

A large scale plasmid DNA preparation (Qiagen/CsCl) was produced from a sequence confirmed clone. The quality of the plasmid DNA was confirmed by high 260/280 ratio, high super coiled/nicked DNA ratio, low endotoxin levels (< 10U/mg DNA) and negative bio burden.

1C. Expression of PSMA constructs in mammalian cells

The expression of the PSMA cytosolic, secreted, and modified antigens was determined by FACS. Mammalian 293 cells were transfected with the PJV7563 PMED vectors encoding the various immunogenic PSMA polypeptides. Three days later, the 293 cells were stained with mouse anti-PSMA antibody, followed with a fluorescent conjugated (FITC) rat anti-mouse secondary antibody. The data below, which were reported as mean fluorescent intensity (MFI) over negative controls, confirmed that human PSMA modified antigen is expressed on the cell surface.

Samples	Average mean fluorescent intensity
Untransfected 293 cells	231
293 cells transfected with full length human PSMA (SEQ ID NO:1)	6425
293 cells transfected with human PSMA modified antigen (SEQ ID NO: 9)	12270

1D. Formulations of PSMA plasmids onto gold particles (for ND10/X15)

Particle Mediated Epidermal Delivery technology (PMED) is a needle-free method of administering vaccines to animals or to patients. The PMED system involves

the precipitation of DNA onto microscopic gold particles that are then propelled by helium gas into the epidermis. The ND10, a single use device, uses pressurized helium from an internal cylinder to deliver gold particles and the X15, a repeater delivery device, uses an external helium tank which is connected to the X15 via high pressure hose to deliver the gold particles. Both of these devices were used in studies to deliver the PSMA DNA plasmids. The gold particle was usually 1–3 μm in diameter and the particles were formulated to contain 2 μg of PSMA plasmids per 1mg of gold particles. (Sharpe, M. et al.: P. Protection of mice from H5N1 influenza challenge by prophylactic DNA vaccination using particle mediated epidermal delivery. Vaccine, 2007, 25(34): 6392-98: Roberts LK, et al.: Clinical safety and efficacy of a powdered Hepatitis B nucleic acid vaccine delivered to the epidermis by a commercial prototype device. Vaccine, 2005; 23(40):4867–78).

1E. Transgenic mice used for in vivo studies

Two human HLA transgenic mouse models were used to evaluate the presentation of various PSMA antigens by different HLAs and a human PSMA transgenic mouse model was used to assess the breaking of immune tolerance to human PSMA. The first HLA transgenic mouse model utilizes the HLA A2/DR1 mice (from the Pasteur Institute, Paris, France; also referred to as “Pasteur mice”). Pasteur mice are knock out for murine β-2-microglobulin and do not express functional H-2b molecules; therefore this model is believed to represent the presentation of antigen in the human HLA A2 and DR1 context (Pajot, A., M.-L. Michel, N. Faxilleau, V. Pancre, C. Auriault, D.M. Ojcius, F.A. Lemonnier, and Y.-C. Lone. A mouse model of human adaptive immune functions: HLA-A2.1-/HLA-DR1-transgenic H-2 class I-/class II-knockout mice. *Eur. J. Immunol.* 2004, 34:3060-69.). The second HLA transgenic mouse model uses mice that are knock in with human HLA A24 that is covalently linked tothe human β-2-microglobulin at the H2bk locus. These mice lack murine β-2-microglobulin and do not express functional H-2b molecules. This model allows evaluation of antigen presentation in the context of human HLA A24.

1F. Immunogenicity of the human PSMA proteins in cytosolic, secreted and modified *formats*

Study design. Eight-to-10 week-old transgenic mice were immunized using PMED method with various PSMA DNA constructs in a prime/boost/boost regimen, two weeks apart between each vaccination. Alternatively, mice were primed with adenovirus vectors encoding the PSMA antigen at 1 x 10^9 viral particles in 50μl(PBS) by intramuscular injection. The adenovirus vector (pShuttle-CMV vector from Stratagene)

was modified to contain NheI and BglII restriction sites within the multiple cloning site. The DNA encoding human PSMA modified was then restriction digested with NheI and BglII, ligated into this vector and sequence confirmed. The pShuttle human PSMA modified vector was then recombined with the pAdEasy-1 vector and virus was propagated according to the AdEasy system (Stratagene). Twenty-days later, they were boosted with PMED as described above. In each of the regimens used, antigen specific T cell response was measured 7 days after the last immunization in an interferon-gamma (IFNγ) ELISPOT assay. The ELISPOT assay is similar to the sandwich enzyme-linked immunosorbent assay (ELISA). Briefly, a capture antibody specific to IFNγ BD Bioscience, #51-2525kc) is coated onto a polyvinylidene fluoride (PVDF) membrane in a microplate overnight at 4^0C. The plate is blocked with serum/protein to prevent nonspecific binding to the antibody. After blocking, effector cells (such as splenocytes isolated from PSMA immunized mice) and targets (such as PSMA peptides from peptide library, target cells pulsed with peptides or tumor cells expressing the relevant antigens) or mitogen (which will stimulate splenocytes non-specifically to produce IFNγ are added to the wells and incubated overnight at 37^0C in a 5% CO_2 incubator. Cytokine secreted by effector cells are captured by the coating antibody on the surface of the PVDF membrane. After removing the cells and culture media, 100 µl of a biotinylated polyclonal anti-mouse IFNγ antibody (0.5mg/ml-BD Bioscience, #51-1818kz) was added to each of the wells for detection. The spots are visualized by adding streptavidin-horseradish peroxidase (HRP, BD Bioscience, #557630) and the precipitate substrate, 3-amino-9-ethylcarbazole (AEC), to yield a red color spot. Each spot represents a single cytokine producing T cell. In general, in the studies disclosed here the ELISpot assay was set up as follows: 5×10^5 splenocytes from PSMA immunized mice were cultured (1) in the presence of PSMA specific peptides derived from a PSMA peptide library (see Table 16) made of 15-amino acid peptides overlapping by 11 amino acids, (2) with known HLA A2.1 restricted PSMA specific peptides, or (3) with tumor cells. To measure the recognition of endogenous antigen presentation, splenocytes were cultured with a human HLA A2 prostate cancer cells (i.e. LNCaP, available from ATCC) that naturally express PSMA or cultured with HLA A2 tumor cells transduced with adenovirus encoding and thus expressing the human PSMA modified antigen. In addition, human PSMA ECD protein was added to the ELISpot assay to measure specifically CD4 IFNγ producing cells. For controls where appropriate, HLA A2 restricted HER-2 specific peptide p168-175 or tumor cells not expressing PSMA or irrelevant protein such as BSA were used as a negative control in

the IFNγ ELISpot assay. Data results are given in normalized format for the number of spot forming cells (SFC) that secrete IFNγ in 1 x 10^6 splenocytes. At least three studies were performed for each of the PSMA antigen peptides tested.

Results. Data from the ELISpot assay with splenocytes of Pasteur mice cultured with peptides derived from a PSMA peptide library are presented in Table 1. A positive response is defined as having SFC >100. As shown in Table 1, the immunogenic PMSA polypeptides made with all three antigen formats, the human PSMA cytosolic, secreted, and modified antigens described in Example 1A above, are capable of inducing T cell responses. The human PSMA modified antigen format induced the best breadth and magnitude of T cell responses.

Table 1. T cell response induced by the human PSMA cytosolic, secreted, and modified antigens in Pasteur mice

aa sequence coverage of target peptide pools from PSMA peptide library	IFN-γ SFC/1x10^6 splenocytes (SD)		
	PSMA cytosolic	PSMA modified	PSMA secreted
13-35	1(14)	809(78)	44(6)
97-117	1(1)	96(17)	0
109-131	8(9)	923(21)	179(24)
121-243	21(4)	1329(109)	320(28)
145-167	23(4)	1499(1)	312(14)
169-191	497(4)	248(14)	183(13)
181-203	43(21)	70(20)	19(10)
205-227	5(1)	112(0)	9(13)
217-239	44(13)	1627(38)	351(10)
265-287	23(4)	527(100)	10(6)
277-299	39(1)	1143(86)	151(4)
289-311	27(1)	429(4)	28(11)
409-431	14(9)	281(18)	12(9)
421-443	4(0)	676(45)	48(14)
433-455	339(18)	713(64)	119(21)
481-503	22	288(9)	1(1)
577-599	227(27)	131(16)	33(16)
589-611	187(13)	27(10)	6(9)
613-635	418(6)	437(1)	55(1)
637-659	222(31)	49(10)	95(16)
649-671	203(21)	1625(33)	420(11)
661-683	102(14)	1633(140)	366(48)
697-719	179(4)	1357(58)	342(6)
709-731	40(11)	1162(59)	223(4)
721-743	56(6)	1409(103)	344(23)
733-750	50(11)	1512(51)	365(27)

( ) = standard deviation

Data from the ELISpot assay on T cell responses induced by various PSMA vaccine formats in Pasteur mice (which that recognized HLA A2.1 restricted PSMA peptide pulsed target cells as well as PSMA+ HLA A2.1 LNCaP tumor cells) are presented in Table 2. PC3, which is a human prostate cancer cell line that does not express PSMA, was used here as a negative control. A positive response is defined as having SFC >50. As shown in Table 2, the various PSMA constructs tested are capable of inducing T cells that recognize known HLA A2 restricted PSMA epitopes as well as PSMA protein and human prostate cancer cells LNCaP. However, the PSMA modified construct was shown to induce the best breadth and magnitude T cell response.

Table 2. T cell responses induced by the human PSMA cytosolic, secreted, and modified antigens in Pasteur mice that recognized HLA A2.1 restricted PSMA peptide pulsed target cells as well as PSMA+ HLA A2.1 LNCaP tumor cells.

Target peptide or protein	IFN-γ SFC/1x10^6 splenocytes		
HLA A2.1 restricted peptides	PSMA cytosolic	PSMA modified	PSMA secreted
PSMA p663	1554(4)	1524.9(45)	444(23)
PSMA p275	14(10)	304(21)	3(1)
PSMA p662	41(15)	925.1(77)	455(25)
PSMA p627	1(1)	222(14)	9(8)
PSA p64	0	2(4)	1(1)
Protein or tumor cells	IFN-γ SFC/1x10^6 splenocytes		
PSMA ECD protein	45(11)	731(16)	13(5)
LNCap	4(2)	96(12)	5(3)
PC3	0	1(1)	1(1)

( ) = standard deviation

1G. Humoral immune response measured in Pasteur mice or nonhuman primates

1G1. Sandwich ELISA Assay. The standard sandwich ELISA assay was done using an automated Biotek system. The plates were coated with 25µl of native PSMA protein at a 1.0 µg/ml in PBS overnight, the plates were washed and blocked with 35µl/well of 5% FBS 1X PBS-T 0.05% and incubated for 1 hour at RT on a shaker at 600 RPM. The blocking media was decanted and serial dilute vaccinated mouse serum with half log dilutions in 5%FBS 1X PBS-T 0.05% starting at 1:100 or 1:500 were made and 25µ samples of the diluted serum were added to each well of the 96 well plates and incubated for 1 hour at RT on a shaker at 600 RPM. The plates were washed 3 times with 75ul/well in 1 X PBS-T 0.05% using the Biotek ELx405, and 25µl/well of 1:30,000 diluted anti-mouse IgG HRP (AbCam cat# ab20043) secondary antibody (diluted in 1X PBS-T 0.05%) was added to each well of the 96 well plates and incubated for 1 hour at RT on a shaker at 600 RPM. Plates were washed 5X with 75ul/well in 1 X PBS-T 0.05% using the Biotek Elx405. TMB Substrate was diluted at 1:10 and 25µl was added to each well and incubated at RT for 30 minutes. The reaction was stopped by adding 12.5µl/well of 1M H2SO4. Plates were read using the Spectramax Plus at 450nm wavelength. Data were reported as titers and these could be reported as first positive

(average and both values above 5%FBS PBS + 3 time Standard Deviation) and/or as calculated titers at OD of 0.5 or 1.0. Serum from irrelevant vaccinated mice were used as negative controls.

Table 3. Induction of anti-PSMA antibody response by human PSMA antigens as measured by an ELISA assay.

Antigen format	ELISA (OD =1) Average (+/-SD)	N	# of positive
PSMA cytosolic	499 (0)	4	0/4
PSMA modified	1067 (518)	4	4/4
PSMA secreted	959 (920)	4	1/4

Results. Data presented in Table 3 shows that the human PSMA cytosolic antigen did not induce any anti-PSMA responses, while the human PSMA modified antigen consistently induced good anti-PSMA antibody responses in all mice.

Data presented in Table 5 shows that antibodies induced by the human PSMA antigens reacted to multiple peptide epitopes in the PSMA library. Serum from the individual mice in each group was pooled in equal amounts and tested at a 1:500 dilution in an ELISA assay. A negative control group of mice vaccinated with anti-diphtheria (CRM) toxoid was tested in parallel. Each well of the 96 well ELISA plate was coated with 0.03µg of a single15aa peptide derived from the PSMA peptide library. An OD value above 0.10 is considered positive.

1G2. FACS Cell Binding Assay. Various prostate cancer cell lines were used for this assay. LNCaP (ATCC) was used as human prostate cancer cells expressing PSMA and PC3 (ATCC) was used as negative human prostate cancer cells that do not expressing PSMA. In some assays, a TRAMP-C2 cell line engineered to stably express the human native full length PSMA and the parental TRAMP-C2 cell line that does not express PSMA (negative control) were used for the cell binding assay. The cell binding assay was performed as follows: LNCaP and PC3 cells (or TRAMP-C2PSMA and TRAMP C2) were plated in separate wells at 2x 10^5 cells/well (50 µL) in a 96 well plate. Sera from PSMA vaccinated mice, as described in 1f, were diluted 1:50 with FACS buffer (PBS pH 7.4, 1% FBS, 25 mM HEPES, and 1 mM EDTA). Fifty µL of diluted J591-A antibody (mouse anti-human PSMA antibody, clone J591-A from ATCC) were added to the diluted test sera or FACS buffer (unstained samples) to achieve the appropriate cell numbers per well in the staining plate. All was mixed by pipetting and then kept on ice for 20 min. The cells were washed twice with FACS buffer; each wash

was by centrifugation at 1200RPM at 5^{0}C for 5 minutes. Fifty µL of secondary staining solution were added containing a 1:200 dilution of PE-labeled goat anti-mouse Ig (Sigma, cat P9670-5) and 0.25 µl of Live/Dead Aqua stain (Invitrogen, cat. # L34957) to each of the cell containing wells and kept on ice for 20 min. Cells were washed twice as described earlier. Washed cell pellets were resuspended in 125 uL FACS buffer and then 75 uL 4% paraformaldehyde solution were added to each well to fix the cells. Samples were kept on ice and protected from light for at least 15 min. Samples were run on FACS Canto II. Ten thousand live cell events were recorded for each sample. Control samples for each cell type were 1) unstained cells, 2) cells with secondary antibody only, 3) Cells with J591 plus secondary antibody, and 4) cells with naïve serum plus secondary antibody. Data were reported as mean fluorescent intensity (MFI) over negative controls.

Results of FACS Cell Binding Assay. Table 4 shows that antibodies induced by both human PSMA secreted and modified antigens are capable of binding to human PSMA positive prostate cancer cells (LNCaP) and not to PSMA negative prostate cancer cells (PC3). The PSMA modified antigen consistently induced good anti-PSMA antibody response in all mice.

Table 4. Binding of anti-PSMA antibodies to human prostate cancer cells as measured by FACS.

Antigen Format	Fold over background Average (+/-SD)	N	# of positive
PSMA cytosolic	1.40 (0.12)	4	0/4
PSMA modified	6.01(0.38)	4	4/4
PSMA secreted	5.50 (4.10)	4	3/4
background (PC3)	1.36 (0.04)	4	NA

Table 5. Antibodies induced by PSMA vaccine reacted to multiple peptides in the PSMA library. Based on this result, four B cell epitopes of PSMA were identified, 1: aa 138-147, 2: aa 119-123, 3: aa 103-106, 4: aa 649-659.

Target peptide or protein		ELISA O.D. results	
		PSMA vaccinated serum	CRM-197 vaccinated serum
Peptides from PSMA library (no. of first aa)	93	0.21	0.05
	101	0.27	0.05
	133	0.58	0.05
	137	0.89	0.05
	141	0.12	0.05
	645	0.17	0.05
PSMA protein		3.87	0.05

1G3. Antibody-Dependent Cell-Mediated Cytotoxicity (ADCC) Assay

Study design. An Indian rhesus macaque was immunized with a nucleic acid encoding a human PSMA modified antigen delivered by adenovirus (1e11 V.P. injected intramuscularly) followed by 2 PMED immunizations (8 actuations/ immunization, 4 actuations per each right and left side of the lower abdomen) with 8 and 6 week intervals respectively. The animal also received intradermal injections of 3 mg of CpG (PF-03512676) in proximity to each inguinal draining lymph node at the time of the second PMED immunization. The antibody dependent cell-mediated cytotoxicity was determined from the plasma collected from the blood before any immunizations (pre-immune plasma) and 8 days after the last PMED immunization (immune plasma).

Antibody-dependent cell-mediated cytotoxicity assay. Antibody-dependent cell-mediated cytotoxicity was determined using the standard chromium 51 release assay. Human prostate cancer cell lines LNCaP and PC3 were used as target cells. Freshly isolated human PBMC cells were used as effector cells. Effectors to target cells were set at 30:1. Briefly, for one labeling reaction, $1.5x10^6$ target cells in 200ul were incubated with 200 µCi ^{51}Cr (37°C, 5% CO_2 for 1 hour). Cells were washed three times and the cell concentration was adjusted to $2x10^5$ cells/ml. Control monoclonal antibodies (mAb) or test plasma (1:50) were made at 2X concentration and 175ul of each of the (depending on the size of the assay) mAb/plasma dilution were added to 175ul of target cells. The mixture was incubated for 30 minutes at 4^0C in an Eppendorf tube. Cells were washed once to free unbound antibodies. At this time, 100ul of freshly isolated effector cells were added to each well of the 96 well plate along with 100ul of monoclonal antibodies or test plasma bound target cells and incubated at 37^0C and 5% CO_2 for 4hrs . Samples were tested in duplicates. 100 µl 2N HCl were added to the target wells for maximum release and 100 µl of media were added to the target wells for

spontaneous release. Specific lysis was calculated as follows: Percent release=(ER-SR)/(MR-SR)x100 where ER (effectors + target cells release) was experimental release, SR(target cells alone incubated with media) was spontaneous release, and MR(target cells alone incubated with 2N HCl) was maximum release. Percent specific lysis was calculated by subtracting irrelevant target (PC3) release from antigen specific target (LNCaP) release.

Table 6. Antibody dependent cytotoxicity activity measured in plasma from human PSMA modified vaccinated animal.

	Percent specific lysis at E:T of 30:1 (based on type of antibodies and targets used in an ADCC assay)				
Targets	Herceptin	Rituxan	Pre-immune plasma (naive)	Post-immune plasma	None
LNCaP	56.14	8.99	0	49.9	0
PC3	8.04	0	0	0	0

Results. The data from the antibody dependent cytotoxicity assay are presented in Table 6. LNCaP, a human prostate PSMA+ cancer cell line coated with immune plasma derived from the hPSMA immunized animal, was lysed by effector cells while PC3, a human prostate PSMA- cancer cell line coated with the same immune serum, was not lysed by effector cells. Similarly, LNCaP coated with pre-immune plasma was not lysed by effector cells. Herceptin, a monoclonal antibody against HER-2 was used as a positive control since LNCaP cells are known to express HER-2 (Li, Cozzi et al. 2004). Rituxan, a monoclonal against B cell antigen (CD20) was used as a negative control antibody since LNCaP cells do not express CD20. Both monoclonal antibodies are reported to have ADCC activities (Dall'Ozzo, Tartas et al. 2004; Collins, O'Donovan et al. 2011).

EXAMPLE 2. CONSTRUCTION OF PSMA SHUFFLED ANTIGENS

This example illustrates the construction and certain biological properties of various immunogenic PSMA polypeptides that are variants of the human PSMA modified antigen (SEQ ID NO:9) as described in Example 1.

2A. Design of PSMA Shuffled Antigens

Various immunogenic PSMA polypeptides that are variants of the human PSMA modified antigen (SEQ ID NO:9) as described in Example 1 were designed. These variants were created by introducing mutations selected from orthologs of the human PSMA into the human PSMA modified antigen sequence. These variants are referred to, interchangeably, as "PSMA shuffled antigens" or "shuffled PSMA modified antigens" in

the disclosure. The principle and procedure used in creating these variants are provided below.

A computational algorithm was written to select point mutations for the shuffled variant. First, a multiple sequence alignment of PSMA and 12 orthologs (Appendix 2a) was assembled using NCBI's PSI-BLAST. The output from PSI-BLAST included propensities for each residue at each PSMA position among the orthologs. The perl script then used these propensities to select point mutations as follows:

1) Among all positions, the most commonly observed residue is selected that does not match the identity in the native human PSMA.

2) Verify that this mutation position does not overlap with identified Class I or II human PSMA epitopes to ensure that the point mutation is not within a conserved T cell epitope as defined herein above (Table 19).

3) Calculate similarity of mutation to the human residue via the BLOSUM62 matrix to verify that the BLOSUM62 similarity score for the residue substitution is within the range of 0 - 1 (inclusive).

This iterative procedure is followed until a certain percent sequence identity (below 100) is reached with respect to the human PSMA.

To serve as the input to this algorithm, the PSMA orthologs were assembled to construct a position-specific probability matrix using PSI-BLAST from NCBI. Additionally, the identified epitope regions of PSMA were listed in a file which was also provided to the shuffle algorithm. The non-shuffling regions were also extended to the cytosolic and transmembrane regions of the protein to avoid membrane-bound functionality problems. The orthologous PSMA protein sequences, BLOSUM62 matrix, and PSI-BLAST program were downloaded from the NCBI site.

The shuffling script was then run using these input data and produced a variant of human PSMA with 94% sequence identity with the original human PSMA. Additionally, three mutations to improve HLA-A2 binding were introduced based on their performance in the Epitoptimizer algorithm (Houghton, Engelhorn et al. 2007). These mutations are M664L (epitope: 663-671), I676V (epitope: 668-676), and N76L (epitope: 75-83). The resultant antigen is referred to as "shuffled PSMA modified antigen 1," "shuffled PSMA modified 1," or "PSMA shuffled antigen 1".

Results based on epitopes with consensus rank <1% and IC50 by neural Network (single best method)<500 showed that predicted epitopes from HLA A2.1, HLA A3, HLA A11, HLA A24, and HLA B7 were highly conserved in this shuffled antigen. Two additional variants of the human PSMA modified antigen described in Example 1 were

designed 'with higher sequence identities and a more restrictive BLOSUM score cutoff of 1 to remove all non-conservative substitutions. These two variants are also referred to as "shuffled PSMA modified antigen 2" and "shuffled PSMA modified antigen 3," respectively. Percent identities of shuffled PSMA modified antigens 1- 3 with respect to the human PSMA modified construct (e.g., amino acids 15-750 of the human PSMA) are approximately 93.6%, 94.9%, and 96.4%, respectively.

The shuffled PSMA modified antigen 1 has the amino acid sequence of SEQ ID NO:3 and has the following mutations relative to the human PSMA modified antigen:
N47S, T53S, K55Q, M58V, L65M, N76L, S98A, Q99E, K122E, N132D, V154I, I157V, F161Y, D191E, M192L, V201L, V225I, I258V, G282E, I283L, R320K, L362I, S380A, E408K, L417I, H475Y, K482Q, M509V, S513N, E542K, M583L, N589D, R598Q, S613N, I614L, S615A, Q620E, M622L, S647N, E648Q, S656N, I659L, V660L, L661V, M664L, I676V

The shuffled PSMA modified antigen 2 has the amino acid sequence of SEQ ID NO:5 and has the following mutations relative to the human PSMA modified antigen:
Mutations:
N47S, K55Q, M58V, Q91E, S98A, A111S, K122E, N132D, V154I, I157V, F161Y, V201L, V225I, I258V, S312A, R320K, K324Q, R363K, S380A, E408K, H475Y, K482Q, Y494F, E495D, K499E, M509L, N540D, E542K, N544S, M583I, I591V, R598Q, R605K, S613N, S647N, E648Q, S656N, V660L

The shuffled PSMA modified antigen 3 has the amino acid sequence of SEQ ID NO:7 and has the following mutations relative to the human PSMA modified antigen:
Mutations:
T339A, V342L, M344L, T349N, N350T, E351K, S401T, E408K, M470L, Y471H, H475Y, F506L, M509L, A531S, N540D, E542K, N544S, G548S, V555I, E563V, V603A, R605K, K606N, Y607H, D609E, K610N, I611L

2B. Immune responses measured post vaccination in Pasteur mice

Study design. Eight- to 10-week old Pasteur mice were immunized using PMED method with the various plasmid DNAs expressing shuffled PSMA modified antigens in a prime/boost/boost regimen, two weeks apart between each vaccination as described in Example 1F. Antigen specific T and B cell responses were measured 7 days after the last immunization in an interferon-gamma (IFNγ) ELISPOT assay and sandwich ELISA respectively.

Table 7. T cell responses induced by various shuffled PSMA modified antigens to peptide pools in PSMA peptide library

Amino acid sequence coverage of target peptide pools from PSMA peptide library	IFN-γ SFC/1x10^6 splenocytes (SD)			
	Human PSMA modified antigen	Shuffled PSMA modified antigen1	Shuffled PSMA modified antigen 2	Shuffled PSMA modified antigen 3
13-35	608(31)	135(4)	539(33)	339(16)
109-131	132(14)	97(21)	49(13)	360(40)
121-243	275(7)	146(17)	104(17)	542(119)
145-167	218(6)	158(8)	98(8)	505(16)
157-179	212(14)	293(24)	800(0)*	800 (0)*
169-191	50(11)	52(14)	814(23)	804(65)
181-203	415(33)	8(0)	243(18)	103(1)
205-227	125(7)	1(1)	17(7)	7(4)
217-239	883(47)	302(0)	467(52)	538(14)
229-251	565(24)	188(23)	150(17)	460(122)
265-287	418(8)	2(0)	154(25)	168(23)
277-299	908(79)	132(3)	574(25)	670(74)
289-311	417(27)	20(8)	260(3)	374(51)
409-431	377(7)	61(10)	38(3)	48(11)
421-443	720(34)	110(9)	720(17)	38(17)
433-455	974(51)	211(16)	800 (0)*	771(52)
481-503	400(59)	0(0)	116(6)	100(34)
589-611	60(14)	245(30)	679(35)	364(11)
601-623	70(9)	79(13)	344(20)	27(1)
613-635	629(41)	102(11)	772(93)	634(9)
637-659	226(17)	292(0)	539(16)	420(198)
649-671	530(74)	319(16)	614(20)	644(65)
661-683	507(52)	248(9)	330(3)	661(16)

Results. ELISpot data presented in Table 7 demonstrates that overall the shuffled PSMA modified antigens are capable of inducing T cell responses in breadth and magnitude very similar to the human PSMA modified antigen. SFC >100 is considered positive. The "*" symbol represents too numerous to accurately count.

Table 8. T cell responses induced by shuffled PSMA modified antigens to HLA A2 targets and PSMA protein.

IFNγ ELISPOT targetstargets	IFN-γ SFC/1x10^6 splenocytes(SD)			
	Human PSMA modified antigen	Shuffled PSMA modified antigen 1	Shuffled PSMA modified antigen 2	Shuffled PSMA modified antigen 3
PSMA p168	261(21)	337(16)	800+(0)	800+(0)
PSMA p275	540(66)	2(2)	181(17)	134(17)
PSMA p663	441(46)	152(10)	219(6)	600(48)
HER-2 p106	1(1)	1(1)	1(1)	1(1)
PSMA ECD protein	839(70)	165(31)	569(44)	319(6)
BSA protein	1(1)	1(1)	1(1)	2(0)
LNCaP	229(45)	40(3)	137(23)	45(6)
MeWo	3(1)	1(1)	2(2)	1(1)
MeWo-Ad-hPSMA	365(33)	31(10)	341(46)	415(128)

As shown in Table 8, all the shuffled PSMA antigens are capable of inducing T cells that recognized known HLA A2 restricted PSMA epitopes as well as human HLA A2 tumor cells transduced with adenovirus bearing the PSMA transgene to express PSMA. The tumor cells that did not express PSMA served as negative controls and were not recognized. SFC>50 is considered positive.

Table 9. T cell responses induced by shuffled PSMA modified antigens to specific to CD4 T cells.

aa sequence coverage of target peptide pools from PSMA peptide library	IFN-γ SFC/1x10^6 CD8 depleted splenocytes(SD)			
	Human PSMA modified antigen	Shuffled PSMA modified antigen 1	Shuffled PSMA modified antigen 2	Shuffled PSMA modified antigen 3
17-31	396(51)	49(33)	294(3)	209(13)
281-295	528(6)	51(1)	592(9)	461(24)
285-299	512(34)	55(18)	529(38)	471(38)
429-443	552(51)	51(1)	524(17)	0
581-595	11(1)	0	199(24)	0

ELISpot data shown in Table 9 were obtained with splenocytes that were depleted of CD8; therefore the data represents T cell responses to specific to CD4 T cells. The data show that the CD4 response elicited by shuffled PSMA modified antigen 2 is very similar to that induced by the human PSMA modified antigen. SFC>50 is considered positive.

Table 10. Induction of anti-PSMA antibody response as measured by an ELISA assay

Antigen	ELISA (OD=0.5)	# of positive
Human PSMA modified antigen	1159 (802)	7/7
Shuffled PSMA modified antigen 1	899 (1016)	4/7
Shuffled PSMA modified antigen 2	4898 (3636)	6/6
Shuffled PSMA modified antigen 3	1482 (3092)	1/5

Data in Table 10 demonstrates that all the shuffled PSMA modified antigens are capable of inducing anti-human PSMA antibody responses. Shuffled PSMA modified antigen 2 and the human PSMA modified antigen induced consistent antibody responses in all mice.

Table 11. T cell responses in HLA A24 mice induced by the human PSMA modified antigen and shuffled PSMA modified antigen 2.

Amino acid sequence coverage of target peptide pools from PSMA peptide library	IFN-γ SFC/1x10^6 splenocytes (SD)	
	Human PSMA modified antigen	Shuffled PSMA modified antigen 2
217-231	280(10)	271(7)
233-247	219(2)	0
237-251	197(1)	228(1)
249-263	203(1)	28(1)
273-287	57(2)	323(3)
277-291	194(24)	337(18)
293-307	147(6)	379(11)
309-323	17(1)	441(14)
401-415	256(1)	292(3)
429-443	255(7)	0
433-447	59(1)	179(6)
481-495	167(11)	475(21)
557-571	194(14)	297(1)
601-615	500(35)	166(10)
605-619	500(28)	143(7)
613-627	218(4)	0

697-711	0	141(8)
729-743	0	140(1)
733-747	0	271(3)
737-750	0	401(8)

ELISpot data in Table 11 demonstrates that overall the T cell response induced by shuffled PSMA modified antigen 2 in HLA A24 mice is very similar in breadth and magnitude to the human PSMA modified antigen. SFC >100 is considered positive.

2C. Breaking of immune tolerance to human PSMA by shuffled PSMA modified antigens

Study design. The human PSMA transgenic mouse model uses mice that were made using the minimal rat probasin promoter driving the expression of PSMA specifically in the prostate gland (Zhang, Thomas et al. 2000) *Endocrinology* 141(12): 4698-4710. These mice were made in the C57BL/6 background. RT-PCR and immune histochemistry staining data confirmed the expression of PSMA in the ventral and dorsolateral roots of the prostate gland in these PSMA transgenic mice. The endogenous expression of human PSMA protein in these mice is expected to generate immune tolerance.

Results. As shown in Table 12, only 20% of the PSMA transgenic mice were able to mount a T cell response to human PSMA using the human PSMA modified antigen. However, 67% of the PSMA transgenic mice were able to mount a PSMA specific T cell response using the shuffled PSMA modified antigen 2. The data suggests that the inclusion of non-self amino acid sequences in the shuffled PSMA modified antigen 2 improved the breaking tolerance to the self human PSMA antigen. SFC>50 is considered positive.

Table 12. T cell responses in human PSMA transgenic mice to known PSMA epitope (PADYFAPGVKSYPDG*; Durso RJ, Clin Cancer Res.* 2007 Jul 1;13(13):3999-400).

Antigen	IFN-γ SFC/1 x 10^6 splenocytes (SD)										# of positive
Human PSMA modified antigen	7 (3)	126 (20)	1 (2)	3 (1)	10 (5)	22 (5)	30 (3)	12 (0)	7 (2)	404 (4)	2/10
Shuffled PSMA modified antigen 2	474 (52)	104 (18)	7 (3)	111 (8)	12 (2)	21 (2)	139 (12)	246 (9)	226 (11)	NA	6/9

EXAMPLE 3. DESIGN OF VARIOUS IMMUNOGENIC PSA POLYPEPTIDES

Example 3 illustrates the construction and certain biological properties of immunogenic PSA polypeptides in cytosolic, secreted, and membrane-bound forms.

3A. Construction of Various PSA Antigen Forms

Similar to what was described in Example 1 for the three different immunogenic PSMA polypeptide forms (e.g., the cytosolic, membrane-bound, and secreted forms), immunogenic PSA polypeptides in the three forms were also designed based on the human PSA sequence. An immunogenic PSA polypeptide in cytosolic form, which consists of amino acids 25-261 of the native human PSA, is constructed by deleting the secretory signal and the pro domain (amino acids 1-24). The amino acid sequence of this cytosolic immunogenic PSA polypeptide is provided in SEQ ID NO: 17. The secreted form of the PSA polypeptide is the native full length human PSA (amino acids 1-261). An immunogenic PSA polypeptide in membrane-bound form is constructed by linking the immunogenic PSA polypeptide cytosolic form (amino acids 25-261 of the native human PSA) to the human PSMA transmembrane domain (amino acids 15-54 of the human PSMA).

3B. Immune responses in Pasteur and HLA A24 mice

Study design. Eight to 10 week old HLA A2 Pasteur mice or HLA A24 mice were immunized with DNA expressing the various PSA antigens using PMED provided in Example 3A in a prime/boost/boost regimen with two week intervals between each vaccination as described in Example 1. The antigen specific T and B cell responses were measured 7 days after the last immunization in an interferon-gamma (IFNγ) ELISPOT assay and sandwich ELISA.

Table 13. Induction of T cell responses in Pasteur mice and HLA A24 mice vaccinated with PSA polypeptides

T cell response detected in HLA A2 Pasteur mice			
Amino acid sequence coverage of target peptide pools from PSA peptide library	IFN-γ SFC/1x10^6 splenocytes (SD)		
	PSA cytosolic	PSA membrane-bound	PSA secreted
25-47	12 (0)	134 (6)	27 (1)
49-71	150 (0)	23 (1)	151(10)
61-83	904 (17)	27 (7)	452 (14)
73-95	128 (25)	8 (6)	78 (14)
85-107	17 (7)	205 (18)	11 (1)
97-117	26 (3)	378 (25)	13 (1)
217-239	16 (8)	234 (8)	6 (6)
229-251	96 (34)	844 (6)	35 (12)

T cell response detected in HLA A24 mice			
145-167	357 (2)	Not determined	Not determined

Results. Table 13 shows ELISpot data derived from splenocytes isolated from HLA A2 Pasteur mice or HLA A24 mice cultured with peptides derived from the PSA peptide library. T cell responses can be detected in both HLA A2 and HLA A24 mice. SFC>100 is considered positive.

Table 14. The induction of T cell responses by PSA antigens in Pasteur mice to PSA+ HLA A2.1+ SKmel5 human cancer cells

HLA A2.1+ human cancer cells or protein	IFN-γ SFC/1x10^6 splenocytes (SD)		
	PSA cytosolic	PSA membrane-bound	PSA secreted
SKmel5-Ad-eGFP	7.7 (9.6)	1.2 (1.4)	2.9 (2.7)
SKmel5-Ad-PSA	112.0 (169.3)	546.1 (379.6)	18.7 (18.5)
PSA protein	108.8 (161.0)	536.9 (380.9)	20.6 (21)

ELISpot data shown in table 14 indicates that immunogenic PSA polypeptides in both cytosolic and membrane-bound forms are capable of inducing T cells that recognize human tumor cells transduced with adenovirus to express the cytosolic PSA antigen (SKmel5-Ad-PSA) but not cells transduced with adenovirus to express eGFP (SKmel5-Ad-eGFP). These two antigens also elicited response to PSA protein. The PSA secreted antigen failed to induce T cells to both SKmel5-Ad-PSA or PSA protein. SFC>50 is considered positive.

Table 15. The induction of anti-PSA antibody response as measured by a sandwich ELISA assay

Antigen Forms	ELISA (OD=1.0) Average (SD)	# of positive
PSA cytosolic	99 (0)	0/6
PSA membrane-bound	4838 (835)	6/6
PSA secreted	1151 2410)	2/6

Data in Table 15 demonstrates that immunogenic PSA polypeptides in both secreted and membrane-bound forms are capable of inducing anti-PSA antibody responses.

Table 16. Human PSMA Peptide Library peptide pools and corresponding amino acid sequences

PSMA peptide pool (aa no.)	aa sequences of individual peptides	PSMA peptide pool (aa no.)	aa sequences of individual peptides
1-23	MWNLLHETDSAVATA	373-395	ILGGHRDSWVFGGID
	LHETDSAVATARRPR		HRDSWVFGGIDPQSG
	DSAVATARRPRWLCA		WVFGGIDPQSGAAVV
13-35	ATARRPRWLCAGALV	385-407	GIDPQSGAAVVHEIV
	RPRWLCAGALVLAGG		QSGAAVVHEIVRSFG
	LCAGALVLAGGFFLL		AVVHEIVRSFGTLKK
25-47	ALVLAGGFFLLGFLF	397-419	EIVRSFGTLKKEGWR
	AGGFFLLGFLFGWFI		SFGTLKKEGWRPRRT
	FLLGFLFGWFIKSSN		LKKEGWRPRRTILFA
37-59	FLFGWFIKSSNEATN	409-431	GWRPRRTILFASWDA
	WFIKSSNEATNITPK		RRTILFASWDAEEFG
	SSNEATNITPKHNMK		LFASWDAEEFGLLGS
49-71	ATNITPKHNMKAFLD	421-443	WDAEEFGLLGSTEWA
	TPKHNMKAFLDELKA		EFGLLGSTEWAEENS
	NMKAFLDELKAENIK		LGSTEWAEENSRLLQ
61-83	FLDELKAENIKKFLY	433-455	EWAEENSRLLQERGV
	LKAENIKKFLYNFTQ		ENSRLLQERGVAYIN
	NIKKFLYNFTQIPHL		LLQERGVAYINADSS
73-95	FLYNFTQIPHLAGTE	445-467	RGVAYINADSSIEGN
	FTQIPHLAGTEQNFQ		YINADSSIEGNYTLR
	PHLAGTEQNFQLAKQ		DSSIEGNYTLRVDCT
85-107	GTEQNFQLAKQIQSQ	457-479	EGNYTLRVDCTPLMY
	NFQLAKQIQSQWKEF		TLRVDCTPLMYSLVH
	AKQIQSQWKEFGLDS		DCTPLMYSLVHNLTK
97-117	QSQWKEFGLDSVELA	469-491	LMYSLVHNLTKELKS
	KEFGLDSVELAHYDV		LVHNLTKELKSPDEG
	LDSVELAHYDVLLSY		LTKELKSPDEGFEGK
109-131	ELAHYDVLLSYPNKT	481-503	LKSPDEGFEGKSLYE
	YDVLLSYPNKTHPNY		DEGFEGKSLYESWTK
	LSYPNKTHPNYISII		EGKSLYESWTKKSPS
121-243	NKTHPNYISIINEDG	493-515	LYESWTKKSPSPEFS
	PNYISIINEDGNEIF		WTKKSPSPEFSGMPR
	SIINEDGNEIFNTSL		SPSPEFSGMPRISKL
133-155	EDGNEIFNTSLFEPP	505-527	EFSGMPRISKLGSGN
	EIFNTSLFEPPPPGY		MPRISKLGSGNDFEV
	TSLFEPPPPGYENVS		SKLGSGNDFEVFFQR
145-167	EPPPPGYENVSDIVP	517-539	SGNDFEVFFQRLGIA
	PGYENVSDIVPPFSA		FEVFFQRLGIASGRA
	NVSDIVPPFSAFSPQ		FQRLGIASGRARYTK
157-179	IVPPFSAFSPQGMPE	529-551	GIASGRARYTKNWET
	FSAFSPQGMPEGDLV		GRARYTKNWETNKFS

	SPQGMPEGDLVYVNY		YTKNWETNKFSGYPL
169-191	MPEGDLVYVNYARTE	541-563	WETNKFSGYPLYHSV
	DLVYVNYARTEDFFK		KFSGYPLYHSVYETY
	VNYARTEDFFKLERD		YPLYHSVYETYELVE
181-203	RTEDFFKLERDMKIN	553-575	HSVYETYELVEKFYD
	FFKLERDMKINCSGK		ETYELVEKFYDPMFK
	ERDMKINCSGKIVIA		LVEKFYDPMFKYHLT
193-215	KINCSGKIVIARYGK	565-587	FYDPMFKYHLTVAQV
	SGKIVIARYGKVFRG		MFKYHLTVAQVRGGM
	VIARYGKVFRGNKVK		HLTVAQVRGGMVFEL
205-227	YGKVFRGNKVKNAQL	577-599	AQVRGGMVFELANSI
	FRGNKVKNAQLAGAK		GGMVFELANSIVLPF
	KVKNAQLAGAKGVIL		FELANSIVLPFDCRD
217-239	AQLAGAKGVILYSDP	589-611	NSIVLPFDCRDYAVV
	GAKGVILYSDPADYF		LPFDCRDYAVVLRKY
	VILYSDPADYFAPGV		CRDYAVVLRKYADKI
229-251	SDPADYFAPGVKSYP	601-623	AVVLRKYADKIYSIS
	DYFAPGVKSYPDGWN		RKYADKIYSISMKHP
	PGVKSYPDGWNLPGG		DKIYSISMKHPQEMK
241-263	SYPDGWNLPGGGVQR	613-635	SISMKHPQEMKTYSV
	GWNLPGGGVQRGNIL		KHPQEMKTYSVSFDS
	PGGGVQRGNILNLNG		EMKTYSVSFDSLFSA
253-275	VQRGNILNLNGAGDP	625-647	YSVSFDSLFSAVKNF
	NILNLNGAGDPLTPG		FDSLFSAVKNFTEIA
	LNGAGDPLTPGYPAN		FSAVKNFTEIASKFS
265-287	GDPLTPGYPANEYAY	637-659	KNFTEIASKFSERLQ
	TPGYPANEYAYRRGI		EIASKFSERLQDFDK
	PANEYAYRRGIAEAV		KFSERLQDFDKSNPI
277-299	YAYRRGIAEAVGLPS	649-671	RLQDFDKSNPIVLRM
	RGIAEAVGLPSIPVH		FDKSNPIVLRMMNDQ
	EAVGLPSIPVHPIGY		NPIVLRMMNDQLMFL
289-311	LPSIPVHPIGYYDAQ	661-683	LRMMNDQLMFLERAF
	PVHPIGYYDAQKLLE		NDQLMFLERAFIDPL
	IGYYDAQKLLEKMGG		MFLERAFIDPLGLPD
301-323	DAQKLLEKMGGSAPP	673-695	RAFIDPLGLPDRPFY
	LLEKMGGSAPPDSSW		DPLGLPDRPFYRHVI
	MGGSAPPDSSWRGSL		LPDRPFYRHVIYAPS
313-335	APPDSSWRGSLKVPY	685-707	PFYRHVIYAPSSHNK
	SSWRGSLKVPYNVGP		HVIYAPSSHNKYAGE
	GSLKVPYNVGPGFTG		APSSHNKYAGESFPG
325-347	VPYNVGPGFTGNFST	697-719	HNKYAGESFPGIYDA
	VGPGFTGNFSTQKVK		AGESFPGIYDALFDI
	FTGNFSTQKVKMHIH		FPGIYDALFDIESKV
337-359	FSTQKVKMHIHSTNE	709-731	YDALFDIESKVDPSK
	KVKMHIHSTNEVTRI		FDIESKVDPSKAWGE
	HIHSTNEVTRIYNVI		SKVDPSKAWGEVKRQ

349-371	TNEVTRIYNVIGTLR	721-743	PSKAWGEVKRQIYVA
	TRIYNVIGTLRGAVE		WGEVKRQIYVAAFTV
	NVIGTLRGAVEPDRY		KRQIYVAAFTVQAAA
361-383	TLRGAVEPDRYVILG	733-750	YVAAFTVQAAAETLS
	AVEPDRYVILGGHRD		FTVQAAAETLSEVA
	DRYVILGGHRDSWVF		

Table 17. Human PSA Peptide Library

PSA peptide pool (aa no.)	aa sequences of individual peptides	PSA peptide pool (aano.)	aa sequences of individual peptides
1-23	MWVPVVFLTLSVTWI	133-155	TDAVKVMDLPTQEPA
	VVFLTLSVTWIGAAP		KVMDLPTQEPALGTT
	TLSVTWIGAAPLILS		LPTQEPALGTTCYAS
13-35	TWIGAAPLILSRIVG	145-167	EPALGTTCYASGWGS
	AAPLILSRIVGGWEC		GTTCYASGWGSIEPE
	ILSRIVGGWECEKHS		YASGWGSIEPEEFLT
25-47	IVGGWECEKHSQPWQ	157-179	WGSIEPEEFLTPKKL
	WECEKHSQPWQVLVA		EPEEFLTPKKLQCVD
	KHSQPWQVLVASRGR		FLTPKKLQCVDLHVI
37-59	PWQVLVASRGRAVCG	169-191	KKLQCVDLHVISNDV
	LVASRGRAVCGGVLV		CVDLHVISNDVCAQV
	RGRAVCGGVLVHPQW		HVISNDVCAQVHPQK
49-71	VCGGVLVHPQWVLTA	181-203	NDVCAQVHPQKVTKF
	VLVHPQWVLTAAHCI		AQVHPQKVTKFMLCA
	PQWVLTAAHCIRNKS		PQKVTKFMLCAGRWT
61-83	LTAAHCIRNKSVILL	193-215	TKFMLCAGRWTGGKS
	HCIRNKSVILLGRHS		LCAGRWTGGKSTCSG
	NKSVILLGRHSLFHP		RWTGGKSTCSGDSGG
73-95	ILLGRHSLFHPEDTG	205-227	GKSTCSGDSGGPLVC
	RHSLFHPEDTGQVFQ		CSGDSGGPLVCNGVL
	FHPEDTGQVFQVSHS		SGGPLVCNGVLQGIT
85-107	DTGQVFQVSHSFPHP	217-239	LVCNGVLQGITSWGS
	VFQVSHSFPHPLYDM		GVLQGITSWGSEPCA
	SHSFPHPLYDMSLLK		GITSWGSEPCALPER
97-117	PHPLYDMSLLKNRFL	229-251	WGSEPCALPERPSLY
	YDMSLLKNRFLRPGD		PCALPERPSLYTKVV
	LLKNRFLRPGDDSSH		PERPSLYTKVVHYRK
109-131	RFLRPGDDSSHDLML	241-263	SLYTKVVHYRKWIKD
	PGDDSSHDLMLLRLS		KVVHYRKWIKDTIVA
	SSHDLMLLRLSEPAE		YRKWIKDTIVANP
121-243	LMLLRLSEPAELTDA		
	RLSEPAELTDAVKVM		
	PAELTDAVKVMDLPT		

Table 18. PSMA Orthologs

PSMA species	NCBI ID	% ID with human
human	2897946	100
chimpanzee	114639743	99
macaque	109108238	97
dog	73987958	93
horse	149719573	92
pig	47523822	90
cow	156120365	89
rat	149069047	84
mouse	20138153	84
opossum	126327828	80
chicken	118085215	78
platypus	149635150	76
zebra fish	41053648	69

Table 19. Conserved T Cell Epitopes in the Human PSMA as Set Forth in SEQ ID NO:1.

Amino acid Start	Amino acid End	Sequence
168	176	GMPEGDLVY
347	356	HSTNGVTRIY
557	566	ETYELVEKFY
207	215	KVFRGNKVK
431	440	STEWAEENSR
4	12	LLHETDSAV
27	35	VLAGGFFLL
168	177	GMPEGDLVYV
441	450	LLQERGVAYI
469	477	LMYSLVHNL
711	719	ALFDIESKV
663	671	MNDQVMFL
178	186	NYARTEDFF
227	235	LYSDPADYF
624	632	TYSVSFDSL
334	348	TGNFSTQKVKMHIHS
459	473	NYTLRVDCTPLMYSL
687	701	YRHVIYAPSSHNKYA
730	744	RQIYVAAFTVQAAAE

EXAMPLE 4. CONSTRUCTION OF MULTI-ANTIGEN VACCINE CONSTRUCTS

In this Example, several strategies for expressing multiple antigens from single component DNA vaccine construct are described. These multi-antigen DNA vaccine constructs share the same general plasmid backbone as pPJV7563. Although the multi-

antigen expression strategies are described here in the context of a DNA vaccine, the principles will apply similarly in the context of viral vector genetic vaccines (such as adenovirus vectors). Unless otherwise specified, the genes included in the multi-antigen constructs encode the human PSMA modified antigen (noted as PSMA), full length human PSCA (noted as PSCA), and the human PSA cytosolic antigen (noted as PSA), as described in the examples herein above.

EXAMPLE 4A. DUAL ANTIGEN CONSTRUCTS

4A1. Construction of dual antigen constructs utilizing multiple promoters

General Strategy. One strategy for creating multivalent nucleic acid vaccine constructs is to incorporate multiple independent promoters into a single plasmid (Huang, Y., Z. Chen, et al. (2008). "Design, construction, and characterization of a dual-promoter multigenic DNA vaccine directed against an HIV-1 subtype C/B' recombinant." J Acquir Immune Defic Syndr 47(4): 403-411; Xu, K., Z. Y. Ling, et al. (2011). "Broad humoral and cellular immunity elicited by a bivalent DNA vaccine encoding HA and NP genes from an H5N1 virus." Viral Immunol 24(1): 45-56). The plasmid can be engineered to carry multiple expression cassettes, each consisting of a) a eukaryotic promoter for initiating RNA polymerase dependent transcription, with or without an enhancer element, b) a gene encoding a target antigen, and c) a transcription terminator sequence. Upon delivery of the plasmid to the transfected cell nucleus, transcription will be initiated from each promoter, resulting in the production of separate mRNAs, each encoding one of the target antigens. The mRNAs will be independently translated, thereby producing the desired antigens.

Plasmid 460 (PSMA/PSCA Dual promoter). Plasmid 460 was constructed using the techniques of site-directed mutagenesis, PCR, and restriction fragment insertion. First, a Kpn I restriction site was introduced upstream of the CMV promoter in plasmid 5259 using site-directed mutagenesis with MD5 and MD6 primers according to manufacturer's protocol (Quickchange kit, Agilent Technologies, Santa Clara, CA). Second, an expression cassette consisting of a minimal CMV promoter, human PSMA, and rabbit B globulin transcription terminator was amplified by PCR from plasmid 5166 using primers that carried Kpn I restriction sites (MD7 and MD8). The PCR amplicon was digested with Kpn I and inserted into the newly introduced Kpn I site of calf intestinal alkaline phosphatase (CIP)- treated plasmid 5259.

4A2. Construction of dual antigen constructs utilizing 2A peptides

General Strategy. Multiple protein antigens can also be expressed from a single vector through the use of viral 2A-like peptides (Szymczak, A. L. and D. A. Vignali

(2005). "Development of 2A peptide-based strategies in the design of multicistronic vectors." Expert Opin Biol Ther 5(5): 627-638; de Felipe, P., G. A. Luke, et al. (2006). "E unum pluribus: multiple proteins from a self-processing polyprotein." Trends Biotechnol 24(2): 68-75; Luke, G. A., P. de Felipe, et al. (2008). "Occurrence, function and evolutionary origins of '2A-like' sequences in virus genomes." J Gen Virol 89(Pt 4): 1036-1042; Ibrahimi, A., G. Vande Velde, et al. (2009). "Highly efficient multicistronic lentiviral vectors with peptide 2A sequences." Hum Gene Ther 20(8): 845-860; Kim, J. H., S. R. Lee, et al. (2011). "High cleavage efficiency of a 2A peptide derived from porcine teschovirus-1 in human cell lines, zebrafish and mice." PLoS One 6(4): e18556). These peptides, also called cleavage cassettes or CHYSELs (cis-acting hydrolase elements), are approximately 20 amino acids long with a highly conserved carboxy terminal D-V/I-EXNPGP motif (Figure 2). The cassettes are rare in nature, most commonly found in viruses such as Foot-and-mouth disease virus (FMDV), Equine rhinitis A virus (ERAV), Encephalomyocarditis virus (EMCV), Porcine teschovirus (PTV), and Thosea asigna virus (TAV) (Luke, G. A., P. de Felipe, et al. (2008). "Occurrence, function and evolutionary origins of '2A-like' sequences in virus genomes." J Gen Virol 89(Pt 4): 1036-1042). With a 2A-based multi-antigen expression strategy, genes encoding multiple target antigens can be linked together in a single open reading frame, separated by 2A cassettes. The entire open reading frame can be cloned into a vector with a single promoter and terminator. Upon delivery of the genetic vaccine to a cell, mRNA encoding the multiple antigens will be transcribed and translated as a single polyprotein. During translation of the 2A cassettes, ribosomes skip the bond between the C-terminal glycine and proline. The ribosomal skipping acts like a cotranslational autocatalytic “cleavage” that releases upstream from downstream proteins. The incorporation of a 2A cassette between two protein antigens results in the addition of ~20 amino acids onto the C-terminus of the upstream polypeptide and 1 amino acid (proline) to the N-terminus of downstream protein. In an adaptation of this methodology, protease cleavage sites can be incorporated at the N terminus of the 2A cassette such that ubiquitous proteases will cleave the cassette from the upstream protein (Fang, J., S. Yi, et al. (2007). "An antibody delivery system for regulated expression of therapeutic levels of monoclonal antibodies in vivo." Mol Ther 15(6): 1153-1159).

Plasmid 451 (PSMA-T2A-PSCA). Plasmid 451 was constructed using the techniques of overlapping PCR and restriction fragment exchange. First, the gene encoding human PSMA amino acids 15-750 was amplified by PCR using plasmid 5166 as a template with primers 119 and 117. The gene encoding full-length human PSCA

was amplified by PCR using plasmid 5259 as a template with primers 118 and 120. PCR resulted in the addition of overlapping TAV 2A (T2A) sequences at the 3' end of PSMA and 5' end of PSCA. The amplicons were mixed together and amplified by PCR with primers 119 and 120. The PSMA-T2A-PSCA amplicon was digested with Nhe I and Bgl II and inserted into similarly digested plasmid 5166. A glycine-serine linker was included between PSMA and the T2A cassette to promote high cleavage efficiency.

Plasmid 454 (PSCA-F2A-PSMA). Plasmid 454 was created using the techniques of PCR and restriction fragment exchange. First, the gene encoding full-length human PSCA was amplified by PCR using plasmid 5259 as a template with primers 42 and 132. The amplicon was digested with BamH I and inserted into similarly digested, CIP-treated plasmid 5300. A glycine-serine linker was included between PSCA and the FMDV 2A (F2A) cassette to promote high cleavage efficiency.

Plasmid 5300 (PSA-F2A-PSMA) Plasmid 5300 was constructed using the techniques of overlapping PCR and restriction fragment exchange. First, the gene encoding PSA amino acids 25-261 was amplified by PCR from plasmid 5297 with primers MD1 and MD2. The gene encoding human PSMA amino acids 15-750 was amplified by PCR from plasmid 5166 with primers MD3 and MD4. PCR resulted in the addition of overlapping F2A sequences at the 3' end of PSA and 5' end of PSMA. The amplicons were mixed together and extended by PCR. The PSA-F2A-PSMA amplicon was digested with Nhe I and Bgl II and inserted into similarly digested plasmid pPJV7563.

4A3. Dual antigen constructs utilizing internal ribosomal entry sites

General Strategy: A third strategy for expressing multiple protein antigens from a single plasmid or vector involves the use of an internal ribosomal entry site, or IRES. Internal ribosomal entry sites are RNA elements (Figure 3) found in the 5' untranslated regions of certain RNA molecules (Bonnal, S., C. Boutonnet, et al. (2003). "IRESdb: the Internal Ribosome Entry Site database." Nucleic Acids Res 31(1): 427-428). They attract eukaryotic ribosomes to the RNA to facilitate translation of downstream open reading frames. Unlike normal cellular 7-methylguanosine cap-dependent translation, IRES-mediated translation can initiate at AUG codons far within an RNA molecule. The highly efficient process can be exploited for use in multi-cistronic expression vectors (Bochkov, Y. A. and A. C. Palmenberg (2006). "Translational efficiency of EMCV IRES in bicistronic vectors is dependent upon IRES sequence and gene location." Biotechniques 41(3): 283-284, 286, 288). Typically, two transgenes are inserted into a vector between a promoter and transcription terminator as two separate open reading

frames separated by an IRES. Upon delivery of the genetic vaccine to the cell, a single long transcript encoding both transgenes will be transcribed. The first ORF will be translated in the traditional cap-dependent manner, terminating at a stop codon upstream of the IRES. The second ORF will be translated in a cap-independent manner using the IRES. In this way, two independent proteins can be produced from a single mRNA transcribed from a vector with a single expression cassette.

Plasmid 449 (PSMA-mIRES-PSCA). Plasmid 449 was constructed using the techniques of overlapping PCR and restriction fragment exchange. First, the gene encoding full length human PSCA was amplified by PCR from plasmid 5259 with primers 124 and 123. The minimal EMCV IRES was amplified by PCR from pShuttle-IRES with primers 101 and 125. The overlapping amplicons were mixed together and amplified by PCR with primers 101 and 123. The IRES-PSCA amplicon was digested with Bgl II and BamH I and inserted into Bgl II-digested, CIP-treated plasmid 5166. In order to fix a spontaneous mutation within the IRES, the IRES containing Avr II to Kpn I sequence was replaced with an equivalent fragment from pShuttle-IRES.

Plasmid 603 (PSCA-pIRES-PSMA). Plasmid 603 was constructed using the techniques of PCR and seamless cloning. The gene encoding full length human PSCA attached at its 3'end to a preferred EMCV IRES was amplified from plasmid 455 by PCR with primers SD546 and SD547. The gene encoding human PSMA amino acids 15-750 was amplified by PCR from plasmid 5166 using primers SD548 and SD550. The two overlapping PCR amplicons were inserted into Nhe I and Bgl II-digested pPJV7563 by seamless cloning according to manufacturer's instructions (Invitrogen, Carlsbad, CA).

Plasmid 455 (PSCA-mIRES-PSA). Plasmid 455 was constructed using the techniques of overlapping PCR and restriction fragment exchange. First, the gene encoding human PSA amino acids 25-261 was amplified by PCR from plasmid 5297 with primers 115 and 114. The minimal EMCV IRES was amplified by PCR from pShuttle-IRES with primers 101 and 116. The overlapping amplicons were mixed together and amplified by PCR with primers 101 and 114. The IRES-PSA amplicon was digested with Bgl II and BamH I and inserted into Bgl II-digested, CIP-treated plasmid 5259. In order to fix a spontaneous mutation within this clone, the Bgl II to BstE II sequence was replaced with an equivalent fragment from a fresh overlapping PCR reaction.

EXAMPLE 4B. TRIPLE ANTIGEN DNA CONSTRUCTS

General Strategy. The abilities of the dual antigen expression vectors to direct the expression of PSMA, PSCA, and/or PSA were characterized in transfected HEK293

cells (Figures 4-6). A number of dual antigen expression cassettes, including PSA-F2A-PSMA, PSMA-mIRES-PSCA, PSMA-T2A-PSCA, PSA-T2A-PSCA, PSCA-F2A-PSMA, PSCA-pIRES-PSMA, and PSMA-mIRES-PSA, were selected for incorporation in various combinations into triple antigen expression vectors. In all cases, the vectors were based on the parental pPJV7563 plasmid backbone. Four vectors (plasmids 456, 457, 458, and 459) utilized a single full CMV promoter with a rabbit B globulin transcription terminator to drive expression of all three antigens. Two other vectors (plasmids 846 and 850) incorporated a dual promoter strategy in combination with either an IRES or 2A to drive expression of the three antigens. Vectors with multiple 2A cassettes were engineered to carry different cassettes to minimize the likelihood of recombination between the first and second cassette during plasmid/vector amplification. Antigen expression was demonstrated by flow cytometry (Figure 7) and western blotting (Figure 8).

Plasmid 456 (PSA-F2A-PSMA-mIRES-PSCA). Plasmid 456 was constructed by restriction fragment exchange. Plasmid 5300 was digested with Nhe I and Hpa I and the ~1.8 kb insert was ligated into similarly digested plasmid 449.

Plasmid 457 (PSA-F2A-PSMA-T2A-PSCA). Plasmid 457 was constructed by restriction fragment exchange. Plasmid 5300 was digested with Nhe I and Hpa I and the ~1.8 kb insert was ligated into similarly digested plasmid 451.

Plasmid 458 (PSA-T2A-PSCA-F2A-PSMA). Plasmid 458 was constructed using the techniques of PCR and restriction fragment exchange. The gene encoding human PSA amino acids 25-261 was amplified by PCR from plasmid 5297 with primers 119 and 139, resulting in the addition of a T2A sequence and Nhe I restriction site at the 3' end. The amplicon was digested with Nhe I and inserted into similarly digested plasmid 454.

Plasmid 459 (PSCA-F2A-PSMA-mIRES-PSA). Plasmid 459 was constructed by restriction fragment exchange. Plasmid 454 was digested with Nhe I and Bgl II and the PSCA-F2A-PSMA containing insert was ligated into similarly digested plasmid 455.

Plasmid 846 (CBA-PSA, CMV-PSCA-pIRES-PSMA). Plasmid 846 was constructed using the techniques of PCR and seamless cloning. First, an expression cassette was synthesized that consisted of 1) the promoter and 5' untranslated region from the chicken beta actin (CBA) gene, 2) a hybrid chicken beta actin / rabbit beta globin intron, 3) the gene encoding human PSA amino acids 25-261, and 4) the bovine growth hormone terminator. This PSA expression cassette was amplified by PCR from plasmid 796 with primers 3SalICBA and 5SalIBGH. The amplicon was cloned into the

SalI site of plasmid 603 using a GeneArt Seamless Cloning and Assembly Kit (Invitrogen, Carlsbad, CA). Upon delivery of this plasmid into a cell, PSA expression will be driven off the CBA promoter while PSCA and PSMA expression will be driven off the CMV promoter.

Plasmid 850 (CBA-PSA, CMV-PSCA-F2A-PSMA). Plasmid 850 was constructed using the techniques of PCR and seamless cloning. First, the CBA promoter-driven PSA expression cassette was amplified by PCR from plasmid 796 with primers 3SalICBA and 5SalIBGH. The amplicon was cloned into the *SalI* site of plasmid 454 using GeneArt Seamless Cloning. Upon delivery of this plasmid into a cell, PSA expression will be driven off the CBA promoter while PSCA and PSMA expression will be driven off the CMV promoter.

Table 20. List of Plasmids Expressing Multiple-Antigens

1st Antigen	Expression strategy	2nd Antigen	Expression strategy	3rd Antigen	Plasmid ID #
PSMA					5166
PSCA					5259
PSA					5297
PSMA	2 promoters	PSCA			460
PSMA	T2A	PSCA			451
PSCA	F2A	PSMA			454
PSA	F2A	PSMA			5300
PSMA	IRES	PSCA			449
PSCA	IRES	PSMA			603
PSCA	IRES	PSA			455
PSA	F2A	PSMA	mIRES	PSCA	456
PSA	F2A	PSMA	T2A	PSCA	457
PSA	T2A	PSCA	F2A	PSMA	458
PSCA	F2A	PSMA	mIRES	PSA	459
PSA	2 promoters	PSCA	pIRES	PSMA	796
PSA	2 promoters	PSCA	pIRES	PSMA	846
PSA	2 promoters	PSCA	F2A	PSMA	850

Table 21. List of Primers Used in the Construction of the Multi-antigen Plasmids

Primer	Sequence (5' to 3')	Strand
42	CGTTGACGCAAATGGGCGGTAGG	Sense
101	TCAGAGATCTGACCCCCTAACGTTACTGGC	Sense
114	TATAGGATCCTCAGGGGTTGGCCACGATG	Antisense
115	GAAAAACACGATGATAATATGGCCAGCATTGTGGGAGGCTGGGAGTG	Sense
116	CCACAATGCTGGCCATATTATCATCGTGTTTTTCAAAGGAAAACCACGTCC	Antisense
117	CATCTCCACAGGTCAATAATGAACCCCTACCTTCGGATCCGGCTACTTCACTCAAAGTC	Antisense
118	GTTCATTATTGACCTGTGGAGATGTCGAAGAAAACCCAGGACCCGCAAGCAAGGCTGTGCTGCTTGCCCTG	Sense
119	TTGCCTCTCACATCTCGTCAATCTCCGCGAGGAC	Sense
120	GATCTTTTGTACAATATGATCTTGTGGCAATGTCCC	Antisense
123	TATAGGATCCCTATAGCTGGCCGGGTCC	Antisense
124	CACGATGATAATATGGCCAGCAAGGCTGTGCTGCTTGCC	Sense
125	CACAGCCTTGCTGGCCATATTATCATCGTGTTTTTCAAAGGAAAACCACGTCC	Antisense
132	TATAGGATCCTAGCTGGCCGGGTCCCCAGAG	Antisense
139	ATATGCTAGCGGGTCCTGGGTTTTCTTCGACATCTCCACAGGTCAATAATGAACCCCTACCTTCGGATCCGGGGTTGGCCACGATGGTGTCC	Antisense
SD546	CTGTGACGAACATGGCTAGCAAGG	Sense
SD547	ATTATCATCGTGTTTTTCAAAGGAAAACC	Antisense
SD548	AAACACGATGATAATATGGCCACAACCATGGCGCGCCGCCCGC	Sense
SD550	TTTTGTTAGGGCCCAGATCTTTAGGC	Antisense
MD1	GACGAACATGGCTAGCATTGTGGGAGGCTG	Sense
MD2	CCACATCGCCTGCCAGTTTCAGCAGATCAAAGTTCAGGGTCTGGGATCCGGGGTTGGCCACGATGGTGTC	Antisense
MD3	GATCTGCTGAAACTGGCAGGCGATGTGGAAAGCAACCCAGGCCCAATGGCAAGCGCGCGCCGCCCGCGCTG	Sense
MD4	GTTAGGGCCCAGATCTTTAGGCTACTTCACTCAAAGTC	Antisense
MD5	CTTGTATTACTGTTTATGTAAGCAGACAGGGTACCAATATTGGCTATTGGCCATTGCATAC	Sense
MD6	GTATGCAATGGCCAATAGCCAATATTGGTACCCTGTCTGCTTACATAAACAGTAATACAAG	Antisense
MD7	CATGCATGGGTACCAATCTTCCGAGTGAGAGACACAAAAAATTCC	Sense
MD8	GATCGATCGGTACCCTGCAGGTCGAGCACCAAAATCAACGGG	Antisense
5SalIBGH	GTTTATGTAAGCAGACAGGTCGACCCATAGAGCCCACCGCATCCCCAGC	Antisense
3SalICBA	TGGCCAATAGCCAATATTGTCGACTGGGTCGAGGTGAGCCCCACGTTCTG	Sense

EXAMPLE 4C. TRIPLE ANTIGEN ADENOVIRUS CONSTRUCTS

General Strategy. As with DNA plasmids, viral vaccine vectors can be engineered to deliver multiple prostate cancer antigens. The three multi-antigen expression strategies described above for DNA vaccines - dual promoters, 2A peptides, and internal ribosome entry sites – were incorporated in various combinations to create triple antigen adenovirus vectors. Briefly, the multi-antigen expression cassettes were cloned into a pShuttle-CMV plasmid modified to carry two copies of the tetracycline operator sequence (TetO2). Recombinant adenovirus serotype 5 vectors were created using the AdEasy Vector System according to manufacturer's protocols (Agilent

Technologies, Inc., Santa Clara, CA). Viruses were amplified in HEK293 cells and purified by double cesium chloride banding according to standard protocols. Prior to in vivo studies, viral stocks were thoroughly characterized for viral particle concentration, infectivity titer, sterility, endotoxin, genomic and transgene integrity, transgene identity and expression.

Adenovirus-733 (PSA-F2A-PSMA-T2A-PSCA). Ad-733 is the viral equivalent of plasmid 457. Expression of the three antigens is driven off a single CMV promoter with a tetracycline operator for repressing transgene expression during large scale production in Tet repressor expressing HEK293 lines. Multi-antigen expression strategies include two different 2A sequences.

Adenovirus-734 (PSA-T2A-PSCA-F2A-PSMA). Ad-734 is the viral equivalent of plasmid 458. Expression of the three antigens is driven off a single CMV promoter with a tetracycline operator for repressing transgene expression during large scale production in Tet repressor expressing HEK293 lines. Multi-antigen expression strategies include two different 2A sequences.

Adenovirus-735 (PSCA-F2A-PSMA-mIRES-PSA). Ad-735 is the viral equivalent of plasmid 459. Expression of the three antigens is driven off a single CMV promoter with a tetracycline operator for repressing transgene expression during large scale production in Tet repressor expressing HEK293 lines. Multi-antigen expression strategies include a 2A sequence and an IRES.

Adenovirus-796 (CBA-PSA, CMV-PSCA-pIRES-PSMA). Ad-796 is the viral equivalent of plasmid 846. Expression of PSA is driven off the chicken beta actin promoter while PSCA and PSMA expression is driven off the CMV-TetO2 promoter. Multi-antigen expression strategies include two promoters and an IRES.

Adenovirus-809 (CBA-PSA, CMV-PSCA-F2A-PSMA). Ad-809 is the viral equivalent of plasmid 850. Expression of PSA is driven off the chicken beta actin promoter while PSCA and PSMA expression is driven off the CMV-TetO2 promoter. Multi-antigen expression strategies include two promoters and a 2A sequence.

EXAMPLE 5. IMMUNOGENICITY OF TRIPLE ANTIGEN DNA VACCINES

Example 5 illustrates the capability of triple antigen nucleic acid vaccine constructs expressing PSMA, PSCA and PSA to elicit antigen-specific T and B cell responses to all three encoded prostate antigens.

Cellular Immune Response Study. Immunogenicity of triple antigen constructs containing PSMA, PSCA and PSA, as described in Example 5, was studied in C57BL/6 mice according to the procedure described below.

Female C57BL/6 mice were primed on day 0 and boosted on days 14, 28 and 49 with DNA vaccine constructs encoding human -PSMA, PSCA and PSA antigens by PMED administration. In total, four different triple antigen vaccination strategies were evaluated, which included three DNA vaccines that co-expressed the target proteins and one co-formulation approach. For co-expression, single DNA plasmids encoding all three prostate antigens linked by 2A peptides or internal ribosome entry sites (IRES) were used as follows: PSA-F2A-PSMA-T2A-PSCA (plasmid ID#457), PSA-T2A-PSCA-F2A-PSMA (plasmid ID#458) and PSCA-F2A-PSMA-IRES-PSA (plasmid ID#459). For the co-formulation approach, three different DNA plasmids, each individually encoding PSMA, PSCA or PSA, were co-formulated onto a single gold particle for PMED delivery. With the exception of co-formulation, the DNA elements that control co-expression (2A and IRES) differ in length, transgene expression efficiency and the presence of foreign genetic material attached to the target transgenes. As controls, C57BL/6 mice were vaccinated with DNA expressing a single prostate antigen, either PSMA, PSCA or PSA. For the co-expressed triple or single antigen DNA vaccines, a dose 2μg of DNA vaccine plasmid was given per PMED administration, whereas 1μg of each of the co-formulated triple antigen DNA vaccines (a total of 3μg) was administered per PMED administration. Cellular immune responses against the triple and single antigen vaccines were measured by collecting the spleens from each animal on day 56, seven days after the final PMED vaccination. Splenocytes were isolated and subjected to an IFN-γ ELISPOT assay to measure the PSMA, PSCA and PSA-specific T cell responses. Briefly, $2x10^5$ splenocytes from individual animals were plated per well with $5x10^4$ per well of TRAMP-C2 (transgenic adenocarcinoma mouse prostate) cells stably expressing a single human prostate antigen or PSMA, PSCA and PSA together, or with individual or pools of human PSMA, PSCA and PSA-specific peptides at 10μg/ml (see Table 22 for peptides and peptide pool composition), or medium alone as a control. Each condition was performed in triplicate. The plates were incubated for 20h at 37°C and 5% CO_2, washed and developed after incubation as per the manufacturer's instructions. The number of IFN-γ spot forming cells (SFC) was counted by a Cellular Technology Ltd. (CTL) reader. The results are presented in Figures 9 and 10, which show the average number of PSMA, PSCA or PSA-specific SFCs +/- the standard deviation of five mice per group, normalized to $1x10^6$ splenocytes.

Table 22. The 15mer PSMA, PSCA and PSA peptides that were tested in the ELISPOT assay. The amino acid position of the N and C-terminal end of each peptide is indicated.

Prostate antigen	Peptides	Tested individually or pool
PSMA	577-591	Individual
PSMA	589-603	Individual
PSMA	601-615	Individual
PSMA	629-643	Individual
PSMA	641-655	Individual
PSMA	77-91	Pool 1
	91-111	
	153-167	
	229-243	
	365-379	
PSMA	401-415	Pool 2
	429-443	
	521-535	
	613-627	
PSMA	657-671	Pool 3
	685-699	
	701-715	
	733-747	
PSCA	25-39	Individual
PSA	65-79	Individual
PSA	73-87	Individual

Antibody Response Study. Antibody responses against the triple and single antigen vaccines were measured by collecting the serum from each animal on day 56, seven days after the final PMED vaccination. Serum was subjected to enzyme-linked immunosorbent assays (ELISA) to determine the anti-PSMA and anti-PSCA antibody titers. In brief, ELISA plates were coated with 1µg/ml of human PSMA or PSCA and incubated overnight at 4ºC. Plates were then blocked and incubated at RT for 1h with 1% bovine serum albumin (BSA). Each serum sample was serially diluted in duplicate starting at a 1:100 dilution and incubated for 1h at RT. After washing, a horseradish-peroxidise (HRP)-conjugated goat anti-mouse polyclonal IgG antibody was incubated at RT for 1h. After washing, the TMB Peroxidase EIA-Substrate was incubated at RT for 30min. The colorimetric reaction was stopped by addition 1N sulfuric acid and the absorbance then read at 450nm. Titration curves were plotted for each serum sample (sample dilution versus absorbance). The serum titer (subsequently transformed into reciprocal titer) was then taken as the most dilute serum sample tested with an optical density (OD) value of above the lower limit of detection (LLOD; background plus 3 standard deviations) or the serum dilution calculated to achieve an OD value of 1.0. The

results are presented in Figures 11 and 12, which show the average titers +/- the standard deviation of five mice per group.

Serum was also subjected to a fluorescence-activated cell sorting (FACS) assay to measure antibody binding to either human PSMA or PSCA expressed on the cell surface of appropriate cell lines, thus determining whether antibodies generated by the multi-antigen vaccines were capable of recognizing native PSMA and PSCA conformations, respectively. LNCaP (human prostate adenocarcinoma) cells were utilized to measure antibody binding to native PSMA. PC3 (human prostate cancer) cells served as a control in the FACS assay, as these cells do not express human PSMA. MIA-PaCa-2 (human pancreatic carcinoma) cells transduced with an adenovirus expressing human PSCA (Ad-PSCA) were utilized to measure antibody binding to native PSCA. Untransduced MIA-PaCa-2 cells served as the control. In brief, to measure anti-PSMA antibody binding, $2x10^5$ LNCaP or PC3 cells were incubated with a 1:100 dilution of mouse serum or 15µg/ml of the control mouse-anti-human PSMA monoclonal antibody (mAb) (clone J591-A) for 20 min at 4ºC. To measure anti-PSCA antibody binding, $2x10^5$ Ad-PSCA transduced and untransduced MIA-PaCa-2 cells were incubated with a 1:30 dilution of mouse serum or 4µg/ml of the control mouse anti-human PSCA mAb (clone 7F5) for 20 min at 4ºC. Subsequently, cells were washed and incubated with a secondary Phycoerythrin (PE)-conjugated goat-anti-mouse IgG antibody and a live/dead dye for an additional 20 min at 4ºC. After the incubation, cells were washed and resuspended in 1.5% paraformaldehyde, and 10,000 live cells were acquired on a FACS Canto II. The results are presented in Figures 13 and 14, which show the average fold change in mean fluorescence intensity (MFI) of the mouse serum over the secondary anti-mouse antibody alone +/- the standard deviation of five mice per group. Antibody titers were not measured because PSA was expressed as a cytoplasmic protein by the multi-antigen vaccines investigated in this study.

Results:

Figures 9A-9D show the results of a representative study that evaluates the cellular immune responses of the triple antigen vaccines by IFN-γ ELISPOT assay. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, seven days after the last PMED vaccination, recognition of the endogenous prostate antigens was assessed by examining T cell responses to (A) TRAMP C2-PSMA, (B) TRAMP C2-PSCA, (C) TRAMP C2-PSA, and (D) TRAMP C2-PSMA-PSA-PSCA cells by IFN-γ ELISPOT assay. The TRAMP C2 cells served as a background control for the assay. For IFN-γ T cell responses to endogenous PSMA, a

significant response to TRAMP C2-PSMA was observed following the single PSMA PMED vaccination, which was consistent with responses seen in other studies. Similar PSMA-specific IFN-γ T cell response to TRAMP C2-PSMA was detected following the triple antigen vaccinations. In contrast, complete ablation of the response was observed following co-formulated PSMA, PSCA and PSA vaccination (* indicates $p < 0.05$ by two-way ANOVA). For IFN-γ T cell responses to endogenous PSCA, no significant difference in response to the TRAMP C2-PSCA cells was observed when comparing the single PSCA vaccine to the four different triple antigen vaccines. For IFN-γ T cell responses to endogenous PSA, a significant decrease in the response magnitude to TRAMP C2-PSA was detected when comparing the immunogenicity of the single PSA vaccine to either PSCA-F2A-PSMA-IRES-PSA (*** indicates $p < 0.001$ by two-way ANOVA) or the co-formulated vaccine (* indicates $p < 0.05$ by two-way ANOVA). When examining the response to TRAMP C2-PSMA-PSCA-PSA, the highest magnitude IFN-γ T cell response was observed following the PSA-F2A-PSMA-T2A-PSCA vaccine. Taken together, these data demonstrate recognition of endogenous PSMA, PSCA and PSA and generation of antigen-specific T cell responses to all three prostate antigens using a co-expression DNA vaccination strategy, especially with the PSA-F2A-PSMA-T2A-PSCA vaccine construct. However, the co-formulation DNA vaccination strategy resulted in a loss of antigen-specific IFN-γ T cell responses to PSMA and PSA.

Figures 10A-10D show the results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by IFN-γ ELISPOT assay. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, T cell responses to (A) PSMA peptides, (B) PSMA peptide pools, (C) PSCA peptides and (D) PSA peptides (see Table 22) were assessed by IFN-γ ELISPOT assay. Medium alone served as a background control for the assay. For IFN-γ T cell responses to both the individual and pools of PSMA peptides, compared to the single PSMA vaccine, the highest magnitude response was observed following administration of the PSA-F2A-PSMA-T2A-PSCA triple antigen vaccine. Similarly, the highest magnitude IFN-γ T cell response to PSCA and PSA-specific peptides was detected following administration of the PSA-F2A-PSMA-T2A-PSCA vaccine. The co-formulated PSMA, PSCA and PSA vaccine resulted in low to no T cell responses to the PSMA-specific peptides and low magnitude responses to the PSCA and PSA-specific peptides. These data also demonstrate generation of T cell responses to PSMA, PSCA and PSA when co-expressed from the same vaccine construct. There was consistent and robust IFN-γ T cell responses to all three prostate antigens following PSA-F2A-PSMA-T2A-PSCA

vaccination, and significant decreases in the magnitude of IFN-γ T cell responses to the prostate antigens following PSA-T2A-PSCA-F2A-PSMA, PSMA-F2A-PSMA-IRES-PSA and co-formulated PSMA, PSCA and PSA vaccinations.

Figure 11 shows the results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSMA antibody titers. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, serum anti-PSMA antibody titers were assessed by ELISA. All animals vaccinated with PSMA generated significant anti-PSMA antibody titers. There were no significant differences between titers, although vaccination with PSA-F2A-PSMA-T2A-PSCA resulted in slightly lower titers compared to the other groups vaccinated with PSMA. These data demonstrate the generation of anti-PSMA-specific antibodies following triple antigen vaccination, using both co-expression and co-formulation vaccine strategies.

Figure 12 shows the results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSCA antibody titers. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, serum anti-PSCA antibody titers were assessed by ELISA. Antibody titers were detected in mice vaccinated with PSCA alone and co-formulated PSMA, PSCA and PSA. These results indicate that co-formulation of PSMA, PSCA and PSA elicits a detectable anti-PSCA antibody titer compared to the co-expressed DNA vaccination strategies.

Figure 13 shows the results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSMA antibody cell-surface binding. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, recognition of cell-surface native PSMA was assessed by serum antibody binding to LNCaP and PC3 cells. The PC3 cells served as a background control for the assay. PSA-F2A-PSMA-T2A-PSCA vaccination resulted in anti-PSMA antibodies with a significantly lower binding capacity to LNCaP cells compared to mice vaccinated with PSA-T2A-PSCA-F2A-PSMA and PSMA alone (* indicates p-value < 0.05 by one-way ANOVA). All other PSMA vaccinated groups showed no significant difference in anti-PSMA antibody binding. The fold-change over secondary antibody alone for the J591-A mAb was 45.3 (data not shown). Overall, these data demonstrate generation of anti-PSMA-specific antibodies that recognize native PSMA following triple antigen vaccination, using both co-expression and co-formulation DNA vaccination strategies.

Figure 14 shows the results of a representative study that evaluates the immunogenicity of the triple antigen vaccines by anti-PSCA antibody cell-surface binding. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, recognition of cell-surface native PSCA was assessed by serum antibody binding to Ad-PSCA transduced and untransduced MIA-PaCa-2 cells. The untransduced, parental cells served as a background control for the assay. With the exception of the single PSMA and single PSA cyto vaccines, all vaccine regimens with PSCA resulted in significant anti-PSCA antibody binding to Ad-PSCA transduced MIA-PaCa-2 cells compared to the parental cells. There were no significant differences in the anti-PSCA antibody binding to Ad-PSCA transduced MIA-PaCa-2 cells between the PSCA-vaccinated groups (one-way ANOVA, p-value > 0.05). The fold change over secondary antibody alone for the 7F5 mAb was 18.7 (data not shown). Overall, these data demonstrate the generation of anti-PSCA-specific antibodies that recognize native PSCA following triple antigen vaccination, using both co-expression and co-formulation DNA vaccination strategies.

EXAMPLE 6. IMMUNOGENICITY OF DUAL ANTIGEN VACCINES

The following examples are provided to illustrate the capability of dual antigen vaccines expressing two prostate antigens to elicit antigen-specific T and B cell responses to the two encoded prostate antigens.

6A. Immunogenicity of dual antigen vaccines containing PSMA and PSCA in C57BL/6:

Study procedure.

Cellular Immune Response Study. Female C57BL/6 mice were primed on day 0 and boosted on days 14, 28, 42 and 70 with human PSMA and PSCA expressing DNA by PMED epidermal injection. In total, five different dual antigen DNA vaccination strategies were evaluated, which included four DNA vaccines that co-expressed the antigens and one co-formulation approach. For co-expression, single DNA vaccine plasmids encoding two prostate antigens, PSMA and PSCA, linked by a dual promoter, 2A peptides or IRES were administered. These included PSMA-PSCA dual promoter (plasmid ID#460), PSMA-T2A-PSCA (plasmid ID#451), PSCA-F2A-PSMA (plasmid ID#454) and PSCA-IRES-PSMA (plasmid ID#603). For co-formulation, two different DNA plasmids, each individually encoding PSMA and PSCA, were co-formulated onto a single gold particle for PMED delivery. With the exception of co-formulation, the DNA elements that control co-expression (dual promoter, 2A and IRES) differ in length, transgene expression efficiency and the presence of foreign genetic material attached to

the target transgenes. As controls, C57BL/6 mice were vaccinated with DNA expressing a single prostate antigen, PSMA or PSCA. For the co-expressed dual or single antigen DNA vaccines, a total dose of 2μg of DNA vaccine was given per PMED administration, whereas 2μg of each DNA vaccine plasmid (total of 4μg of DNA per administration) was given for the co-formulation. Cellular immune responses of the dual and single antigen vaccines were measured by collecting the spleens from each animal on day 77, seven days after the final PMED vaccination. Splenocytes were isolated and subjected to an IFN-γ ELISPOT assay to measure the PSMA and PSCA-specific T cell responses. Briefly, $2x10^5$ splenocytes from individual animals were plated per well with $5x10^4$ per well of TRAMP-C2 cells expressing a single endogenous human prostate antigen or PSMA, PSCA and PSA together, or with individual or pools of human PSMA and PSCA-specific peptides at 10μg/ml (see Table 22 for peptides and peptide pool composition), or medium alone as a control. Each condition was performed in triplicate. The plates were incubated for 20h at 37°C and 5% CO_2, washed and developed after incubation as per the manufacturer's instructions. The number of IFN-γ SFC was counted by a CTL reader. The results are presented in Figures 15 and 16, which show the average number of PSMA or PSCA-specific SFCs +/- the standard deviation of five mice per group, normalized to $1x10^6$ splenocytes.

Antibody Response Study. Antibody responses against the dual and single antigen vaccines were measured by collecting the serum from each animal on day 77, seven days after the final PMED vaccination. The anti-PSMA and anti-PSCA antibody titers in the serum was determined using ELISA as described in Example 5.. The results are presented in Figures 17 and 18, which show the average titers +/- the standard deviation of five mice per group.

Serum was also subjected to a FACS assay to measure antibody binding to either human PSMA or PSCA expressed on the cell surface of appropriate cell lines, thus determining whether antibodies generated by the multi-antigen vaccines were capable of recognizing native PSMA and PSCA conformations, respectively. Antibody binding to cell-surface native PSA was not measured because PSA was expressed as a cytoplasmic protein by the multi-antigen vaccines investigated in this study. The FACS assay was conducted according to procedure as described in Example 5.. The results presented in Figures 19 and 20, show the average fold-change in MFI of the mouse serum over the secondary anti-mouse antibody alone +/- the standard deviation of five mice per group. Antibody titers and binding to cell-surface native PSA were not

measured because PSA was expressed as a cytoplasmic protein by the multi-antigen vaccines investigated in this study.

Results.

Figures 15A-165C show the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by IFN-γ ELISPOT assay. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28, 42 and 70. On day 77, recognition of endogenous PSMA and PSCA was assessed by examining T cell responses to (A) TRAMP C2-PSMA, (B) TRAMP C2-PSCA and (C) TRAMP C2-PSMA-PSA-PSCA cells by IFN-γ ELISPOT assay. The TRAMP C2 cells served as a background control for the assay. For IFN-γ T cell responses to endogenous PSMA, the magnitude of the response TRAMP C2-PSMA was significantly decreased following vaccination with PSMA-PSCA dual promoter, PSMA-T2A-PSCA, PSCA-IRES-PSMA and co-formulated PSMA PSCA compared to vaccination with PSMA alone (** and *** indicate p-values < 0.01 and < 0.001, respectively, by two-way ANOVA). However, the PSCA-F2A-PSMA vaccine construct elicited a similar magnitude IFN-γ T cell response to the TRAMP C2-PSMA cells as the single PSMA vaccine. For IFN-γ T cell responses to endogenous PSCA, significantly increased responses were observed following vaccination with several of the dual antigen vaccines, including PSMA-PSCA dual promoter, PSCA-F2A-PSMA, PSCA-IRES-PSMA and co-formulated PSMA PSCA compared to the PSCA vaccine alone (*, ** and *** indicate p-values of < 0.05, 0.01 and 0.001, respectively, by two-way ANOVA). The PSCA-T2A-PSMA vaccine construct elicited a similar magnitude IFN-γ T cell response to the TRAMP C2-PSCA cells as the single PSCA vaccine. Comparing the IFN-γ T cell responses to TRAMP C2-PSMA-PSA-PSCA, there were no significant differences between the groups vaccinated with different dual antigen vaccines. Taken together, these data demonstrate generation of PSMA and PSCA-specific T cell responses following dual antigen vaccination, using both co-expression and co-formulation DNA vaccination strategies.

Figures 16A-16C show the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by IFN-γ ELISPOT assay. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28, 42 and 70. On day 77, T cell responses to (A) PSMA peptides, (B) PSMA peptide pools and (C) PSCA peptides (see Table 22) were assessed by IFN-γ ELISPOT assay. Medium alone served as a background control for the assay. For IFN-γ T cell responses to both the individual and pools of PSMA peptides, the highest magnitude responses compared to the single PSMA vaccine were observed following the PSMA-T2A-PSCA and PSCA-F2A-PSMA

dual antigen vaccinations. A significant reduction in the IFN-γ T cell response to the individual PSMA peptides was observed following vaccination with PSMA-PSCA dual promoter, PSCA-IRES-PSMA and co-formulated PSMA PSCA. The IFN-γ T cell response to the PSCA-specific peptide was similar between the groups vaccinated with the different dual antigen vaccines. These data also demonstrate generation of T cell responses to both PSMA and PSCA when co-expressed on the same DNA vaccine construct, or delivered as a co-formulation.

Figure 17 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody titers. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28, 42 and 70. On day 77, serum anti-PSMA antibody titers were assessed by ELISA. All animals vaccinated with PSMA generated significant anti-PSMA antibody titers. Mice vaccinated with the dual vaccine construct, PSCA-F2A-PSMA, and the single PSMA vaccine generated significantly higher antibody titers compared to all other groups of mice vaccinated with PSMA (one-way ANOVA, p-value < 0.05). Vaccination with PSMA-PSCA dual promoter and co-formulated PSMA and PSCA resulted in higher antibody titers compared to mice that received the PSMA-T2A-PSCA vaccine. Taken together, these data demonstrate generation of anti-PSMA-specific antibodies following dual antigen DNA vaccination with PSMA and PSCA, using both co-expression and co-formulation vaccination strategies.

Figure 18 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody titers. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28, 42 and 70. On day 77, serum anti-PSCA antibody titers were assessed by ELISA. Mice vaccinated with the co-formulated PSMA and PSCA, and the single PSCA vaccine generated significantly higher antibody titers compared to all other groups of mice vaccinated with PSCA (one-way ANOVA). Vaccination with PSMA-PSCA dual promoter resulted in higher antibody titers compared to vaccination with PSMA-T2A-PSCA, PSCA-F2A-PSMA and PSCA-IRES-PSMA. These results indicate that co-expression or co-formulation of PSMA and PSCA elicits anti-PSCA antibodies.

Figure 19 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody cell-surface binding. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28, 42 and 70. On day 77, recognition of cell-surface native PSMA was assessed by serum antibody binding to LNCaP and PC3 cells. The PC3 cells served as a background

control for the assay. With the exception of the single PSCA vaccine, all vaccine regimens with PSMA resulted in significant anti-PSMA antibody binding to LNCaP cells compared to the control PC3 cells. There were no significant differences in the anti-PSMA antibody binding to LNCaP cells between the PSMA-vaccinated groups (one-way ANOVA, p-value > 0.05). The fold change over secondary antibody alone for the J591-A mAb was 45.3 (data not shown). These data demonstrate generation of anti-PSMA-specific antibodies that recognized native PSMA following dual antigen DNA vaccination, using both co-expression and co-formulation vaccination strategies.

Figure 20 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody cell-surface binding. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28, 42 and 70. On day 77, recognition of cell-surface native PSCA was assessed by serum antibody binding to Ad-PSCA transduced and untransduced MIA-PaCa-2 cells. The untransduced, parental cells served as a background control for the assay. With the exception of the single PSMA vaccine, all vaccine regimens with PSCA resulted in significant anti-PSCA antibody binding to Ad-PSCA transduced MIA-PaCa-2 cells compared to the control cells. There were no significant differences in the anti-PSCA antibody binding to Ad-PSCA transduced MIA-PaCa-2 cells between the PSCA-vaccinated groups (one-way ANOVA, p-value > 0.05). The fold change over secondary antibody alone for the 7F5 mAb was 18.7 (data not shown). Overall, these data demonstrate generation of anti-PSCA-specific antibodies that recognized native PSCA following dual antigen DNA vaccination, using both co-expression and co-formulation vaccination strategies.

6B. Immunogenicity of dual antigen vaccines containing either PSMA and PSA or PSCA and PSA in C57BL/6

Study Procedure.

Cellular Immune Response Study. Female C57BL/6 mice were primed on day 0 and boosted on days 14 and 28 with human PSMA, PSCA and PSA expressing DNA by PMED epidermal injection. In total, four different dual antigen vaccines strategies were evaluated, which included two co-expression approaches and two co-formulation strategies. For co-expression, a single DNA plasmid encoding two prostate antigens, PSMA and PSA linked a 2A peptide (plasmid ID#5300) or PSCA and PSA linked by IRES (plasmid ID#455) were administered. For co-formulation, plasmids individually encoding PSMA, PSCA or PSA were co-formulated onto a single gold particle for PMED delivery. Specifically, these included PSMA and PSA co-formulated and PSCA and PSA

co-formulated. As controls, C57BL/6 mice were vaccinated with DNA expressing a single prostate antigen, PSMA, PSCA or PSA. For the co-expressed dual or single antigen vaccines, a dose 2μg of DNA was given per PMED administration, whereas 2μg of each DNA vaccine plasmid (total of 4μg of DNA per administration) was given for the co-formulation. Cellular immune responses of the dual and single antigen vaccines were measured by collecting the spleens from each animal on day 35. Splenocytes were isolated and subjected to an IFN-γ ELISPOT assay to measure the PSMA, PSCA and PSA-specific T cell responses. Briefly, $2x10^5$ splenocytes from individual animals were plated per well with $5x10^4$ per well of TRAMP-C2 cells expressing a single endogenous human prostate antigen or PSMA, PSCA and PSA together, or with individual or pools of human PSMA, PSCA and PSA-specific peptides at 10μg/ml (see Table 22 for peptides and peptide pool composition), or medium alone as a control. Each condition was performed in triplicate. The plates were incubated for 20h at 37°C and 5% CO_2, washed and developed after incubation as per manufacturer's instructions. The number of IFN-γ SFC was counted by a CTL reader. The results are presented in Figures 21 and 22, which show the average number of PSMA, PSCA and PSA-specific SFCs +/- the standard deviation of five mice per group, normalized to $1x10^6$ splenocytes.

Antibody Response Study. Female C57BL/6 mice were primed on day 0 and boosted on days 14, 28 and 49 with human PSMA, PSCA and PSA expressing DNA by PMED. Antibody responses against the dual and single antigen vaccines were measured by collecting the serum from each animal on day 56, seven days after the final PMED vaccination. The anti-PSMA and anti-PSCA antibody titers in the serum was determined using ELISA assay as described in Example 5. The results are presented in Figures 23 and 24, which show the average titers +/- the standard deviation of five mice per group.

Serum was also subjected to a FACS assay to measure antibody binding to either human PSMA or PSCA expressed on the cell surface of appropriate cell lines, thus determining whether antibodies generated by the multi-antigen vaccines were capable of recognizing native PSMA and PSCA conformations, respectively. Antibody binding to cell-surface native PSA was not measured because PSA was expressed as a cytoplasmic protein by the multi-antigen vaccines investigated in this study. The FACS assay was conducted according to the procedure as described in Example 5. The results are presented in Figures 25 and 26, which show the average fold change in MFI of the mouse serum over the secondary anti-mouse antibody alone +/- the standard deviation of five mice per group. Antibody titers and binding to cell-surface native PSA

were not measured because PSA was expressed as a cytoplasmic protein by the multi-antigen vaccines investigated in this study.

Results.

Figures 21A-21D show the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by IFN-γ ELISPOT assay. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14 and 28. On day 35, recognition of endogenous PSMA, PSCA and PSA was assessed by examining T cell responses to (A) TRAMP C2-PSMA, (B) TRAMP C2-PSCA, (C) TRAMP C2-PSA and (D) TRAMP C2-PSMA-PSA-PSCA cells by IFN-γ ELISPOT assay. The TRAMP C2 cells served as a background control for the assay. For IFN-γ T cell responses to endogenously expressed PSMA on cells, no significant differences were observed between responses to TRAMP C2-PSMA following vaccination with dual antigens containing PSMA (PSA-F2A-PSMA and co-formulated PSMA and PSA) and PSMA alone. Likewise, for IFN-γ T cell responses to endogenous PSCA, there were no observed differences in response magnitude to TRAMP C2-PSCA between the dual PSCA-IRES-PSA and co-formulated PSCA and PSA vaccines compared to the single PSCA vaccine. For IFN-γ T cell responses to endogenous PSA, a significant increase in the response magnitude to TRAMP C2-PSA was detected when comparing the immunogenicity of the single PSA vaccine to either PSA-F2A-PSMA (*** indicates $p < 0.001$ by two-way ANOVA) and co-formulated PSMA and PSA (** indicates $p < 0.01$ by two-way ANOVA). There were no observed differences in response magnitude to TRAMP C2-PSA when comparing animals that received the dual PSCA and PSA vaccines to the single PSA vaccine. When examining the IFN-γ T cell response to TRAMP C2-PSMA-PSA-PSCA, there were no significant differences in the response between the groups vaccinated with different dual antigen vaccines. Taken together, these data demonstrate the generation of PSMA and PSA-specific T cell responses, as well as PSCA and PSA-specific T cell responses following dual antigen DNA vaccination, using both co-expression and co-formulation vaccine strategies.

Figure 22 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody titers. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, serum anti-PSMA antibody titers were assessed by ELISA. All animals vaccinated with PSMA generated significant anti-PSMA antibody titers. There was no significant difference in the antibody titers between mice vaccinated with PSA-F2A-PSMA, co-formulated PSMA and PSA, and PSMA alone (one-way ANOVA, p-value >

0.05). Taken together, these data demonstrate the generation of anti-PSMA-specific antibodies following dual antigen DNA vaccination with PSMA and PSA, using both co-expression and co-formulation vaccine strategies.

Figure 23 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody titers. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, serum anti-PSCA antibody titers were assessed by ELISA. All animals vaccinated with PSCA generated significant anti-PSCA antibody titers. There was no significant difference in the antibody titers between mice vaccinated with PSCA-IRES-PSA, co-formulated PSCA and PSA, and PSCA alone (one-way ANOVA, p-value > 0.05), although the antibody titers generated following PSCA-IRES-PSA vaccination trended lower than the other groups vaccinated with PSCA. These results indicate that co-expression or co-formulation of PSCA and PSA elicits anti-PSCA antibodies.

Figure 24 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSMA antibody cell-surface binding. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, recognition of cell-surface native PSMA was assessed by serum antibody binding to LNCaP and PC3 cells. The PC3 cells served as a background control for the assay. There were no significant differences in the anti-PSMA antibody binding to LNCaP cells between the PSMA-vaccinated groups (one-way ANOVA, p-value > 0.05). The fold change over secondary antibody alone for the J591-A mAb was 45.3 (data not shown). Overall, these data demonstrate the generation of anti-PSMA-specific antibodies that recognized native PSMA following dual antigen vaccination, using both co-expression and co-formulation vaccine strategies.

Figure 25 shows the results of a representative study that evaluates the immunogenicity of the dual antigen vaccines by anti-PSCA antibody cell-surface binding. Briefly, 5 mice per group were primed on day 0 and boosted with PMED on days 14, 28 and 49. On day 56, recognition of cell-surface native PSCA was assessed by serum antibody binding to Ad-PSCA transduced and untransduced MIA-PaCa-2 cells. The untransduced, parental cells served as a background control for the assay. All groups of mice vaccinated with PSCA demonstrated very low anti-PSCA antibody binding to Ad-PSCA transduced MIA-PaCa-2 cells. PSCA-IRES-PSA vaccination resulted in significantly decreased binding to Ad-PSCA transduced MIA-PaCa-2 cells compared to mice vaccinated with PSCA alone (* indicates $p < 0.05$ by one-way ANOVA). Taken

together, these data demonstrate that co-expression or co-formulation of PSCA and PSA results in very low recognition of native PSCA by anti-PSCA-specific antibodies.

EXAMPLE 7. IMMUNOGENICITY OF THE HUMAN PSMA MODIFIED ANTIGEN

Study design. The immune responses induced by DNA vaccination using a construct encoding an immunogenic PSMA polypeptide (the "human PSMA modified antigen" or "hPSMA modified") consisting 15-750 amino acids (aa) of the native human PSMA protein of SEQ ID NO: 1 were compared with those induced by the native human full-length PSMA protein (hPSMA full length). Groups of female C57BL/6 mice or female Pasteur (HLA-A2/DR1) transgenic mice were primed on day 0 and boosted on days 14, 28 by PMED administration with a 2µg dose of a DNA vaccine encoding either hPSMA full-length or hPSMA modified protein. Mice were bled and sacrificed on day 35 (7 days after the third vaccination) and T cell immune responses against the hPSMA full-length protein were determined in splenocytes by IFN- γ ELISPOT assay. For C57BL/6 mice, single cell suspensions of $5x10^5$ splenocytes from individual animals were plated per well with 10µg purified hPSMA protein, $5x10^4$ TRAMP-C2 cells alone, or TRAMP-C2 cells expressing hPSMA or a PSMA-PSA-PSCA fusion protein. For Pasteur (HLA-A2/DR1) transgenic mice, single cell suspensions of $5x10^5$ splenocytes from individual animals were plated per well with $5x10^4$ K562 cells expressing human HLA-A2 that had been pulsed with known HLA-A2-restricted $CD8^+$ T cell epitopes derived from the human PSMA protein sequence (Table 23). Responses in Pasteur mice were also determined using 10µg/ml purified PSMA protein or $5x10^4$ SK-Mel5 cells that had been transduced with Adenoviral vectors expressing a control protein (Ad-eGFP) or the full-length human PSMA protein (Ad-hPSMA). Each condition was performed in triplicate. The plates were incubated for 20h at 37°C and 5% CO_2, washed and developed after incubation as per the manufacturer's instruction. The number of IFN-γ SFC was counted by a CTL reader. The results are presented in Figures 19 and 20, which show the average number of PSMA-specific SFC/million splenocytes +/- the standard deviation per group.

ELISA assay. Antibody responses induced by the modified and full-length PSMA vaccines were measured in serum from each animal collected on day 35. Serum from was subjected to ELISA to determine the anti-PSMA antibody titers in the serum was determined using the ELISA assay as described in Example 5. The results are presented in Figure 26, which shows the average titers +/- the standard deviation of the number of mice per group.

FACS assay. Serum was also subjected to a FACS assay to measure antibody binding to either human PSMA expressed on the cell surface of appropriate cell lines, thus determining whether antibodies generated by the modified and full-length PSMA vaccines were capable of recognizing native PSMA conformation. The FACS assay was conducted according to the procedure as described in Example 5. The results are presented in Figure 29, which show the average fold change in MFI of the mouse serum over the secondary anti-mouse antibody alone +/- the standard deviation of the number of mice per group.

Table 23. HLA-A2 restricted peptide epitopes tested in the assays conducted for the Pasteur (HLA-A2/DR1) transgenic mice. Peptides were tested individually at a concentration of 10 μg/ml. The amino acid position of the N and C-terminal end of each peptide is indicated.

Prostate antigen	Peptides	Purpose
hHer2	106-114	HLA-A2-restricted control peptide derived from the human Her2 protein
PSMA	168-177	HLA-A2-restricted PSMA test peptide
PSMA	663-671	HLA-A2-restricted PSMA test peptide
PSMA	275-289	HLA-A2-restricted PSMA test peptide

Results. Figure 26 shows the results of a representative study to evaluate the T cell immune response elicited by the human PSMA modified (aa 15-750) versus full-length human PSMA (aa 1-750) in C57BL/6 mice determined by IFN-γ ELISPOT assay. Five (5) mice per group were primed on day 0 and boosted PMED with DNA vaccines expressing hPSMA modified or hPSMA full-length proteins on days 14 and 28. On day 35, the response elicited against the hPSMA full-length protein were compared by determining T cell responses to TRAMP C2-PSMA or purified human PSMA ECD protein (referred to Purified hPSMA protein in Fig. 26) by IFNγ ELISPOT assay. TRAMP C2 cells served as a background control for the assay. The magnitude of the IFN-γ T cell responses elicited to TRAMP C2-PSMA or purified hPSMA protein were not significantly different (two-way ANOVA, p-value > 0.05) between groups. These results indicate that the DNA vaccines expressing hPSMA modified and hPSMA full-length proteins elicit equivalent T cell immune responses in C57BL/6 mice.

Figures 27A and 27B show the results of a representative study to evaluate the T cell immune response of human PSMA modified antigen (aa 15-750) versus full-length human PSMA antigen (aa 1-750) in Pasteur (HLA-A2/DR1) transgenic mice by IFN-γ ELISPOT assay. Ten (10) mice per group were primed on day 0 and boosted PMED

with DNA vaccines encoding hPSMA modified or hPSMA full-length protein on days 14 and 28. On day 35, the T cell response elicited against the hPSMA full-length protein was determined by IFN- ELISPOT assay using (A) PSMA derived HLA-A2-restricted peptides representing known $CD8^+$ epitopes and (B) SK-Mel5 cells transduced with Ad-hPSMA or purified hPSMA full-length protein. The hHER2 106 peptide and SK-Mel5 Ad-eGFP served as negative controls in the assays. The hPSMA modified vaccine elicited the highest magnitude of IFN-γ T cell immune responses to the HLA-A2-restricted $CD8^+$ T cell epitopes, although the difference between groups was not significant (two-way ANOVA, p-value > 0.05). Similarly, the hPSMA modified vaccine elicited the highest magnitude of immune response against the SK-Mel5 cells transduced with Ad-hPSMA and significantly (two-way ANOVA, p-value > 0.05) higher frequencies of IFN-γ SFC to the purified hPSMA protein. These results demonstrate that the DNA vaccine expressing the hPSMA modified protein is more potent in inducing T cell responses to the hPSMA protein than the hPSMA full-length protein in Pasteur (HLA-A2/DR1) transgenic mice.

Figure 28 shows the results of a representative study that evaluates the immunogenicity of the human modified and full-length PSMA vaccines by anti-PSMA antibody titers. Briefly, mice were primed on day 0 and boosted with PMED on days 14 and 28. Nine Pasteur mice were vaccinated with modified PSMA, 10 Pasteur mice were vaccinated with full-length PSMA, and 5 C57BL/6 mice per group were vaccinated with either modified or full-length PSMA. On day 35, serum anti-PSMA antibody titers were assessed by ELISA. As expected, C57BL/6 mice generated significantly greater anti-PSMA antibody titers compared to Pasteur mice (one-way ANOVA). Comparing antibody titers between the same strains of mice, there was no significant difference in the antibody titers between mice vaccinated with modified and full-length PSMA (one-way ANOVA, p-value > 0.05). Overall, these results demonstrate that vaccination with the full-length version of human PSMA generates an equivalent anti-PSMA antibody titer compared to the human modified PSMA vaccine.

Figure 29 shows the results of a representative study that evaluates the immunogenicity of the human modified and full-length PSMA vaccines by anti-PSMA antibody cell-surface binding. Briefly, 5 C57BL/6 mice per group were primed on day 0 and boosted with PMED on days 14 and 28. On day 35, recognition of cell-surface native PSMA was assessed by serum antibody binding to LNCaP and PC3 cells. The PC3 cells served as a background control for the assay. There were no significant differences in the anti-PSMA antibody binding to LNCaP cells between mice vaccinated

with modified or full-length PSMA (one-way ANOVA, p-value > 0.05). The fold change over secondary antibody alone for the J591-A mAb was 14.3 (data not shown). Overall, these data demonstrate that it is feasible to generate anti-PSMA-specific antibodies that recognized native PSMA following either modified or full-length PSMA vaccination.

EXAMPLE 8. EFFECT OF ANTI-CTLA-4 ANTIBODY ON VACCINE-INDUCED IMMUNE RESPONSE

The effect of local administration of anti-CTLA-4 monoclonal antibody (CP-675, 206) on the immune responses induced by a human PSMA nucleic acid molecule provided by the invention was investigated in a monkey study, in which the immune response was assessed by measuring PSMA specific T cell responses using an IFNγ ELISPOT assay.

Animal Treatment and Sample Collection. Three groups of male Indian rhesus macaques, five to six (#1 to 5 or 6) per each test group, were immunized with a nucleic acid (SEQ ID NO: 10) that encodes a human PSMA modified antigen (SEQ ID NO: 9) delivered by adenovirus (1e11 V.P. injected intramuscularly) followed by 2 DNA immunizations (8 actuations/ immunization, 4 actuations per each right and left side of the lower abdomen) by PMED with 6 and 9 week intervals respectively. Animals in Groups 2 and 3 additionally received bilateral intradermal injections of 3 mg of CpG (PF-03512676) subsequently after the PMED immunization in proximity to each inguinal draining lymph node. Group 2 also received intravenous injections of anti-CTLA-4 monoclonal antibody (CP-675, 206) at 10 mg/kg and group 3 received intradermal injections of anti-CTLA-4 monoclonal antibody (CP-675, 206) at 5 mg/kg in proximity to each left and right inguinal vaccine draining lymph node at the time of the second PMED immunization.

Peripheral blood samples were collected from each animal sixteen days after the last PMED immunization. Peripheral blood mononuclear cells (PBMCs) were isolated from the samples and were subjected to an IFNγ ELISPOT assay to measure the PSMA specific T cell responses. Briefly, 4e5 PBMCs from individual animals were plated per well with pools of PSMA specific peptides each at 2ug/ml hPSMA ECD protein at 10ug/ml, rhesus PSMA ECD protein at 10ug/ml or nonspecific control peptides (human HER2 peptide pool) each at 2ug/ml in IFNγ ELISPOT plates. The composition of each of the PSMA specific peptide pools is provided in Table 24A. The plates were incubated for 16 hrs at 37 ^{o}C and 5% CO2 and washed and developed after incubation as per manufacturer's instruction. The number of IFNγ spot forming cells (SFC) were counted by CTL reader. Each condition was performed in duplicates. The results are presented

in Table 24B, which shows the average number of the PSMA specific SFC from the triplicates subtracting the average number of SFC from the nonspecific control peptides normalized to 1e6 PBMCs. ^ indicates that the count is not accurate because the numbers of spots were too numerous to count.

IFNγ ELISPOT Assay Procedure. A capture antibody specific to IFNγ (BD Bioscience, #51-2525kc) is coated onto a polyvinylidene fluoride (PVDF) membrane in a microplate overnight at 4^0C. The plate is blocked with serum/protein to prevent nonspecific binding to the antibody. After blocking, effector cells (such as splenocytes isolated from immunized mice or PBMCs isolated from rhesus macaques) and targets (such as PSMA peptides from peptide library, target cells pulsed with antigen specific peptides or tumor cells expressing the relevant antigens) are added to the wells and incubated overnight at 37^0C in a 5% CO_2 incubator. Cytokine secreted by effector cells are captured by the coating antibody on the surface of the PVDF membrane. After removing the cells and culture media, 100 µl of a biotinylated polyclonal anti-humanIFNγ antibody was added to each of the wells for detection. The spots are visualized by adding streptavidin-horseradish peroxidase and the precipitate substrate, 3-amino-9-ethylcarbazole (AEC), to yield a red color spot as per manufacturer's (Mabtech) protocol. Each spot represents a single cytokine producing T cell.

Results. Table 24B. shows the results of a representative IFNγ ELISPOT assay that evaluates and compares the T cell responses induced by the vaccine without (group 1) or with anti-CTLA-4 monoclonal antibody (CP-675, 206) given either systemically by intravenous injections (group 2) or locally by intradermal injections in proximity to the vaccine draining lymph node (group 3). As shown in Table 1B, PSMA vaccine induced measurable IFNγ T cell responses to multiple PSMA specific peptides and proteins in the absence of CpG (PF-03512676) and anti-CTLA-4 monoclonal antibody (CP-675, 206). The responses were modestly enhanced by the addition of CpG (PF-03512676) and systemic delivery of the anti-CTLA-4 antibody (CP-675, 206; group 2). However, a more potent and significant enhancement of the response to multiple PSMA peptides and PSMA protein was observed when the anti-CTLA-4 monoclonal antibody (CP-675, 206) was delivered locally by intradermal injections in proximity to the vaccine draining lymph node (group3).

Table 24A. PSMA peptide pools: Each peptide pool (i.e., P1, P2, P3, H1, H2, R1, and R2) is composed of 15mer peptides from either human PSMA protein (hPMSA protein)

or rhesus PSMA protein (rPMSA protein) sequences as indicated below. The amino acid position of the N and C-terminal end of each peptide is indicated.

P1	P2	P3	H1	H2	R1	R2
h 1-15	h 249-263	h 449-463	h 33-47	h 465-479	r 33-47	r 465-479
h 5-19	h 253-267	h 453-467	h 37-51	h 469-483	r 37-51	r 469-483
h 9-23	h 257-271	h 457-471	h 41-55	h 473-487	r 41-55	r 473-487
h 13-27	h 261-275	h 485-499	h 45-59	h 477-491	r 45-59	r 477-491
h 17-31	h 265-279	h 489-503	h 61-75	h 481-495	r 61-75	r 481-495
h 21-35	h 269-283	h 493-507	h 65-79	h 537-551	r 65-79	r 537-551
h 25-39	h 273-287	h 497-511	h 69-83	h 541-555	r 69-83	r 541-555
h 29-43	h 277-291	h 501-515	h 73-87	h 545-559	r 73-87	r 545-559
h 49-63	h 281-295	h 505-519	h 97-111	h 577-591	r 97-111	r 577-591
h 53-67	h 285-299	h 509-523	h 101-115	h 581-595	r 101-115	r 581-595
h 57-71	h 289-303	h 513-527	h 105-119	h 585-599	r 105-119	r 585-599
h 77-91	h 293-307	h 517-531	h 109-123	h 589-603	r 109-123	r 589-603
h 81-95	h 297-311	h 521-535	h 137-151	h 601-615	r 137-151	r 601-615
h 85-99	h 317-331	h 525-539	h 141-155	h 605-619	r 141-155	r 605-619
h 89-103	h 321-335	h 529-543	h 145-159	h 609-623	r 145-159	r 609-623
h 93-107	h 325-339	h 533-547	h 149-163	h 613-627	r 149-163	r 613-627
h 113-127	h 329-343	h 549-563	h 209-223	h 637-651	r 209-223	r 637-651
h 117-131	h 333-347	h 553-567	h 213-227	h 641-655	r 213-227	r 641-655
h 121-135	h 353-367	h 557-571	h 217-231	h 645-659	r 217-231	r 645-659
h 125-139	h 357-371	h 561-575	h 221-235	h 649-663	r 221-235	r 649-663
h 129-143	h 361-375	h 565-579	h 301-315	h 653-667	r 301-315	r 653-667
h 133-147	h 365-379	h 569-583	h 305-319	h 657-671	r 305-319	r 657-671
h 153-167	h 369-383	h 573-587	h 309-323	h 709-723	r 309-323	r 709-723
h 157-171	h 373-387	h 593-607	h 313-327	h 713-727	r 313-327	r 713-727
h 161-175	h 377-391	h 597-611	h 337-351	h 717-731	r 337-351	r 717-731
h 165-179	h 381-395	h 617-631	h 341-355	h 721-735	r 341-355	r 721-735
h 169-183	h 385-399	h 621-635	h 345-359	h 725-739	r 345-359	r 725-739
h 173-187	h 389-403	h 625-639	h 349-363	h 729-743	r 349-363	r 729-743

h 177-191	h 393-407	h 629-643	h 461-475	h 733-747	r 461-475	r 733-747
h 181-195	h 397-411	h 633-647				
h 185-199	h 401-415	h 661-675				
h 189-203	h 405-419	h 665-679				
h 193-207	h 409-423	h 669-683				
h 197-211	h 413-427	h 673-687				
h 201-215	h 417-431	h 677-691				
h 205-219	h 421-435	h 681-695				
h 225-239	h 425-439	h 685-699				
h 229-243	h 429-443	h 689-703				
h 233-247	h 433-447	h 693-707				
h 237-251	h 437-451	h 697-711				
h 241-255	h 441-455	h 701-715				
h 245-259	h 445-459	h 705-719				
		h737-750				

Table 24B. T cell responses induced by the vaccine without (Group 1) or with anti-CTLA-4 antibody Tremelimumab (CP-675, 206) given systemically by intravenous injections (Group 2) or local intradermal injections (Group 3).

Group	animal ID	recall antigen								
		P1	P2	P3	H1	H2	hPSMA protein	R1	R2	rPSMA protein
1. no immune modulator	#1	7.5	62.5	0.0	210.0	172.5	455.0	3.8	1.3	0.0
	#2	11.3	48.8	0.0	17.5	146.3	111.3	0.0	3.8	0.0
	#3	12.5	342.5	13.8	115.0	517.5	705.0	12.5	40.0	138.8
	#4	6.3	23.8	0.0	211.3	38.8	45.0	5.0	7.5	7.5
	#5	0.0	16.3	0.0	0.0	52.5	45.0	0.0	0.0	0.0
	#6	6.3	442.5	21.3	42.5	238.8	736.3	11.3	8.8	93.8
2. with aCTLA4 (IV)	#1	23.8	57.5	1.3	71.3	292.5	278.8	6.3	6.3	0.0
	#2	0.0	61.3	0.0	2.5	108.8	78.8	0.0	6.3	3.8
	#3	58.8	41.3	7.5	1063.8	82.5	1197.5	22.5	7.5	1.3
	#4	25.0	318.8	27.5	147.5	983.8	1046.3	26.3	86.3	2.5
	#5	15.0	312.5	5.0	402.5	573.8	707.5	97.5	25.0	20.0
3. with aCTLA4 (ID)	#1	48.8	1236.3^	38.8	405.0	1236.3^	1236.8^	218.8	490.0	1120.0
	#2	113.8	946.3	17.5	293.8	1247.5^	1247.5^	162.5	86.3	5.0
	#3	16.3	1248.8^	6.3	465.0	1248.8^	1248.8^	187.5	295.0	11.3
	#4	6.3	828.8	6.3	1006.3	1247.5^	1247.5^	142.5	30.0	17.5
	#5	152.5	566.3	18.8	757.5	1173.8	1242.5^	287.5	57.5	110.0

EXAMPLE 9. SYSTEMIC EXPOSURE OF CTLA-4 ANTIBODY AFTER ADMINISTRATION IN MONKEYS

The blood levels of anti-CTLA-4 antibody Tremelimumab (CP675206) were investigated in Indian *Rhesus macaques* after the antibody was administered by intradermal or intravenous injections.

Animal Treatment and Sample collection. Three animals per treatment group were injected with the anti-CTLA-4 antibody Tremelimumab at 10mg/kg, either with a single intravenous injection into the saphenous vein or multiple 0.2 ml intradermal bilateral injections in the upper thigh in proximity to the inguinal draining lymph nodes. Blood samples were collected at 0, 1, 2, 4, 8, 12, 24, and 48 hrs post injection into 2.0 ml vaccutainer tubes containing lithium heparin as the anticoagulant. Plasma was

collected from the supernatant in the vaccutainer tubes after centrifugation at 1500xg at 4^0Cfor 10 min. The levels of Tremelimumab in the plasma was measured by a quantitative ELISA assay according to the procedure provided below.

Tremelimumab Quantitative ELISA Assay Procedure. The 384-well high bind assay plates (VWR-Greiner Bio-One Cat#82051-264) were coated with 25µl/well of CD-152 (CTLA-4; Ancell Immunology Research Products Cat# 501-020) at 1.0µg/ml in 100mM carbonate-bicarbonate coating buffer and incubated overnight at 4°C. Plates were washed x6 with 1xPBS-Tween (0.01M PBS pH 7.4/ 0.05% Tween 20) and blocked using 40µL/ well of 5%FBS/ 1xPBS-Tween and incubated shaking at 600 rpm RT for 1 hour. Standards were prepared by making the following dilutions of Tremelimumab: 200, 67, 22, 7.4, 2.5, 0.82, 0.27, 0.09 and 0.03 ng/mL. The samples were diluted to 1:100, 1:1,000 and 1:10,000. The diluent consisted of 1% naive cynomolgus macaque sera and 5% FBS in 1xPBS-Tween (0.01M PBS pH 7.4/ 0.05% Tween 20). 25µL/ well of each standard, sample and diluent control were transferred in duplicate into the plate and incubated shaking at 600 rpm RT for 1 hour. After washing x 6 with 1xPBS-Tween, 25µL/ well of secondary antibody (goat anti-human IgG HRP, Southern Biotech Cat# 9042-05) at a 1:5,000 dilution with 1xPBS-Tween was added and then incubated shaking at 600 rpm room temperature for 1 hour. After washing x 6 with 1xPBS-Tween, 25µL/ well of TMB Peroxidase EIA-Substrate (solution A+B) (Bio-Rad Cat#172-1067) were added and the plates were incubated at RT for 4 minutes. The colorimetric reaction was stopped by addition of 12.5µL/ well 1N Sulfuric acid and the absorbance then read at 450nm. The amount of Tremelimumab in each sample was quantified using the standard curve with 0.27 to 67 ng/mL used as the quantitative range.

Results. The plasma anti-CTLA-4 levels from a representative study are presented in Fig. 30. As shown, intradermal injection of the anti-CTLA-4 antibody Tremelimumab displays a slower release kinetics of the antibody in the blood and a lower systemic exposure (AUC_{0-24}= 4.9 x10^6 ng·hr/ml) profile than intravenous injections (AUC_{0-24}= 7.2 x10^6 ng·hr/ml).

EXAMPLE 10. EFFECT OF ANTI-CTLA-4 ANTIBODY ON VACCINE-INDUCED IMMUNE RESPONSES IN MICE

Study Procedure. Female BALB/c mice, 6 per group, were primed and boosted with rHer-2 expressing DNA by PMED separated by a four week interval. 150 µg of the monoclonal antibody specific to mouse CTLA-4 (clone 9H10, Bioxcell or #BE0131) or isotype control monoclonal antibodies (Bioxcell #BE0091) was administered on the days of PMED actuation and 100 µg on the days after PMED by local intradermal or systemic

intraperitoneal injections as indicated in the legends. The polyfunctional (multi-cytokine positive) T cell immune responses were measured from splenocytes isolated from individual mice 7 days after the last PMED immunizations by ICS assay. After a 5hr stimulation with a vaccine specific epitope peptide (rHer-2 specific antigen specific CD8 (p66), CD4 (p169) epitope or irrelevant peptide HBV (core antigen p87)) at 10μg/ml, the splenocytes were first stained for CD4, CD3 and CD8 which was followed by permeabilization and staining for IFNα, TNFα and IL-2 expression that was analyzed by flow cytometry. The total number of antigen specific single, double or triple cytokine positive T cells per total spleen of each animal is calculated by subtracting the responses to the irrelevant peptide HBV from the vaccine specific responses and normalized by the total number of splenocytes isolated per spleen.

Results. Figures 31A and 31B show the results of a representative study that evaluates the immunomodulatory activity of anti-CTLA-4 monoclonal antibody (clone 9H10) on the quality of the vaccine induced immune responses by intracellular cytokine staining assay. Seven days after the last PMED, significant increases in antigen specific single and double cytokine positive CD8 T cell responses by the local intradermal delivery of anti-CTLA-4 and double and triple cytokine positive CD8 T cell responses by the systemic delivery was observed. Additionally, significant increases in antigen specific single cytokine positive CD4 T cells by intradermal delivery and double cytokine positive cells by systemic delivery of anti-CTLA-4 was observed (*indicates $P<0.05$ by Student's T-test).

EXAMPLE 11. SYNERGISTIC EFFECT OF SUNITINIB IN COMBINATION WITH AN ANTI-CANCER VACCINE

Study Procedure. The Anti-tumor efficacy of sunitinib malate in combination with an anti-cancer DNA vaccine was investigated in BALB/neuT transgenic female mice. Heterozygote BALB/neuT transgenic female mice that express rat Her-2 (rHer-2) tumor associate antigen were implanted subcutaneously with 1e6 TUBO cells expressing rHer-2 which are derived from the spontaneous mammary tumors of BALB/neuT mice. After 7days post tumor cell implantation, the mice were dosed once a day orally with either vehicle or sunitinib malate at doses as indicated in the legends. Three days after the initiation of sunitinib malate therapy, the mice were immunized with regimens comprised of either (a) control vaccine that expresses an antigen that is not expressed in the tumor or the mouse or (b) DNA cancer vaccine construct that expresses a rat Her-2 antigen of SEQ ID NO: 54 (rHER2) which is expressed in the tumor and the mouse. The tumor growth rate was analyzed by measuring the long (a) and short diameter (b) of the

subcutaneous TUBO tumors twice a week and calculating the volume as a x b^2x 0.5 mm^3. The average and standard error of the mean of the tumor volumes from 10 mice per each treatment group are plotted against the days after tumor implantation.

Results. Figure 32 shows the results of a representative study that evaluates and compares the subcutaneous tumor growth rate upon treatment with sunitinib malate as a monotherapy or in combination with the DNA cancer vaccine. While the tumors from mice that received the DNA cancer vaccine (rHER2: intramuscular injection of 1e9 V.P. of rHer-2 expressing adenovirus followed by two biweekly actuations of rHer-2 expressing DNA by PMED) continued to grow rapidly, the tumors from mice that received sunitinib malate at either 20 mg/kg or 40 mg/kg doses with control vaccines (control: intramuscular injection of 1e9 V.P. of eGFP expressing adenovirus followed by two biweekly, actuations of HBV core antigen expressing DNA by PMED) significantly decreased the tumor growth rate, with 20 mg/kg displaying suboptimal efficacy compared to the 40 mg/kg dose. However when the cancer vaccine was co-administered with the suboptimal dose of sunitinib malate at 20 mg/kg, the tumors grew at a much slower growth rate than in mice treated with the same dose of sunitinib malate co-administered with a control vaccine and similar to that of mice treated with sunitinib malate at a higher dose. Cancer vaccine provides additional therapeutic benefit to mice that received suboptimal doses of sunitinib malate.

Figures 33A-33D show the individual tumor growth rates of mice from a representative study that evaluates and compares the anti-tumor efficacy of sunitinib malate at 20mg/kg with control (control) or the DNA cancer vaccine (rHER2). Briefly, after 7days post tumor cell implantation, ten mice per treatment group were daily orally dosed with either vehicle or 20mg/kg sunitinib malate (Sutent) for 34 days. Three days after the initiation of Sutent dosing, a series of immunizations, primed by Adenovirus followed by PMED, were initiated that continued after the discontinuation of Sutent therapy. Specifically the mice were immunized with either control vaccine comprised of an intramuscular injection of 1e9 V.P. of eGFP expressing adenovirus subsequently followed by two biweekly, two 9 days and four weekly actuations of DNA expressing HBV core and surface antigens by PMED or cancer vaccine comprised of rHer-2 expressing adenovirus and DNA instead. The tumors of the animals that received vehicle with the control vaccine became measurable around day 7 and continued growing reaching 2000 mm^3 after 50 days post tumor implant. The tumor growth of the animals that received Sutent with control vaccine was significantly impaired until Sutent therapy was discontinued. The tumors displayed a rapid growth rate immediately after

the discontinuation of Sutent, the majority reaching 2000 mm^3 after 50 days post tumor implant. The tumor growth rate of animals that only received the cancer vaccinations was modestly slower than the animals that did not receive cancer vaccine or Sutent. The combination of cancer vaccine with Sutent not only suppressed the tumor growth during Sutent therapy (Figure 33) but also significantly impaired the progression of the tumor in 60 % of the animals after discontinuation of Sutent treatment.

Figure 34 shows the Kaplan-Meier survival curve of the groups of mice from the study described in Fig 2B that evaluates the anti-tumor efficacy of Sutent with the control (control) or cancer vaccine (rHER2). The mice were sacrificed when the tumor volume reached 2000mm^3 according to IAUCUC guidelines. Only mice treated with Sutent (at 20mg/kg) and cancer vaccine displayed a significantly prolonged survival compared to mice either treated with vehicle and control vaccine, cancer vaccine without Sutent or Sutent without cancer vaccine (*P<0.01 by Log-rank Test).Figures 35A–35D show the percentage of myeloid derived suppressor cells (Gr1+CD11b+) and Treg containing CD25+CD4+ cells in the periphery blood from mice treated in Fig 2B. Briefly, PBMCs were stained and analyzed by flow cytometry for the expression of Gr1, CD11b, CD3, CD4, and CD25 from submandibular bleeds of five mice from each group on d27 (20 days post the initiation of Sutent or vehicle treatment). The mean and standard error of the mean of each treatment group is shown. A statistically significant reduction of % myeloid derived suppressor cells was observed in mice that were treated by Sutent with either control or cancer vaccine compared to mice that did not receive Sutent nor cancer vaccine (vehicle+control). However significantly lower myeloid derived suppressor cells were observed in mice treated with the combination of Sutent with cancer vaccine (Sutent+rHER2) compared to mice that were treated with cancer vaccine without Sutent (vehicle+rHER2) or Sutent without cancer vaccine (Sutent+control). A statistically significant reduction of Treg containing CD25+ CD4+ T cells in the CD4 population was observed by Sutent with cancer vaccine. These mice had significantly lower % of Treg containing CD25+ CD4+ T cells in the CD4 population than mice that were treated with cancer vaccine without Sutent or Sutent without cancer vaccine in their blood. * indicates P<0.05 by Student's T-test.

Figures 36A-36C show the total number of myeloid derived suppressor cells (Gr1+CD11b+), Tregs (CD4+CD25+Foxp3+) and PD-1+ CD8 T cells isolated from tumors of mice. Briefly, the mice were given a single daily oral dose of either vehicle or Sutent at 20mg/kg three days after implantation with TUBO cells for 28 days. The same mice were immunized with either control vaccine comprised of an intramuscular injection

of 1e9 V.P. of eGFP expressing adenovirus subsequently followed by two biweekly administrations of DNA expressing HBV core antigen delivered by PMED or cancer vaccine comprised of rHer-2 expressing adenovirus and DNA. An intradermal injection of 50 μg of CpG (PF-03512676) was given with the PMED administrations in proximity to the right side inguinal draining lymph node. Seven days after the second PMED and CpG administration, individual tumors were isolated, from 6 mice per treatment group. The single cell suspension prepared from the isolated subcutaneous tumors were stained by antibodies specific for Gr1, Cd11b, CD3, CD8, CD25, FoxP3, and PD-1 and analyzed by flow cytometry. The mean and standard error of the mean of the total number of specific cells as indicated in the figures per μg of tumor from each treatment group is plotted. (*indicates $P<0.05$ by Student's T-test) While there was no significant difference in the frequency of immune suppressive Tregs or MDSC found in the tumor when mice were given cancer vaccine (A and B) compared to mice that received control vaccine (A and B), a significant reduction was observed when the mice were treated with Sutent (A and B) compared to mice that received cancer vaccine only. A reduction of PD-1+CD8 T cells was also observed in mice that were treated with Sutent (C) compared to mice that received cancer vaccine (C) only. Taken together, these data demonstrate that agents that reduce Tregs, MDSCs or CD8+PD-1+Tcells in combination with the vaccine would be beneficial in reducing tumor burden in tumor bearing animals.

EXAMPLE 12. ANTI-CANCER EFFICACY OF VACCINE IN COMBINATION WITH SUNITINIB AND ANTI-CTLA-4 ANTIBODY

The anti-tumor efficacy of a cancer vaccine in combination with sunitinib and anti-CTLA-4 monoclonal antibody (clone 9D9) was investigated in subcutaneous TUBO tumor bearing BALB/neuT mice.

Study Procedure. Briefly, ten mice per each group were daily orally dosed with either vehicle or sunitinib malate at 20 mg/kg starting at day 10 post tumor implant until day 64. Vaccination with DNA constructs that either encode no antigen (control vaccine) or a rat Her-2 antigen of SEQ Id NO: 54 (cancer vaccine) as adenovirus vectors initiated on day 13 subsequently followed by two weekly immunizations, two biweekly immunizations, and seven weekly immunizations of respective antigens (HBV antigens or rHer-2) by DNA. The groups of mice (closed circle and open triangle) that were treated with anti-murine CTLA-4 monoclonal antibody were intraperitoneally injected with 250 μg of the antibody on day 20, 27, 41, 55, 62, 69, 76, 83, 90, and 97 right after the PMED injections.

Results. Figure 37 shows the Kaplan-Meier survival curve of the groups of mice from a representative study evaluating the anti-tumor efficacy of sunitinib and anti-murine CTLA-4 monoclonal antibody (clone 9D9) in combination with a cancer vaccine. Increased survival time was observed in mice treated with Sutent with control vaccine (open circle), anti-murine CTLA-4 monoclonal antibody (open triangle) or cancer vaccine (closed triangle). A further increase of survival was observed in mice treated with Sutent and cancer vaccine in combination with anti-murine CTLA-4 (closed circle). P values were calculated by log-rank test.

EXAMPLE 13. SYSTEMIC EXPOSURE OF SUNITINIB AND ANTI-CANCER EFFICACY OF ANTI-CANCER VACCINE IN COMBINATION WITH LOW DOSE SUNITINIB

Sunitinib Systemic Exposure Study.

The kinetics of blood sunitinib was investigated in BALB/neuT mice with subcutaneous TUBO tumors. Briefly, 20 mice per each treatment group were given Sutent orally, at 20mg/kg once a day (SID) or at 10mg/kg twice a day (BID) with 6 hr intervals, 6 days after tumor implantation. Submandibular blood from 2-3 mice was collected into lithium heparin tubes at several time points after Sutent dosing as indicated (0, 2, 4, 6, 8, 10, 12, and 24hr). The plasma supernatant was recovered from the tubes after centrifugation at x1000g for 15 min. and the sunitinib levels from the plasma samples were measured by LC/MS/MS. The mean and standard error of the mean of each group at each time point is plotted.

Results are presented in Figure 38. The mean and standard error of the mean of each group at each time point is plotted. The dotted horizontal line marks the minimum sunitinib blood level, 50ng/ml, that is necessary to effectively inhibit tumor growth in monotherapy (Mendel, D., et al.: "In vivo antitumor activity of SU11248, a novel tyrosine kinase inhibitor targeting vascular endothelial growth factor and platelet-derived growth factor receptors: determination of a pharmacokinetic/ pharmacodynamic relationship". Clinical Cancer Research, 203, 9:327-337). As shown, the blood suntinib levels in the mice that received either 20mg/kg SID or 10mg/kg BID only maintain the target effective dose of 50ng /ml that effectively inhibits tumor growth transiently within 24hr. The blood levels in 20 mg/kg SID group peaked above 50 ng/ml at 2hrs, dropped to 50ng/ml at 6hrs and cleared the blood by 12 hrs post Sutent dosing he levels in the group that received 10 mg/kg BID peaked above 50ng/ml at 2hrs but rapidly dropped below 50 ng/ml by 4hrs that peaked again 2 hrs after the second dose. The levels rapidly dropped to 50ng/ml by 4hrs and cleared the blood by 18 hrs after the second dose. Despite the

bi-daily dosing regimen, the animals that received 10mg/kg, remained to display lower duration of exposure at target concentration than the 20mg/kg single daily dosing regimen.

Anti-tumor Efficacy Study.

Anti-tumor efficacy of long term administration of low dose sunitinib in combination with an anti-cancer vaccine was investigated in BALB/neuT mice with subcutaneous TUBO tumors. Briefly, the mice were given sunitinib malate (Sutent) for 31days at 20 mg/kg SID or for 104 days at 10 mg/kg BID and received either control vaccine or cancer vaccine. The control vaccine, which delivers no antigen, and the cancer vaccine, which delivers a rat her-2 antigen (rHer-2) of SEQ ID NO: 54, was given by adenovirus on day 9 subsequently followed by five biweekly administrations of the DNA by PMED delivering HBV antigens or rHer-2 respectively.

The results are presented in Figure 39. While the cancer vaccine improved the survival of mice given Sutent at 20 m/kg, there was even significant improvement of the survival of mice given Sutent at 10 mg/kg (*P=0.05 by Log rank test).

EXAMPLE 14. EFFECT OF CPG OR CD40 AGONIST ON THE IMMUNE RESPONSES INDUCED BY CANCER VACCINE

Immunogenicity Studies in BALB/c Mice

The effect of local administration of immune modulators on the magnitude and quality of antigen specific immune responses induced by a cancer was investigated in BALB/c mice, in which the immune response was assessed by measuring rHER2 specific T cell responses using the IFNγ ELISPOT assay or intracellular cytokine staining assay. Briefly, 4 to 6 female BALB/c mice per group as indicated were immunized with DNA plasmid expression constructs encoding rHER2 antigen sequences (SEQ ID NO:54) by PMED delivery system. The immune modulators, CpG7909 (PF-03512676) and anti-CD40 monoclonal agonistic antibody, were administered locally by intradermal injections in proximity to the vaccine draining inguinal lymph node subsequently after the PMED actuations. Antigen specific T cell responses were measured by IFNγ ELISPOT or intracellular cytokine staining assay according to the procedure described below.

Intracellular Cytokine Staining (ICS) Assay

The rHer-2 specific polyfunctional (multi-cytokine positive) T cell immune responses were measured from splenocytes or PBMCs isolated from individual animals by ICS assay. Typically 1e6 splenocytes were incubated with Brefeldin A at 1μg/ml and peptide stimulant (rHer-2 specific CD8 p66, rHer-2 specific CD4 p169 or irrelevant HBV

p87) at 10 μg/ml for 5hr at 37^{0}C in a 5% CO_2 incubator. After the stimulation, the splenocytes were washed and blocked with Fcγ block (anti-mouse CD16/CD32) for 10 min. at 4^{0}C followed by a 20min staining with Live/dead aqua stain, anti-mouse CD3ePE-Cy7, anti-mouse CD8a Pacific blue, and anti-mouse CD45R/B220 PerCP-Cy5.5. The cells were washed, fixed with 4% paraformaldehyde overnight at 4^{0}C, permeabilized with BD fix/perm solution for 30 min at RT and incubated with anti-mouse IFNγ APC, anti-mouse TNFα Alexa488 and anti-mouse IL-2 PE for 30 min at RT. The cells were washed and 20, 000 CD4 or CD8 T cells were acquired for analysis by flow cytometry. The total number of antigen specific single, double or triple cytokine positive T cells per total spleen of each animal is calculated by subtracting the rHer-2 specific responses to the irrelevant peptide HBV from the vaccine specific responses and normalized to the total number of splenocytes isolated from the spleen.

IFNγ ELISPOT Assay Results

Figure 40 shows the IFNγ ELISPOT results from groups of mice from a representative study evaluating the magnitude of antigen specific T cell responses induced by the rHER2 vaccine when given with the immune modulators as indicated. Briefly, each mouse per treatment group (n=4) was immunized with DNA plasmid expression constructs encoding rHER2 antigen sequences (SEQ ID NO:54) by PMED immediately followed by either 100ug of control rat IgG monoclonal antibody (Bioxcell #BE0089: control mAb) or 50μg CpG7909 or 100ug of anti-CD40 monoclonal antibody (Bioxcell #BE0016-2: a-CD40 mAb) as indicated. The antigen specific immune responses were measured by IFNγ ELISPOT assay from 5e5 splenocytes mixed with control or rHer-2 specific p66 peptides at 10μg/ml concentration, 7 days after the PMED actuation. The number of total IFNγ secreting cells from splenocytes containing1e5 CD8 T cells were calculated from the ELISPOT results from individual animals and the % of CD8 T cells in splenocytes and mean and standard mean of error of each group are plotted. As shown, both CpG7909 and the anti-CD40 monoclonal antibody both significantly enhanced the magnitude of antigen specific immune responses induced by rHer-2 DNA compared to mice that received control antibodies.

Intracellular Cytokine Staining (ICS) Assay Results. Figures 41A and 41B show the results of a representative study that evaluates the immunomodulatory activity of CpG 7909 on the quality of the vaccine induced immune responses by intracellular cytokine staining assay. Briefly, each animal was immunized twice with the DNA plasmid expression constructs encoding rHER2 antigen sequences (SEQ ID NO:54)

delivered by PMED with a 4-week interval. The mice in each group (n=5) were given intradermal injections of either PBS (PMED group) or 50μg of CpG 7909 (PMED+CpG group) in proximity to the right side vaccine draining inguinal node immediately following both DNA immunizations by PMED. Seven days after the last immunization by PMED, an ICS assay was performed on the splenocytes isolated from each individual mice to detect antigen specific polyfunctional CD8 or CD4 T cells that secrete IFNγ, TNFα and/ or IL-2. A significant increase in rHer-2 specific multi-cytokine positive CD8 and CD4 T cell responses were detected from mice treated with the local delivery of CpG 7909 compared to PBS. An increase in the single cytokine positive CD8 population was observed in the animals that received local delivery of CpG7909 administration compared to PBS (*indicates P<0.05 by Student's T-test).

Figures 42A and 42B show the results of a representative study that evaluates the immunomodulatory activity of an agonistic anti-CD40 monoclonal antibody on the quality of the vaccine induced immune responses by intracellular cytokine staining assay. Briefly, each animal was immunized twice by DNA plasmid expression constructs encoding rHER2 antigen sequences (SEQ ID NO:54) delivered by PMED with a 4week interval. The mice in each group (n=6) were given 100 μg of intradermal injections of either isotype IgG control (PMED with IgG) or anti-CD40 monoclonal antibody (PMED with aCD40) in proximity to the right side vaccine draining inguinal node, one day after the first immunization was administered by PMED. Seven days after the last PMED, an ICS assay was performed on the splenocytes isolated from each individual mice to detect rHer-2 specific polyfunctional CD8 or CD4 T cells that secrete IFNγ, TNFα and/ or IL-2.. A significant increase in the rHer-2 specific triple-cytokine positive CD8 and CD4 T cell responses were detected from mice treated with the local delivery of anti-CD40 monoclonal antibody compared to isotype IgG control. There were also significant increases in rHer-2 specific single and double cytokine positive CD4 T cells by anti-CD40 monoclonal antibody given locally (*indicates P<0.05 by Student's T-test).

EXAMPLE 15. ANTI-CANCER EFFICACY OF CANCER VACCINE IN COMBINATIOIN WITH LOW DOSE SUNITINIB

Anti-tumor efficacy of anti-cancer vaccine in combination with low dose sunitinib was investigated in BALB/neuT mice with spontaneous mammary pad tumors.

Animal treatment. Briefly, 13-14 weeks old female mice were orally given sunitinib malate (Sutent) at 5mg/kg for 112 days twice a day. The control vaccine, which delivers no antigen, and cancer vaccine which delivers a rat Her-2 antigen of SEQ ID NO: 54 (rHer-2), were given by adenovirus injections on day 3 as a prime followed by 7

biweekly administrations by PMED of DNA delivering HBV antigens (control vaccine) or rHer-2 (cancer vaccine) respectively. The survival end point was determined when all ten mammary pads became tumor positive or when the volume of any of the mammary tumors reach 2000mm^3. The results are presented in Figure 43.

Results. Compared to previously published pharmacokinetic profile of Sutent (Mendel, D., Laird, D., et al.: "In vivo antitumor activity of SU11248, a novel tyrosine kinase inhibitor targeting vascular endothelial growth factor and platelet-derived growth factor receptors: determination of a pharmacokinetic/ pharmacodynamic relationship". Clinical Cancer Research, 203, 9:327-337) and previous data (Figure 38), the C_{Max} of Sutent in mice dosed twice a day at 5 mg/kg is expected to be significantly lower than the minimum blood levels necessary to achieve efficient anti-tumor efficacy in mice and man. The data shows a quick and temporary improvement in the survival of the mice treated with low dose Sutent monotherapy. However when given with the cancer vaccine, a more persistent and significant improvement of survival was observed ($P< 0.0001$ by Log rank test).

EXAMPLE 16. ENHANCEMENT OF VACCINE-INDUCED IMMUNE RESPONSES BY LOCAL ADMINISTRATION OF CPG

The immune enhancement of local administration of CpG (PF-03512676) on the immune responses induced by a human PSMA nucleic acid provided by the invention was investigated in a monkey study, in which the immune response was assessed by measuring PSMA specific T cell responses using an IFNγ ELISPOT assay.

Animal Treatment and Sample Collection. Six groups of Chinese cynomolgus macaques, six (#1 to 6) per each test group, were immunized with a plasmid DNA encoding the human PSMA modified antigen (amino acids 15-750 of SEQ ID NO:1) delivered by electroporation. Briefly, all animals received bilateral intramuscular injections of 5 mg of plasmid DNA followed by electroporation (DNA EP) on day 0. Subsequently right after the electroporation, group 2 received bilateral intramuscular injections of 2 mg of CpG mixed with 1 mg Alum in proximity to the DNA injection sites. Group 3 and 4 received bilateral intramuscular injections of 2 mg of CpG delivered without alum in proximity to the DNA injection sites either on day 0 or day 3, respectively. Group 5 received 2 mg of bilateral intradermal injections of CpG delivered in proximity to the vaccine draining inguinal nodes on day 3. Group 6 received bilateral injections of 200 μg of CpG mixed with the DNA solution which was co-electroporated into the muscle on day 0.

IFNγ ELISPOT Assay Procedure. Peripheral blood samples were collected from each animal fifteen days after the DNA immunization. Peripheral blood mononuclear cells (PBMCs) were isolated from the blood samples and were subjected to an IFNγ ELISPOT assay to measure the PSMA specific T cell responses. Briefly, 4e5 PBMCs from individual animals were plated per well with pools of PSMA specific peptides or nonspecific control peptides (human HER2 peptide pool) each at 2ug/ml in IFNγ ELISPOT plates. The composition of each of the PSMA specific peptide pool is provided in Table 1A. The plates were incubated for 16 hrs at 37°C and 5% CO2 and washed and developed after incubation as per manufacturer's instruction. The number of IFNγ spot forming cells (SFC) were counted by CTL reader. Each condition was performed in duplicates. The result of a representative experiment is presented in Table 1B. The reported PSMA specific response is calculated by subtracting the average number of the SFC to the nonspecific control peptides (human HER2 peptide pool) from the average number of SFC to the PSMA peptide pools and normalized to the SFC observed with 1e6 PBMCs. ^ indicates that the count is not accurate because the numbers of spots were too numerous to count. ND indicates not determined.

Results. Table 28 shows the result of a representative IFNγ ELISPOT assay that evaluates and compares the IFNγ T cell responses induced by the vaccine without (group 1) or with CpG (PF-03512676) given locally by intramuscular (groups 2, 3, 4, and 5) or intradermal injections (group 6). There results in Table 1B is plotted in Fig 1. As shown in Table 1B and Fig 1, the PSMA specific IFNγ T cell responses were detected to multiple PSMA specific peptide pools in the absence of CpG (PF-03512676) in all six animals (group 1). The total response to the PSMA peptides measured were modestly higher in a few animals that additionally received CpG (PF-03512676) either by intramuscular (group 4: 3/6) or intradermal (group 5: 2/6) injections 3 days after DNA electroporation. However, when CpG was delivered subsequently right after electroporation on the same day (groups 2 and 3), there were several animals that failed to produce high responses (group 2: 4/6 and group3: 3/6) whether mixed or not mixed with Alum. However higher net responses were detected in 4/6 animals when a ten-fold lower dose of CpG was co-electroporated with the DNA solution into the muscle (group 6) with a statistically higher response ($P<0.05$) to peptide pools H1 and R1 compared to animals that did not receive CpG (group 1). The data shows that low dose of CpG can effectively enhance IFNγ T cell responses induced by a DNA vaccine when co-electroporated into the muscle.

Table 28. PSMA specific IFNγ T cell responses induced by the DNA vaccine without (Group 1) or with CpG (Groups 2, 3, 4, 5 and 6) is measured by IFNγ ELISPOT assay from PBMCS, 15 days after DNA electroporation

Group	Animal ID	Recall Antigen						
		P1	P2	P3	H1	H2	R1	R2
1	#1	36	31	1	126	183	5	14
	#2	6	3	13	61	524	6	141
	#3	11	4	8	108	1049	3	56
	#4	10	0	13	20	151	13	10
	#5	8	6	11	39	469	14	18
	#6	26	5	0	145	356	8	30
2	#1	3	10	0	15	35	0	0
	#2	0	0	8	4	6	13	0
	#3	3	0	0	0	10	11	0
	#4	6	209	4	111	414	23	9
	#5	15	5	30	171	104	68	6
	#6	0	0	0	9	9	6	8
3	#1	14	19	8	123	1066	10	60
	#2	14	16	20	384	393	104	8
	#3	0	0	15	0	6	0	0
	#4	0	0	0	33	21	0	4
	#5	4	91	1	875	^1235	233	109
	#6	0	0	0	0	3	0	0
4	#1	0	33	15	1025	^1209	280	90
	#2	0	313	3	23	656	6	31
	#3	61	120	61	428	1190	143	53
	#4	0	0	8	599	870	34	111
	#5	0	1	8	19	226	10	36
	#6	111	55	39	231	613	121	99
5	#1	21	9	0	355	1131	73	5
	#2	0	0	0	118	233	0	0
	#3	0	0	0	18	129	0	0
	#4	0	28	78	68	294	58	8
	#5	25	0	28	329	1125	134	5
	#6	0	0	0	23	39	4	0
6	#1	0	0	13	650	1096	270	5
	#2	34	1	74	124	474	29	15
	#3	0	3	14	684	1074	126	64
	#4	8	9	0	136	321	49	1
	#5	13	23	35	ND	^1235	333	195
	#6	0	0	0	421	^1201	138	29

EXAMPLE 17. ENHANCEMENT OF VACCINE-INDUCED IMMUNE RESPONSES BY LOCAL ADMINISTRATION OF ANTI-CTLA-4 ANTIBODY

The effect of low dose subcutaneous administration of anti-CTLA-4 monoclonal antibody (CP-675, 206) on the immune responses induced by a rhesus PSMA nucleic acid was investigated in a monkey study, in which the immune response was assessed by measuring PSMA specific T cell responses using an IFNγ ELISPOT assay. The rhesus PSMA nucleic acid used in the study has the sequence as set forth in SEQ ID NO: 56) and encodes an immunogenic PSMA polypeptide of SEQ ID NO: 55.

Animal Treatment and Sample Collection. Five groups of male Indian rhesus macaques, seven (#1 to 7) per each test group, were immunized with an adenovirus encoding a rhesus PSMA modified polypeptide delivered by bilateral intramuscular injections (2x 5e10 V.P.). Immediately following the adenovirus injections, group 1 received vehicle, and groups 2 to 4 received bilateral subcutaneous injections of anti-CTLA-4 antibody (CP-675, 206) at doses 2x 25mg, 2x 16.7mg and 2x 8.4mg respectively in proximity to the vaccine draining lymph node.

Nine days after the immunization, peripheral blood mononuclear cells (PBMCs) were isolated from each animal and were subjected to an IFNγ ELISPOT assay to measure the rhesus PSMA specific T cell responses. Briefly, 4e5 PBMCs from individual animals were plated per well with pools of rhesus PSMA specific peptides (P1, P2, P3 or R1+R2 defined in table 24A) or nonspecific control peptides (human HER2 peptide pool) each at 2ug/ml in IFNγ ELISPOT plates. The plates were incubated for 16 hrs at 37 ^{o}C and 5% CO2 and washed and developed after incubation as per manufacturer's instruction. The number of IFNγ spot forming cells (SFC) were counted by CTL reader. Each condition was performed in duplicates. The average of the duplicates from the background adjusted SFC of the rhesus PSMA specific peptide pools was normalized to the response in 1e6 PBMCs. The individual and sum responses to the peptide pools from each individual animal are presented in Table 29.

IFNγ ELISPOT Assay Procedure. A capture antibody specific to IFNγ BD Bioscience, #51-2525kc) is coated onto a polyvinylidene fluoride (PVDF) membrane in a microplate overnight at 4^{0}C. The plate is blocked with serum/protein to prevent nonspecific binding to the antibody. After blocking, effector cells (such as splenocytes isolated from immunized mice or PBMCs isolated from rhesus macaques) and targets (such as PSMA peptides from peptide library, target cells pulsed with antigen specific

peptides or tumor cells expressing the relevant antigens) are added to the wells and incubated overnight at 37^0C in a 5% CO_2 incubator. Cytokine secreted by effector cells are captured by the coating antibody on the surface of the PVDF membrane. After removing the cells and culture media, 100 µl of a biotinylated polyclonal anti-humanIFNγ antibody was added to each of the wells for detection. The spots are visualized by adding streptavidin-horseradish peroxidase and the precipitate substrate, 3-amino-9-ethylcarbazole (AEC), to yield a red color spot as per manufacturer's (Mabtech) protocol. Each spot represents a single cytokine producing T cell.

Results. Table 29. shows the results of a representative IFNγ ELISPOT assay that compares the T cell responses induced by the vaccine without (group 1) or with (groups 2-4) anti-CTLA-4 monoclonal antibody (CP-675, 206) given locally by subcutaneous injections in proximity to the vaccine draining lymph node. The vaccine generated an immune response (group1) that was significantly enhanced by the local administration of the anti-CTLA-4 antibody (CP-675, 206) at a dose of 50mg (group 2, P=0.001 by Student's T-test using underestimated values). The response was also significantly enhanced by low doses of anti-CTLA-4 antibody at 33.4 mg (group3: P=0.004 by Student T-test using underestimated values) and 16.7mg (group4: P=0.05 by Student T-test) respectively. The data suggests that low doses of anti-CTLA-4 delivered by subcutaneous injection can significantly enhance the vaccine induced immune responses.

Table 29. IFNγ T cell responses induced by the vaccine without (Group 1) or with subcutaneous injections of anti-CTLA-4 antibody (CP-675, 206). ^ indicates that the count is underestimated due to the high spot numbers. TNTC means too numerous to count.

Group	aCTLA4 dose, mg	animal ID	peptide pool				Sum
			P1	P2	P3	R1+R2	
1	NA	1	21	0	0	108	129
		2	59	480	28	353	920
		3	133	29	359	305	826
		4	0	28	1	35	64
		5	41	6	30	99	176
		6	1	0	849	169	1019
		7	0	0	0	23	23
2	50.0	1	^1105	704	^1116	^1116	^4041
		2	371	26	661	779	1837
		3	393	559	216	198	1366
		4	^1100	^1100	406	1078	^3684
		5	778	325	554	419	2076
		6	^1079	^1079	844	^1079	^4081
		7	423	103	535	398	1459
3	33.4	1	^425	^425	^425	^425	^1700
		2	^580	^580	^580	^580	^2320
		3	TNTC	TNTC	TNTC	TNTC	TNTC
		4	321	778	370	409	1878
		5	331	466	311	446	1554
		6	545	121	^631	^1194	^2491
		7	446	299	^1078	^1060	^2883
4	16.7	1	^964	296	^964	^964	^3188
		2	76	76	76	76	304
		3	^984	^984	^984	^984	^3936
		4	260	489	648	^1109	^2506
		5	119	45	28	140	332
		6	55	76	43	198	372
		7	146	726	141	400	1413

EXAMPLE 18. IMMUNOMODULATION OF MYELOID DERIVED SUPPRESSOR CELLS BY LOW DOSE SUNITINIB

The following example is provided to illustrate the immunomodulatory effects of low dose sunitinib on Myeloid Derived Suppressor Cells (MDSC) *in vivo*, in a non-tumor mouse model.

Study Procedures.

To generate MDSC enriched splenocytes, TUBO cells ($1x10^6$) were implanted into the flanks of 5 BALB/neuT mice, and left for approx. 20-30 days until tumor volume reached between 1000-1500mm^3. Mice were then sacrificed, spleens removed and the MDSC enriched splenocytes recovered. Splenocytes were labeled for 10 minutes with 5 µM CFSE, washed with PBS and counted. Labeled cells were subsequently resuspended at $5x10^7$ splenocytes/ml in PBS solution and adoptively transferred via an i.v. tail vein injection into naïve BALB/c recipient mice. Three days prior to adoptive transfer, the recipient mice began bi-daily dosing with vehicle or sunitinib malate (Sutent) at 5 mg/kg, 10 mg/kg and 20 mg/kg. Following adoptive transfer, recipient mice continued to receive bi-daily dosing of Vehicle or sunitinib for two further days, after which point the mice were sacrificed, spleens removed, splenocytes recovered and processed for phenotypic analysis.

Splenocytes were counted and resuspended at $5x10^6$ cells/ml in FACS staining buffer (PBS, 0.2% (w/v) bovine serum albumin, and 0.02% (w/v) Sodium Azide). For flow cytometry staining of splenocytes, $2.5x10^6$ cells were first incubated with anti-bodies to CD16/CD32, 10 minutes at 4ºC, to block Fc receptors and minimize non-specific binding. Splenocytes were then stained for 20 minutes at 4ºC with appropriate fluorophore conjugated antibodies (Biolegend) to murine cell surface markers. For T cells (anti-CD3 (Pacific Blue), clone 17A2) and for MDSC (anti-GR-1 (APC), clone RB6-8C5 and anti-CD11b (PerCp Cy5.5), clone M1/70). A live/dead stain was also included. Following antibody incubation, stained splenocytes were washed with 2mls of FACS buffer, pelleted by centrifugation and resuspended in 0.2ml of FACS buffer prior to data acquisition on a BD CANTO II flow cytometer. To monitor the effect of Sunitinib or Vehicle on the adoptively transferred MDSC survival, we calculated the percentage of CFSE+,CD3-,GR1+,CD11b+ in the live, singlet gate. We then determined the number of adoptively transferred MDSC per spleen by calculating what actual cell number the percentage represented of total splenocytes count. Data was analyzed by FloJo and Graph pad software.

Results. The data presented in Table 31 represents the mean number of adoptively transferred CSFE+,CD3-,GR1+,CD11b+ cells recovered per spleen (n=7/group), 2 days post adoptive transfer, from mice bi-daily dosed with either Vehicle or 5mg/kg, 10mg/kg and 20 mg/kg Sunitinib. The data demonstrates that Sunitinib, dosed bi-daily, *in vivo,* has an immunomodulatory effect on MDSCs, even when dosed as low as 5mg/kg, resulting in a statistically significant reduction in the numbers recovered when compared to the vehicle treated control group.

Table 31. Mean number of CFSE+,CD3-,GR1+,CD11b+ MDSCs recovered from the spleen, 7 mice per group, and the corresponding standard error. Statistical significance was determined by one-way ANOVA using the Dunnett's multiple comparison test, comparing the Sunitinib dosed groups against the 0mg/kg (vehicle) group.

	Sunitinib Dose (mg/kg)			
	0 (Vehicle)	5	10	20
MDSC # /spleen Mean +/- SEM	17470 +/- 2017	10980 +/- 1082	4207 +/- 338	4440 +/- 440
Statistical significance, $p<0.05$?	NA	Yes	Yes	Yes

EXAMPLE 19. IMMUNOGENICITY OF TRIPLE ANTIGEN ADENOVIRUS AND DNA CONSTRUCTS

The following example is provided to illustrate the capability of triple antigen vaccine constructs (either in the form of adenovirus vector or DNA plasmid) expressing three antigens PSMA, PSCA and PSA provided by the invention to elicit specific T cell responses to all three encoded antigens in nonhuman primates.

In Vivo Study Procedures. The T cell immunogenicity of five adenovirus vectors each expressing three antigens (PSMA, PSCA and PSA; Ad-733, Ad-734, Ad-735, Ad-796 and Ad-809) provided by the invention were compared to the mix of three adenovirus vectors each only expressing a single antigen (PSMA, PSA or PSCA), 9 days post prime. The response to single adenovirus expressing a single antigen (groups 1-3) was evaluated to demonstrate the specificity. Briefly, Indian rhesus macaques (n=6 for groups 1 and 3, n=7 for group 2 and n=8 for groups 4-9) were intramuscularly injected with a total of 1e11 V.P. followed by intradermal injections of anti-CTLA-4 at 10 mg/kg on the same day. Nine days after the injections, peripheral blood mononuclear cells (PBMCs) were isolated from each animal and were subjected to an IFNγ ELISPOT assay to measure the PSMA, PSA and PSCA specific T cell responses.

Thirteen weeks after the adenovirus and anti-CTLA-4 injections when the T cell responses have contracted, the monkeys received DNA (Group 1: PSMA, plasmid 5166; Group 2: PSA, plasmid 5297; Group 3: PSCA, plasmid 5259; Group 4: mix of PSMA, PSA and PSCA, plasmids 5166, 5259 and 5297; Group 4: plasmid 457; Group 6: plasmid 458; Group 7: plasmid 459; Group 8: plasmid 796 and Group 9: plasmid 809) boost vaccinations delivered by electroporation. In summary, each animal received a total 5mg of plasmid DNA provided by the invention which delivers the same expression cassette encoded in the adenovirus used in the prime. Nine days after the boost vaccination, peripheral blood mononuclear cells (PBMCs) were isolated from each animal and were subjected to an IFNγ ELISPOT assay.

IFNγ ELISPOT assay. Briefly, 4e5 PBMCs from individual animals were plated per well with PSMA specific peptide pools P1, P2, P3 or H1 and H2 (Table 24A), PSA specific pool 1 or 2 (Table 25), PSCA specific pool (Table 26) or nonspecific control peptides (human HER2 peptide pool) each at 2ug/ml in IFNγ ELISPOT plates. The plates were incubated for 16 hrs at 37 ^{o}C and 5% CO2 and washed and developed after incubation as per manufacturer's instruction. The number of IFNγ spot forming cells (SFC) were counted by CTL reader. Each condition was performed in duplicates. The average of the duplicates from the background adjusted SFC of the antigen specific peptide pools was normalized to the response in 1e6 PBMCs. The antigen specific responses in the tables present the sum of the responses to the corresponding antigen specific peptides or peptide pools.

Results: Table 27 represents a study that evaluates the T cell immunogenicity of five different adenoviruses each expressing all three antigens in comparison to the mixture of three adenoviruses each expressing a single antigen in Indian rhesus macaques by IFNγ ELISPOT. The majority of animals that only received Ad-PSMA (group 1) injections induced specific responses to PSMA but not to PSA or PSCA (Student's T-test, $P<0.03$. One animal (#4) that induced responses to PSCA preferentially was removed from the statistical analysis). The animals that only received injections of Ad-PSA (group 2) induced specific responses to PSA but not to PSMA or PSCA (Student's T-test, $P<0.02$). The animals that only received injections of Ad-PSCA (group 3) induced specific responses to PSCA but not to PSMA or PSA (Student's T-test, $P<0.03$). All five triple-antigen expressing adenovirus vectors (groups 5-9) induced IFNγ T cell responses to all three antigens which the magnitude varied by animal. The magnitude of the responses to PSCA induced by the triple antigen expressing

adenoviruses were similar to the mix of individual vectors (group 4). However the magnitude of responses to PSMA induced by Ad-809 (group9) and responses to PSA induced by Ad-796 (group8) were each significantly superior to the mix (Student's T-test, P=0.04 and P=0.02) respectively. These results indicate that vaccinating with an adenovirus expressing triple antigens can elicit equivalent or superior T cell immune responses to vaccinating with the mix of individual adenoviruses in nonhuman primates.

Table 28 shows the IFNγ ELISPOT results represents a study that evaluates the immunogenicity of the five different triple antigen expression cassettes provided in the invention delivered by an adenovirus prime in combination with anti-CTLA-4 followed by an electroporation boost of the corresponding plasmid DNA. The immune responses are compared to the mix of three constructs expressing a single antigen delivered similarly by an adenovirus prime with anti-CTLA-4 and DNA electroporation boost immunizations.

All of the animals that only received Ad-PSMA with anti-CTLA-4 followed by plasmid-PSMA (group 1) immunizations induced specific responses to PSMA but not to PSA or PSCA. Similarly all of the animals that only received Ad-PSA with anti-CTLA-4 followed by plasmid-PSA immunizations (group 2) induced specific responses to PSA but not to PSMA or PSCA and finally all of the animals that only received Ad-PSCA with anti-CTLA-4 followed by plasmid-PSCA (group 3) immunizations induced specific responses to PSCA but not to PSMA or PSA (Student's T-test, $P<0.01$).

All animals that have been immunized with either the triple-antigen expressing vectors (groups 5-9) or the mix (group 4) induced IFNγ T cell responses to all three antigens. The frequency of PSCA or PSA specific IFNγ T cells detected were similar in all of these groups (groups 4-9) respectively. However construct groups 7 and 9 that received triple antigen expression vector vaccinations produced significantly higher frequency of responses to PSMA than the mix of three single antigen expressing constructs (group 4). These results indicate that adenovirus and DNA vaccines expressing triple antigens in one cassette can elicit equivalent or superior IFNγ T cell responses to the mix of adenoviruses and DNAs expressing the single antigens in nonhuman primates.

Table 25. PSA peptide pools: The amino acid position and sequence of fifteen amino acid peptides overlapping by thirteen amino acids from PSA peptide library is shown.

PSA peptide pool 1		PSA peptide pool 2	
amino acid no.	PSA peptide sequence	amino acid no.	PSA peptide sequence
5-19	VVFLTLSVTWIGAAP	129-143	PAELTDAVKVMDLPT
9-23	TLSVTWIGAAPLILS	131-145	ELTDAVKVMDLPTQE
11-25	SVTWIGAAPLILSRI	133-147	TDAVKVMDLPTQEPA
13-27	TWIGAAPLILSRIVG	135-149	AVKVMDLPTQEPALG
15-29	IGAAPLILSRIVGGW	137-151	KVMDLPTQEPALGTT
17-31	AAPLILSRIVGGWEC	139-153	MDLPTQEPALGTTCY
19-33	PLILSRIVGGWECEK	141-155	LPTQEPALGTTCYAS
21-35	ILSRIVGGWECEKHS	143-157	TQEPALGTTCYASGW
23-37	SRIVGGWECEKHSQP	145-159	EPALGTTCYASGWGS
25-39	IVGGWECEKHSQPWQ	147-161	ALGTTCYASGWGSIE
27-41	GGWECEKHSQPWQVL	149-163	GTTCYASGWGSIEPE
29-43	WECEKHSQPWQVLVA	151-165	TCYASGWGSIEPEEF
31-45	CEKHSQPWQVLVASR	153-167	YASGWGSIEPEEFLT
33-47	KHSQPWQVLVASRGR	155-169	SGWGSIEPEEFLTPK
35-49	SQPWQVLVASRGRAV	157-171	WGSIEPEEFLTPKKL
37-51	PWQVLVASRGRAVCG	159-173	SIEPEEFLTPKKLQC
39-53	QVLVASRGRAVCGGV	161-175	EPEEFLTPKKLQCVD
41-55	LVASRGRAVCGGVLV	163-177	EEFLTPKKLQCVDLH
43-57	ASRGRAVCGGVLVHP	165-179	FLTPKKLQCVDLHVI
45-59	RGRAVCGGVLVHPQW	167-181	TPKKLQCVDLHVISN
47-61	RAVCGGVLVHPQWVL	169-183	KKLQCVDLHVISNDV
49-63	VCGGVLVHPQWVLTA	171-185	LQCVDLHVISNDVCA
51-65	GGVLVHPQWVLTAAH	173-187	CVDLHVISNDVCAQV
53-67	VLVHPQWVLTAAHCI	175-189	DLHVISNDVCAQVHP
55-69	VHPQWVLTAAHCIRN	177-191	HVISNDVCAQVHPQK
57-71	PQWVLTAAHCIRNKS	179-193	ISNDVCAQVHPQKVT
59-73	WVLTAAHCIRNKSVI	181-195	NDVCAQVHPQKVTKF
61-75	LTAAHCIRNKSVILL	183-197	VCAQVHPQKVTKFML
63-77	AAHCIRNKSVILLGR	185-199	AQVHPQKVTKFMLCA
65-79	HCIRNKSVILLGRHS	187-201	VHPQKVTKFMLCAGR
67-81	IRNKSVILLGRHSLF	189-203	PQKVTKFMLCAGRWT
69-83	NKSVILLGRHSLFHP	191-205	KVTKFMLCAGRWTGG
71-85	SVILLGRHSLFHPED	193-207	TKFMLCAGRWTGGKS
73-87	ILLGRHSLFHPEDTG	195-209	FMLCAGRWTGGKSTC
75-89	LGRHSLFHPEDTGQV	197-211	LCAGRWTGGKSTCSG
77-91	RHSLFHPEDTGQVFQ	199-213	AGRWTGGKSTCSGDS
79-93	SLFHPEDTGQVFQVS	201-215	RWTGGKSTCSGDSGG

81-95	FHPEDTGQVFQVSHS	203-217	TGGKSTCSGDSGGPL
83-97	PEDTGQVFQVSHSFP	205-219	GKSTCSGDSGGPLVC
85-99	DTGQVFQVSHSFPHP	207-221	STCSGDSGGPLVCNG
87-101	GQVFQVSHSFPHPLY	209-223	CSGDSGGPLVCNGVL
89-103	VFQVSHSFPHPLYDM	211-225	GDSGGPLVCNGVLQG
91-105	QVSHSFPHPLYDMSL	213-227	SGGPLVCNGVLQGIT
93-107	SHSFPHPLYDMSLLK	215-229	GPLVCNGVLQGITSW
95-109	SFPHPLYDMSLLKNR	217-231	LVCNGVLQGITSWGS
97-111	PHPLYDMSLLKNRFL	219-233	CNGVLQGITSWGSEP
99-113	PLYDMSLLKNRFLRP	221-235	GVLQGITSWGSEPCA
101-115	YDMSLLKNRFLRPGD	223-237	LQGITSWGSEPCALP
103-117	MSLLKNRFLRPGDDS	225-239	GITSWGSEPCALPER
105-119	LLKNRFLRPGDDSSH	227-241	TSWGSEPCALPERPS
107-121	KNRFLRPGDDSSHDL	229-243	WGSEPCALPERPSLY
109-123	RFLRPGDDSSHDLML	231-245	SEPCALPERPSLYTK
111-125	LRPGDDSSHDLMLLR	233-247	PCALPERPSLYTKVV
113-127	PGDDSSHDLMLLRLS	235-249	ALPERPSLYTKVVHY
115-129	DDSSHDLMLLRLSEP	237-251	PERPSLYTKVVHYRK
117-131	SSHDLMLLRLSEPAE	239-253	RPSLYTKVVHYRKWI
119-133	HDLMLLRLSEPAELT	241-255	SLYTKVVHYRKWIKD
121-135	LMLLRLSEPAELTDA	243-257	YTKVVHYRKWIKDTI
123-137	LLRLSEPAELTDAVK	245-259	KVVHYRKWIKDTIVA
125-139	RLSEPAELTDAVKVM	247-261	VHYRKWIKDTIVANP
127-141	SEPAELTDAVKVMDL	249-261	YRKWIKDTIVANP
		251-261	KWIKDTIVANP

Table 26. PSCA peptide pool: The amino acid position and sequence of fifteen amino acid peptides overlapping by thirteen amino acids from PSCA peptide library is shown.

5

amino acid no.	PSCA peptide sequence
1-15	MKAVLLALLMAGLAL
3-17	AVLLALLMAGLALQP
5-19	LLALLMAGLALQPGT
7-21	ALLMAGLALQPGTAL
9-23	LMAGLALQPGTALLC
11-25	AGLALQPGTALLCYS
13-27	LALQPGTALLCYSCK
15-29	LQPGTALLCYSCKAQ
17-31	PGTALLCYSCKAQVS
19-33	TALLCYSCKAQVSNE
21-35	LLCYSCKAQVSNEDC

23-37	CYSCKAQVSNEDCLQ
25-39	SCKAQVSNEDCLQVE
27-41	KAQVSNEDCLQVENC
29-43	QVSNEDCLQVENCTQ
31-45	SNEDCLQVENCTQLG
33-47	EDCLQVENCTQLGEQ
35-49	CLQVENCTQLGEQCW
37-51	QVENCTQLGEQCWTA
39-53	ENCTQLGEQCWTARI
41-55	CTQLGEQCWTARIRA
43-57	QLGEQCWTARIRAVG
45-59	GEQCWTARIRAVGLL
47-61	QCWTARIRAVGLLTV
49-63	WTARIRAVGLLTVIS
51-65	ARIRAVGLLTVISKG
53-67	IRAVGLLTVISKGCS
55-69	AVGLLTVISKGCSLN
57-71	GLLTVISKGCSLNCV
59-73	LTVISKGCSLNCVDD
61-75	VISKGCSLNCVDDSQ
63-77	SKGCSLNCVDDSQDY
65-79	GCSLNCVDDSQDYYV
67-81	SLNCVDDSQDYYVGK
69-83	NCVDDSQDYYVGKKN
71-85	VDDSQDYYVGKKNIT
73-87	DSQDYYVGKKNITCC
75-89	QDYYVGKKNITCCDT
77-91	YYVGKKNITCCDTDL
79-93	VGKKNITCCDTDLCN
81-95	KKNITCCDTDLCNAS
83-97	NITCCDTDLCNASGA
85-99	TCCDTDLCNASGAHA
87-101	CDTDLCNASGAHALQ
89-103	TDLCNASGAHALQPA
91-105	LCNASGAHALQPAAA
93-107	NASGAHALQPAAAIL
95-109	SGAHALQPAAAILAL
97-111	AHALQPAAAILALLP
99-113	ALQPAAAILALLPAL
101-115	QPAAAILALLPALGL
103-117	AAAILALLPALGLLL
105-119	AILALLPALGLLLWG
107-121	LALLPALGLLLWGPG
109-123	LLPALGLLLWGPGQL
111-125	PALGLLLWGPGQL

Table 27. IFNγ T cell responses induced by the single antigen (Group 1: Ad-PSMA; Group 2: Ad-PSA; Group 3: Ad-PSCA; Group 4: mix of Ad-PSMA, Ad-PSA and Ad-PSCA) or triple antigen expressing adenovirus vectors (Group 4: Ad-733; Group 6: Ad-734; Group 7: Ad-735; Group 8: Ad-796 and Group 9: Ad-809) after adenovirus prime with anti-CTLA-4 analyzed by ELISPOT assay.

Response to PSMA peptides		animal ID							
		1	2	3	4	5	6	7	8
Group No.	1	2356	988	1505	335	501	2145	NA	NA
	2	342	1776	154	329	158	438	321	NA
	3	0	1276	40	126	20	0	NA	NA
	4	304	1198	774	2007	1277	1310	1159	2774
	5	943	2670	2757	780	1082	2251	1566	544
	6	472	2092	4248	1369	1760	2964	1447	263
	7	2161	2202	939	869	3513	1654	3424	900
	8	1166	799	2566	663	1043	497	1334	560
	9	1621	3247	2031	980	2942	1882	1918	3805

Response to PSA peptides		animal ID							
		1	2	3	4	5	6	7	8
Group No.	1	0	0	0	48	0	42	NA	NA
	2	1419	1426	298	1223	1346	1120	1694	NA
	3	6	462	91	0	77	0	NA	NA
	4	790	1093	1611	790	186	783	2016	1964
	5	101	510	955	665	336	1512	1052	119
	6	236	673	2155	724	504	1600	930	83
	7	0	1086	494	663	2265	117	1712	84
	8	1893	2060	1490	1759	2352	1700	2232	1326
	9	1193	1432	207	1738	1886	949	492	1940

Response to PSCA peptides		animal ID							
		1	2	3	4	5	6	7	8
Group No.	1	795	425	874	1069	219	203	NA	NA
	2	669	713	391	199	164	560	461	NA
	3	510	1234	1099	1115	1194	339	NA	NA
	4	778	528	680	1101	165	531	1175	1009
	5	378	1061	1161	143	71	756	766	204
	6	118	380	1190	403	829	1225	148	261
	7	615	1141	794	564	1175	490	856	204
	8	968	1136	745	290	550	976	955	841
	9	929	434	1150	745	1120	246	1195	970

Table 28. IFNγ T cell responses induced by the single antigen (Group 1: PSMA; Group 2: PSA; Group 3: PSCA; Group 4: mix of PSMA, PSA and PSCA) or triple antigen expressing vectors (Groups 5 - 9) after adenovirus prime with anti-CTLA-4 and DNA electroporation boost immunizations analyzed by ELISPOT assay.

Response to PSMA peptides		animal ID							
		1	2	3	4	5	6	7	8
Group No.	1	1327	1535	1643	535	1506	1267	NA	NA
	2	15	266	26	191	10	46	1305	NA
	3	0	445	5	75	4	6	NA	NA
	4	365	675	731	1134	244	714	999	1683
	5	270	1623	2254	626	860	2245	1453	1046
	6	541	1151	2923	1094	1061	1746	691	489
	7	1183	1183	1453	1649	2844	1470	2321	991
	8	486	69	399	216	351	758	416	1389
	9	1430	2631	2015	475	1368	1826	1851	3141

Response to PSA peptides		animal ID							
		1	2	3	4	5	6	7	8
Group No.	1	0	0	0	1	0	26	NA	NA
	2	1883	1236	1574	393	461	941	1565	NA
	3	33	30	9	13	8	11	NA	NA
	4	571	1129	1180	210	88	274	924	360
	5	50	1255	1344	628	210	638	948	1161
	6	88	228	1390	489	1006	908	683	51
	7	0	211	321	156	1509	56	199	85
	8	414	611	85	105	544	1080	331	1883
	9	434	821	556	343	1160	510	144	1115

Response to PSCA peptides		animal ID							
		1	2	3	4	5	6	7	8
Group No.	1	615	799	533	74	258	61	NA	NA
	2	194	170	133	133	8	66	405	NA
	3	819	1071	873	839	1045	724	NA	NA
	4	543	506	664	470	70	673	761	1235
	5	154	455	1218	109	218	1094	285	569
	6	56	293	603	506	745	911	63	165
	7	429	298	939	589	1226	263	803	451
	8	279	214	871	61	144	511	193	963
	9	379	191	1196	73	699	198	616	836

EXAMPLE 20. REDUCTION OF STAT3 PHOSPHORYLATION BY SUNITINIB

The following example is provided to illustrate the capability of sunitinib to directly inhibit the phosphorylation of STAT3 (signal transducer of activator of transcription 3), a key mediator of immune suppression in the spleen.

Study Procedure. The acute effect of Sutent on the phosphorylation status of STAT3 in the spleen was investigated in a subcutaneous tumor mouse model to evaluate the direct immunomodulatory effects of the compound. Briefly, 10-12 week old female BALB/neuT mice were implanted with 1e6 TUBO cells subcutaneously in the right flank. After forty one days post tumor implant, Sutent was given by oral gavage at 20 mg/kg. At 0, 1, 3, 7 and 24 hrs post Sutent dosing, three animals per timepoint were sacrificed under IAUCUC guidelines and spleens were immediately snap frozen in liquid nitrogen to preserve the phosphorylation status. Spleens from female BALB/c mice were snap frozen to use as healthy mice controls.

STAT3 assay procedures. Snap frozen spleens were homogenized at 100mg tissue per 500 μL lysis buffer (70 mM NaCl, 50 mM β-glycerol phosphate, 10 mM HEPES, 1% Triton X-100, 100 mM Na_3VO_4, 100 mM PMSF, 1 mg/mL leupeptin) using a polytron tissue homogenizer. Resulting digests were centrifuged at 10,000g for 15 minutes. The supernatant was isolated and protein concentrations were determined using BCA protein assay kit (Pierce, Rockford, Illinois). Forty micrograms of protein were added to each well of either a total STAT3 (eBioscience, cat no. 85-86101-11) or phosphor-STAT3 (eBioscience, cat no. 85-86102-11) ELISA Kit. Relative levels of either protein were compared with standards provided in the kit and with standards purchased independently (Signaling Technologies, cat no. 9333-S).

Results. Table 29 shows the result of a representative STAT assay that evaluates the effect of Sutent on the phosphorylation status of STAT3 in the spleen. Both spleen extracts from healthy or tumor bearing mice exhibited similar levels of STAT3 protein by ELISA (Total STAT3). However, compared to healthy BALB/c, the extracts from tumor bearing mice had significantly higher levels of phosphorylated STAT3 (Student's T-test, $P<0.001$). The phosphorylation levels rapidly decreased to levels similar to healthy animals only 1hr after Sutent treatment and maintained at lower levels than the untreated mice up to 7hrs. At 24hrs the phosphorylation levels of STAT3 completely recovered to levels before Sutent treatment. The phosphorylation kinetics mirrors the levels of circulating Sutent in the blood. The rapid response of STAT3 phosphorylation in the spleen reflecting the pharmacokinetic profile of Sutent suggests a direct immunomodulatory function of Sutent in tumor bearing animals.

Table. 29. The relative levels of phosphorylated STAT3 and total STAT3 from healthy BALB/c and tumor bearing BALB/neuT mice before or after Sutent treatment at multiple time points.

Strain	Time Point, hrs	Phospho-STAT3			Total STAT3		
		Individual values	Mean	SEM	Individual values	Mean	SEM
Balb/c	0	0.11	0.09	0.01	0.12	0.13	0.00
		0.08			0.12		
		0.09			0.14		
Tumor bearing BALB/neuT	0	1.08	1.31	0.12	0.08	0.09	0.01
		1.38			0.11		
		1.46			NA		
	1	0.26	0.23	0.02	0.12	0.09	0.01
		0.25			0.08		
		0.19			0.08		
	3	0.19	0.19	0.02	0.15	0.13	0.02
		0.15			0.09		
		0.22			0.16		
	7	0.19	0.27	0.04	0.10	0.08	0.01
		0.31			0.07		
		0.29			0.08		
	24	1.54	1.44	0.07	0.08	0.08	0.00
		1.30			0.08		
		1.47			0.08		

RAW SEQUENCE LISTING

SEQ ID NO: 1. AMINO ACID SEQUENCE OF THE FULL LENGTH HUMAN PSMA

MWNLLHETDSAVATARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSNEATNITPKHN
MKAFLDELKAENIKKFLYNFTQIPHLAGTEQNFQLAKQIQSQWKEFGLDSVELAHYDV
LLSYPNKTHPNYISIINEDGNEIFNTSLFEPPPPGYENVSDIVPPFSAFSPQGMPEGDL
VYVNYARTEDFFKLERDMKINCSGKIVIARYGKVFRGNKVKNAQLAGAKGVILYSDPA
DYFAPGVKSYPDGWNLPGGGVQRGNILNLNGAGDPLTPGYPANEYAYRRGIAEAVG
LPSIPVHPIGYYDAQKLLEKMGGSAPPDSSWRGSLKVPYNVGPGFTGNFSTQKVKM
HIHSTNEVTRIYNVIGTLRGAVEPDRYVILGGHRDSWVFGGIDPQSGAAVVHEIVRSF
GTLKKEGWRPRRTILFASWDAEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGN
YTLRVDCTPLMYSLVHNLTKELKSPDEGFEGKSLYESWTKKSPSPEFSGMPRISKLG
SGNDFEVFFQRLGIASGRARYTKNWETNKFSGYPLYHSVYETYELVEKFYDPMFKYH
LTVAQVRGGMVFELANSIVLPFDCRDYAVVLRKYADKIYSISMKHPQEMKTYSVSFDS
LFSAVKNFTEIASKFSERLQDFDKSNPIVLRMMNDQLMFLERAFIDPLGLPDRPFYRH
VIYAPSSHNKYAGESFPGIYDALFDIESKVDPSKAWGEVKRQIYVAAFTVQAAAETLSE
VA

SEQ ID NO: 2. NUCLEOTIDE SEQUENCE ENCODING THE FULL LENGTH HUMAN PSMA OF SEQ ID NO: 1

atgtggaatctccttcacgaaaccgactcggctgtggccaccgcgcgccgcccgcgctggctgtgcgctggggcgctgg
tgctggcgggtggcttctttctcctcggcttcctcttcgggtggtttataaaatcctccaatgaagctactaacattactccaaa
gcataatatgaaagcatttttggatgaattgaaagctgagaacatcaagaagttcttatataatttacacagataccacatt
tagcaggaacagaacaaaactttcagcttgcaaagcaaattcaatcccagtggaaagaatttggcctggattctgttgag
ctagcacattatgatgtcctgttgtcctacccaaataagactcatcccaactacatctcaataattaatgaagatggaaatg
agattttcaacacatcattatttgaaccacctcctccaggatatgaaaatgtttcggatattgtaccacctttcagtgctttctct
cctcaaggaatgccagagggcgatctagtgtatgttaactatgcacgaactgaagacttctttaaattggaacgggacat
gaaaatcaattgctctgggaaaattgtaattgccagatatgggaaagttttcagaggaaataaggttaaaaatgcccagc
tggcaggggccaaaggagtcattctctactccgaccctgctgactactttgctcctggggtgaagtcctatccagatggttg
gaatcttcctggaggtggtgtccagcgtggaaatatcctaaatctgaatggtgcaggagaccctctcacaccaggttacc
cagcaaatgaatatgcttataggcgtggaattgcagaggctgttggtcttccaagtattcctgttcatccaattggatactatg
atgcacagaagctcctagaaaaaatgggtggctcagcaccaccagatagcagctggagaggaagtctcaaagtgcc
ctacaatgttggacctggctttactggaaacttttctacacaaaaagtcaagatgcacatccactctaccaatgaagtgac
aagaatttacaatgtgataggtactctcagaggagcagtggaaccagacagatatgtcattctgggaggtcaccgggac
tcatgggtgtttggtggtattgaccctcagagtggagcagctgttgttcatgaaattgtgaggagctttggaacactgaaaa

aggaagggtggagacctagaagaacaattttgtttgcaagctgggatgcagaagaatttggtcttcttggttctactgagtg
ggcagaggagaattcaagactccttcaagagcgtggcgtggcttatattaatgctgactcatctatagaaggaaactaca
ctctgagagttgattgtacaccgctgatgtacagcttggtacacaacctaacaaaagagctgaaaagccctgatgaagg
ctttgaaggcaaatctctttatgaaagttggactaaaaaaagtccttccccagagttcagtggcatgcccaggataagca
aattgggatctggaaatgattttgaggtgttcttccaacgacttggaattgcttcaggcagagcacggtatactaaaaattg
ggaaacaaacaaattcagcggctatccactgtatcacagtgtctatgaaacatatgagttggtggaaaagttttatgatcc
aatgtttaaatatcacctcactgtggcccaggttcgaggagggatggtgtttgagctagccaattccatagtgctccctttga
ttgtcgagattatgctgtagttttaagaaagtatgctgacaaaatctacagtatttctatgaaacatccacaggaaatgaag
acatacagtgtatcatttgattcacttttttctgcagtaaagaattttacagaaattgcttccaagttcagtgagagactccagg
actttgacaaaagcaacccaatagtattaagaatgatgaatgatcaactcatgtttctggaaagagcatttattgatccatta
gggttaccagacaggccttttataggcatgtcatctatgctccaagcagccacaacaagtatgcaggggagtcattccc
aggaatttatgatgctctgtttgatattgaaagcaaagtggacccttccaaggcctggggagaagtgaagagacagattt
atgttgcagccttcacagtgcaggcagctgcagagactttgagtgaagtagcc

SEQ ID NO: 3. AMINO ACID SEQUENCE OF PSMA SHUFFLED ANTIGEN 1

MASARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSSEATNISPQHNVKAFLDEMKAE
NIKKFLYLFTQIPHLAGTEQNFQLAKQIQAEWKEFGLDSVELAHYDVLLSYPNETHPNY
ISIIDEDGNEIFNTSLFEPPPPGYENISDVVPPYSAFSPQGMPEGDLVYVNYARTEDFF
KLERELKINCSGKILIARYGKVFRGNKVKNAQLAGAKGIILYSDPADYFAPGVKSYPDG
WNLPGGGVQRGNVLNLNGAGDPLTPGYPANEYAYRRELAEAVGLPSIPVHPIGYYDA
QKLLEKMGGSAPPDSSWKGSLKVPYNVGPGFTGNFSTQKVKMHIHSTNEVTRIYNVI
GTIRGAVEPDRYVILGGHRDAWVFGGIDPQSGAAVVHEIVRSFGTLKKKGWRPRRTII
FASWDAEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLMYSLV
YNLTKELQSPDEGFEGKSLYESWTKKSPSPEFSGVPRINKLGSGNDFEVFFQRLGIAS
GRARYTKNWKTNKFSGYPLYHSVYETYELVEKFYDPMFKYHLTVAQVRGGLVFELAD
SIVLPFDCQDYAVVLRKYADKIYNLAMKHPEELKTYSVSFDSLFSAVKNFTEIASKFNQ
RLQDFDKNNPLLVRMLNDQLMFLERAFVDPLGLPDRPFYRHVIYAPSSHNKYAGESF
PGIYDALFDIESKVDPSKAWGEVKRQIYVAAFTVQAAAETLSEVA

SEQ ID NO: 4. NUCLEOTIDE SEQUENCE ENCODING AMINO ACID SEQUENCE OF PSMA SHUFFLED ANTIGEN 1 OF SEQ ID NO: 3

atggctagcgccagacggcccagatggctgtgcgccggagccctggtgctggccggaggattcttcctgctgggcttcct
gttcggctggttcatcaagagcagcagcgaggccaccaacatcagcccccagcacaacgtgaaggcctttctggacg
agatgaaggccgagaacatcaagaagtttctgtacctgttcacccagatcccccacctggccggcaccgagcagaact
tccagctggccaagcagattcaggctgagtggaaagagttcggcctggacagcgtggagctggcccactacgacgtg
ctgctgtcctaccccaacgagacacaccccaactacatcagcatcatcgacgaggacggcaacgagattttcaacacc

agcctgttcgagccccctcccccctggctacgagaacatctccgacgtggtgccccccctacagcgccttcagccctcagg
gaatgcctgaaggcgacctggtgtacgtgaactacgcccggaccgaggacttcttcaagctggaacgggagctgaag
atcaactgcagcggcaagatcctgatcgccagatacggcaaggtgttccggggcaacaaagtgaagaacgcacagc
tggctggagccaagggcatcatcctgtacagcgaccccgccgactacttcgcccctggcgtgaagtcctaccctgacgg
ctggaacctgcctggcggcggagtgcagcggggcaacgtgctgaacctgaacggagccggcgaccctctgacccca
ggctaccccgccaacgagtacgcctaccggcgggagctggccgaagccgtgggcctgcccagcatccccgtgcacc
ccatcggctactacgacgcccagaaactgctggaaaagatgggcggcagcgcccctcccgacagcagctggaagg
gcagcctgaaggtgccctacaacgtgggccctggcttcaccggcaacttcagcacccagaaagtgaagatgcacatc
cacagcaccaacgaagtgacccggatctacaacgtgatcggcaccatcagaggcgccgtggagcccgacagatac
gtgatcctgggcggccaccgggacgcctgggtgttcggcggcatcgacccccagagcggagccgccgtggtgcacg
agatcgtgcggagcttcggcaccctgaagaagaagggctggcggcccagacggaccatcatcttcgccagctgggac
gccgaggaattcggactgctgggctctaccgagtgggccgaggaaaacagcagactgctgcaggaacggggcgtcg
cctacatcaacgccgacagctccatcgagggcaactacaccctgcgggtggactgcacccccctgatgtacagcctgg
tgtacaacctgaccaaagagctgcagagccccgacgagggcttcgagggcaagagcctgtacgagagctggacca
agaagtcccccagccccgagttcagcggcgtgccccggatcaacaagctgggcagcggcaacgacttcgaggtgttc
ttccagaggctgggcattgccagcggcagagcccggtacaccaagaactggaaaaccaacaagttctccggctaccc
cctgtaccacagcgtgtacgagacatacgaactggtggagaagttctacgaccccatgttcaagtaccacctgaccgtg
gcccaggtccggggagggctggtgttcgaactggccgacagcatcgtgctgcccttcgactgccaggactatgctgtggt
gctgcggaagtacgccgacaaaatctacaacctggccatgaagcaccccgaggaactgaaaacctacagcgtgtcct
tcgacagcctgttcagcgccgtgaagaacttcaccgagatcgccagcaagttcaaccagcggctgcaggacttcgaca
agaacaacccccctgctggtccggatgctgaacgaccagctgatgttcctggaacgggccttcgtggacccccctgggcct
gcctgaccggcccttctaccggcacgtgatctatgcccccagcagccacaacaagtacgctggcgagagcttccccgg
catctacgatgccctgttcgacatcgagagcaaggtggaccccagcaaggcctggggcgaagtgaagcggcagatat
acgtggccgccttcacagtgcaggccgctgccgagacactgagcgaggtggcc

SEQ ID NO: 5. AMINO ACID SEQUENCE OF PSMA SHUFFLED ANTIGEN 2

MASARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSSEATNITPQHNVKAFLDELKAEN
IKKFLYNFTQIPHLAGTEQNFELAKQIQAQWKEFGLDSVELSHYDVLLSYPNETHPNYI
SIIDEDGNEIFNTSLFEPPPPGYENISDVVPPYSAFSPQGMPEGDLVYVNYARTEDFFK
LERDMKINCSGKILIARYGKVFRGNKVKNAQLAGAKGIILYSDPADYFAPGVKSYPDG
WNLPGGGVQRGNVLNLNGAGDPLTPGYPANEYAYRRGIAEAVGLPSIPVHPIGYYDA
QKLLEKMGGAAPPDSSWKGSLQVPYNVGPGFTGNFSTQKVKMHIHSTNEVTRIYNVI
GTLKGAVEPDRYVILGGHRDAWVFGGIDPQSGAAVVHEIVRSFGTLKKKGWRPRRTI
LFASWDAEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLMYSL
VYNLTKELQSPDEGFEGKSLFDSWTEKSPSPEFSGLPRISKLGSGNDFEVFFQRLGIA

SGRARYTKDWKTSKFSGYPLYHSVYETYELVEKFYDPMFKYHLTVAQVRGGIVFELA
NSVVLPFDCQDYAVVLKKYADKIYNISMKHPQEMKTYSVSFDSLFSAVKNFTEIASKF
NQRLQDFDKNNPILLRMMNDQLMFLERAFIDPLGLPDRPFYRHVIYAPSSHNKYAGES
FPGIYDALFDIESKVDPSKAWGEVKRQIYVAAFTVQAAAETLSEVA

SEQ ID NO: 6. NUCLEOTIDE SEQUENCE ENCODING AMINO ACID SEQUENCE OF PSMA SHUFFLED ANTIGEN 2 OF SEQ ID NO:5

atggctagcgccagacggcccagatggctgtgtgctggcgccctggtgctggctggcggctttttcctgctgggcttcctgtt
cggctggttcatcaagagcagcagcgaggccaccaacatcacccccagcacaacgtgaaggcctttctggacgag
ctgaaggccgagaatatcaagaagttcctgtacaacttcacccagatcccccacctggccggcaccgagcagaacttc
gagctggccaagcagatccaggcccagtggaaagagttcggcctggacagcgtggaactgagccactacgacgtgc
tgctgagctaccccaacgagacacaccccaactacatcagcatcatcgacgaggacggcaacgagattttcaacacc
agcctgttcgagccccctccacccggctacgagaacatcagcgacgtggtgccccccctacagcgcattcagtccacag
ggaatgcccgagggcgacctggtgtacgtgaactacgcccggaccgaggacttcttcaagctggaacgggacatgaa
gatcaactgcagcggcaagatcctgatcgccagatacggcaaggtgttccggggcaacaaagtgaagaacgcccag
ctggcaggcgccaagggcatcatcctgtacagcgaccccgccgactacttcgcccctggcgtgaagtcctaccccgac
ggctggaacctgcctggcggcggagtgcagaggggcaacgtgctgaacctgaacggcgctggcgaccctctgaccc
ctggctaccccgccaacgagtacgcctacagacggggaatcgccgaggccgtgggcctgcctagcatccctgtgcac
cccatcggctactacgacgcccagaaactgctggaaaagatgggcggagccgcccctcccgacagctcttggaagg
gcagcctgcaggtcccctacaacgtgggccctggcttcaccggcaacttcagcacccagaaagtgaagatgcacatcc
acagcaccaacgaagtgacccggatctacaacgtgatcggcaccctgaagggcgccgtggaacccgacagatacgt
gatcctgggcggccaccgggacgcctgggtgttcggaggcatcgaccctcagagcggcgctgccgtggtgcacgaga
tcgtgcggagcttcggcacactgaagaagaagggctggcggcccagacggaccatcctgttcgccagctgggacgcc
gaggaattcggcctgctgggcagcaccgagtgggccgaggaaaacagtcggctgctgcaggaacggggcgtcgcct
acatcaacgccgacagcagcatcgagggcaactacaccctgcgggtggactgcacccccctgatgtacagcctggtg
tacaacctgaccaaagagctgcagagccccgacgagggcttcgagggcaagtccctgttcgactcctggaccgagaa
gtcccccagccccgagttcagcggcctgcccagaatcagcaagctgggcagcggcaacgacttcgaggtgttcttcca
gcggctgggaatcgccagcggcagagcccggtacaccaaggactggaaaaccagcaagttctccggctacccccctg
taccacagcgtgtacgagacatacgagctggtggaaaagttctacgaccccatgttcaagtaccacctgaccgtggccc
aggtccgaggcggcatcgtgttcgaactggccaacagcgtggtgctgccattcgattgtcaggactacgccgtggtgctg
aagaagtacgccgacaaaatctacaacatcagcatgaagcacccccaggaaatgaaaacctacagcgtgtccttcg
acagcctgttcagcgccgtgaagaatttcaccgagatcgcctccaagttcaaccagagactgcaggacttcgacaaga
acaaccccatcctgctgcggatgatgaacgaccagctgatgttcctggaacgggccttcatcgacccccctgggcctgcc
cgaccggccctttaccggcacgtgatctatgcccccagcagccacaacaaatacgccggcgagagtttccccggcat

ctacgatgccctgttcgatatcgagagcaaggtggaccccagcaaggcctggggcgaagtgaagcggcagatttacgt
ggccgcattcacagtgcaggctgctgccgagacactgagcgaggtggcc

SEQ ID NO: 7. AMINO ACID SEQUENCE OF PSMA SHUFFLED ANTIGEN 3

MASARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSNEATNITPKHNMKAFLDELKAE
NIKKFLYNFTQIPHLAGTEQNFQLAKQIQSQWKEFGLDSVELAHYDVLLSYPNKTHPN
YISIINEDGNEIFNTSLFEPPPPGYENVSDIVPPFSAFSPQGMPEGDLVYVNYARTEDF
FKLERDMKINCSGKIVIARYGKVFRGNKVKNAQLAGAKGVILYSDPADYFAPGVKSYP
DGWNLPGGGVQRGNILNLNGAGDPLTPGYPANEYAYRRGIAEAVGLPSIPVHPIGYY
DAQKLLEKMGGSAPPDSSWRGSLKVPYNVGPGFTGNFSAQKLKLHIHSNTKVTRIYN
VIGTLRGAVEPDRYVILGGHRDSWVFGGIDPQSGAAVVHEIVRTFGTLKKKGWRPRR
TILFASWDAEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLLHS
LVYNLTKELKSPDEGFEGKSLYESWTKKSPSPELSGLPRISKLGSGNDFEVFFQRLGI
SSGRARYTKDWKTSKFSSYPLYHSIYETYELVVKFYDPMFKYHLTVAQVRGGMVFEL
ANSIVLPFDCRDYAVALKNHAENLYSISMKHPQEMKTYSVSFDSLFSAVKNFTEIASKF
SERLQDFDKSNPIVLRMMNDQLMFLERAFIDPLGLPDRPFYRHVIYAPSSHNKYAGES
FPGIYDALFDIESKVDPSKAWGEVKRQIYVAAFTVQAAAETLSEVA

SEQ ID NO: 8. NUCLEOTIDE SEQEUNCE ENCODING AMINO ACID SEQUENCE OF PSMA SHUFFLED ANTIGEN 3 OF SEQ ID NO:7

atggctagcgccagacggcccagatggctgtgtgctggcgccctggtgctggctggcggctttttcctgctgggcttcctgtt
cggctggttcatcaagagcagcaacgaggccaccaacatcacccccaagcacaacatgaaggcctttctggacgag
ctgaaggccgagaatatcaagaagttcctgtacaacttcacccagatcccccacctggccggcaccgagcagaacttc
cagctggccaagcagatccagagccagtggaaagagttcggcctggacagcgtggaactggcccactacgacgtgc
tgctgagctaccccaacaagacccaccccaactacatcagcatcatcaacgaggacggcaacgagattttcaacacc
agcctgttcgagccccctccacccggctacgagaacgtgtccgacatcgtgccccattcagcgcattcagtccacagg
gaatgcccgagggcgacctggtgtacgtgaactacgcccggaccgaggacttcttcaagctggaacgggacatgaag
atcaactgcagcggcaagatcgtgatcgccagatacggcaaggtgttccggggcaacaaagtgaagaacgcccagc
tggcaggcgccaagggcgtgatcctgtatagcgaccccgccgactacttcgcccctggcgtgaagtcctaccccgacg
gctggaacctgcctggcggcggagtgcagcggggcaacatcctgaacctgaacggcgctggcgacccccctgacccct
ggctatcccgccaacgagtacgcctacagacggggaatcgccgaggccgtgggcctgcctagcatccctgtgcaccc
catcggctactacgacgcccagaaactgctggaaaagatgggcggcagcgcccctcccgatagctcttggagaggca
gcctgaaggtgccctacaacgtgggccctggcttcaccggcaacttcagcgcccagaagctgaagctgcacatccaca
gcaacaccaaagtgacccggatctacaacgtgatcggcaccctgagaggcgccgtggaacccgacagatacgtgat
cctgggcggccaccgggacagctgggtgttcggcggcatcgaccctcagtctggcgccgctgtggtgcacgagatcgt
gcggacctttggcaccctgaagaagaagggctggcggcccagacggaccatcctgttcgccagctgggacgccgag

gaattcggcctgctgggcagcaccgagtgggccgaggaaaacagtcggctgctgcaggaacggggcgtcgcctaca
tcaacgccgacagcagcatcgagggcaactacaccctgcgggtggactgcacccccctgctgcacagcctggtgtac
aacctgaccaaagagctgaagtcccccgacgagggcttcgagggcaagagcctgtacgagagctggaccaagaag
tcccccagccccgagctgagcggcctgcccagaatcagcaagctgggcagcggcaacgacttcgaggtgttcttccag
cggctgggcatcagcagcggcagagcccggtacaccaaggactggaaaaccagcaagttcagcagctacccccctgt
accacagcatctacgagacatacgagctggtggtcaagttctacgaccccatgttcaagtaccacctgaccgtggccca
ggtccgaggcggcatggtgttcgagctggccaacagcatcgtgctgcccttcgactgccgggactacgccgtggccctg
aagaaccacgccgagaacctgtacagcatcagcatgaagcacccccaggaaatgaaaacctacagcgtgtccttcg
acagcctgttcagcgccgtgaagaatttcaccgagatcgcctccaagttcagcgagcggctgcaggacttcgacaaga
gcaaccccatcgtgctgagaatgatgaacgaccagctgatgttcctggaacgggccttcatcgacccccctgggcctgcc
cgaccggccctttaccggcacgtgatctatgcccccagcagccacaacaaatacgccggcgagagtttccccggcat
ctacgatgccctgttcgacatcgagagcaaggtggaccccagcaaggcctggggcgaagtgaagcggcagatttacg
tggccgcattcacagtgcaggccgctgccgagacactgagcgaggtggcc

SEQ ID NO: 9. AMINO ACID SEQUENCE OF A MEMBRANE-BOUND PSMA ANTIGEN

MASARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSNEATNITPKHNMKAFLDELKAE
NIKKFLYNFTQIPHLAGTEQNFQLAKQIQSQWKEFGLDSVELAHYDVLLSYPNKTHPN
YISIINEDGNEIFNTSLFEPPPPGYENVSDIVPPFSAFSPQGMPEGDLVYVNYARTEDF
FKLERDMKINCSGKIVIARYGKVFRGNKVKNAQLAGAKGVILYSDPADYFAPGVKSYP
DGWNLPGGGVQRGNILNLNGAGDPLTPGYPANEYAYRRGIAEAVGLPSIPVHPIGYY
DAQKLLEKMGGSAPPDSSWRGSLKVPYNVGPGFTGNFSTQKVKMHIHSTNEVTRIY
NVIGTLRGAVEPDRYVILGGHRDSWVFGGIDPQSGAAVVHEIVRSFGTLKKEGWRPR
RTILFASWDAEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLMY
SLVHNLTKELKSPDEGFEGKSLYESWTKKSPSPEFSGMPRISKLGSGNDFEVFFQRL
GIASGRARYTKNWETNKFSGYPLYHSVYETYELVEKFYDPMFKYHLTVAQVRGGMV
FELANSIVLPFDCRDYAVVLRKYADKIYSISMKHPQEMKTYSVSFDSLFSAVKNFTEIA
SKFSERLQDFDKSNPIVLRMMNDQLMFLERAFIDPLGLPDRPFYRHVIYAPSSHNKYA
GESFPGIYDALFDIESKVDPSKAWGEVKRQIYVAAFTVQAAAETLSEVA

SEQ ID NO: 10. NUCLEOTIDE SEQEUNCE ENCODING AMINO ACID SEQUENCE OF THE MEMBRANE-BOUND PSMA ANTIGEN OF SEQ ID NO: 9

atggctagcgcgcgccgcccgcgctggctgtgcgctggggcgctggtgctggcgggtggcttctttctcctcggcttcctctt
cgggtggtttataaaatcctccaatgaagctactaacattactccaaagcataatatgaaagcatttttggatgaattgaaa
gctgagaacatcaagaagttcttatataattttacacagataccacatttagcaggaacagaacaaaactttcagcttgca
aagcaaattcaatcccagtggaaagaatttggcctggattctgttgagctggcacattatgatgtcctgttgtcctacccaaa

taagactcatcccaactacatctcaataattaatgaagatggaaatgagattttcaacacatcattatttgaaccacctcctc
caggatatgaaaatgtttcggatattgtaccacctttcagtgctttctctcctcaaggaatgccagagggcgatctagtgtat
gttaactatgcacgaactgaagacttctttaaattggaacgggacatgaaaatcaattgctctgggaaaattgtaattgcca
gatatgggaaagttttcagaggaaataaggttaaaaatgcccagctggcaggggccaaaggagtcattctctactccga
ccctgctgactactttgctcctggggtgaagtcctatccagatggttggaatcttcctggaggtggtgtccagcgtggaaata
tcctaaatctgaatggtgcaggagaccctctcacaccaggttacccagcaaatgaatatgcttataggcgtggaattgca
gaggctgttggtcttccaagtattcctgttcatccaattggatactatgatgcacagaagctcctagaaaaaatgggtggct
cagcaccaccagatagcagctggagaggaagtctcaaagtgccctacaatgttggacctggctttactggaaacttttct
acacaaaaagtcaagatgcacatccactctaccaatgaagtgacaagaatttacaatgtgataggtactctcagagga
gcagtggaaccagacagatatgtcattctgggaggtcaccgggactcatgggtgtttggtggtattgaccctcagagtgg
agcagctgttgttcatgaaattgtgaggagctttggaacactgaaaaaggaagggtggagacctagaagaacaattttgt
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gtggcgtggcttatattaatgctgactcatctatagaaggaaactacactctgagagttgattgtacaccgctgatgtacag
cttggtacacaacctaacaaaagagctgaaaagccctgatgaaggctttgaaggcaaatctctttatgaaagttggacta
aaaaaagtccttccccagagttcagtggcatgcccaggataagcaaattgggatctggaaatgattttgaggtgttcttcc
aacgacttggaattgcttcaggcagagcacggtatactaaaaattgggaaacaaacaaattcagcggctatccactgta
tcacagtgtctatgaaacatatgagttggtggaaaagttttatgatccaatgtttaaatatcacctcactgtggcccaggttcg
aggagggatggtgtttgagctggccaattccatagtgctccctttgattgtcgagattatgctgtagttttaagaaagtatgct
gacaaaatctacagtatttctatgaaacatccacaggaaatgaagacatacagtgtatcatttgattcacttttttctgcagta
aagaattttacagaaattgcttccaagttcagtgagagactccaggactttgacaaaagcaacccaatagtattaagaat
gatgaatgatcaactcatgtttctggaaagagcatttattgatccattagggttaccagacaggccttttataggcatgtcat
ctatgctccaagcagccacaacaagtatgcaggggagtcattcccaggaatttatgatgctctgtttgatattgaaagcaa
agtggacccttccaaggcctggggagaagtgaagagacagatttatgttgcagccttcacagtgcaggcagctgcaga
gactttgagtgaagtagcc

SEQ ID NO: 11. AMINO ACID SEQUENCE OF A CYTOSOLIC PSMA ANTIGEN

MASKSSNEATNITPKHNMKAFLDELKAENIKKFLYNFTQIPHLAGTEQNFQLAKQIQSQ
WKEFGLDSVELAHYDVLLSYPNKTHPNYISIINEDGNEIFNTSLFEPPPPGYENVSDIVP
PFSAFSPQGMPEGDLVYVNYARTEDFFKLERDMKINCSGKIVIARYGKVFRGNKVKN
AQLAGAKGVILYSDPADYFAPGVKSYPDGWNLPGGGVQRGNILNLNGAGDPLTPGY
PANEYAYRRGIAEAVGLPSIPVHPIGYYDAQKLLEKMGGSAPPDSSWRGSLKVPYNV
GPGFTGNFSTQKVKMHIHSTNEVTRIYNVIGTLRGAVEPDRYVILGGHRDSWVFGGID
PQSGAAVVHEIVRSFGTLKKEGWRPRRTILFASWDAEEFGLLGSTEWAEENSRLLQE
RGVAYINADSSIEGNYTLRVDCTPLMYSLVHNLTKELKSPDEGFEGKSLYESWTKKSP
SPEFSGMPRISKLGSGNDFEVFFQRLGIASGRARYTKNWETNKFSGYPLYHSVYETY

ELVEKFYDPMFKYHLTVAQVRGGMVFELANSIVLPFDCRDYAVVLRKYADKIYSISMK
HPQEMKTYSVSFDSLFSAVKNFTEIASKFSERLQDFDKSNPIVLRMMNDQLMFLERAF
IDPLGLPDRPFYRHVIYAPSSHNKYAGESFPGIYDALFDIESKVDPSKAWGEVKRQIYV
AAFTVQAAAETLSEVA

SEQ ID NO: 12. NUCLEOTIDE SEQEUNCE ENCODING AMINO ACID SEQUENCE OF THE CYTOSOLIC PSMA ANTIGEN OF SEQ ID NO: 11

atggctagcaaatcctccaatgaagctactaacattactccaaagcataatatgaaagcatttttggatgaattgaaagct
gagaacatcaagaagttcttatataatttttacacagataccacatttagcaggaacagaacaaaactttcagcttgcaaa
gcaaattcaatcccagtggaaagaatttggcctggattctgttgagctggcacattatgatgtcctgttgtcctacccaaata
agactcatcccaactacatctcaataattaatgaagatggaaatgagattttcaacacatcattatttgaaccacctcctcc
aggatatgaaaatgtttcggatattgtaccacctttcagtgctttctctcctcaaggaatgccagagggcgatctagtgtatgt
taactatgcacgaactgaagacttctttaaattggaacgggacatgaaaatcaattgctctgggaaaattgtaattgccag
atatgggaaagttttcagaggaaataaggttaaaaatgcccagctggcaggggccaaaggagtcattctctactccgac
cctgctgactactttgctcctggggtgaagtcctatccagatggttggaatcttcctggaggtggtgtccagcgtggaaatat
cctaaatctgaatggtgcaggagaccctctcacaccaggttacccagcaaatgaatatgcttataggcgtggaattgcag
aggctgttggtcttccaagtattcctgttcatccaattggatactatgatgcacagaagctcctagaaaaaatgggtggctc
agcaccaccagatagcagctggagaggaagtctcaaagtgccctacaatgttggacctggctttactggaaacttttcta
cacaaaaagtcaagatgcacatccactctaccaatgaagtgacaagaatttacaatgtgataggtactctcagaggag
cagtggaaccagacagatatgtcattctgggaggtcaccgggactcatgggtgtttggtggtattgaccctcagagtgga
gcagctgttgttcatgaaattgtgaggagctttggaacactgaaaaaggaagggtggagacctagaagaacaattttgttt
gcaagctgggatgcagaagaatttggtcttcttggttctactgagtgggcagaggagaattcaagactccttcaagagcgt
ggcgtggcttatattaatgctgactcatctatagaaggaaactacactctgagagttgattgtacaccgctgatgtacagctt
ggtacacaacctaacaaaagagctgaaaagccctgatgaaggctttgaaggcaaatctctttatgaaagttggactaaa
aaaagtccttccccagagttcagtggcatgcccaggataagcaaattgggatctggaaatgattttgaggtgttcttccaa
cgacttggaattgcttcaggcagagcacggtatactaaaaattgggaaacaaacaaattcagcggctatccactgtatc
acagtgtctatgaaacatatgagttggtggaaaagttttatgatccaatgtttaaatatcacctcactgtggcccaggttcga
ggagggatggtgtttgagctggccaattccatagtgctccctttgattgtcgagattatgctgtagttttaagaaagtatgctg
acaaaatctacagtatttctatgaaacatccacaggaaatgaagacatacagtgtatcatttgattcacttttttctgcagtaa
agaattttacagaaattgcttccaagttcagtgagagactccaggactttgacaaaagcaacccaatagtattaagaatg
atgaatgatcaactcatgtttctggaaagagcatttattgatccattagggttaccagacaggccttttataggcatgtcatct
atgctccaagcagccacaacaagtatgcaggggagtcattcccaggaatttatgatgctctgtttgatattgaaagcaaa
gtggacccttccaaggcctggggagaagtgaagagacagatttatgttgcagccttcacagtgcaggcagctgcagag
actttgagtgaagtagcc

SEQ ID NO: 13. AMINO ACID SEQUENCE OF A SECRETED PSMA ANTIGEN

MASETDTLLLWVLLLWVPGSTGDAAKSSNEATNITPKHNMKAFLDELKAENIKKFLYN
FTQIPHLAGTEQNFQLAKQIQSQWKEFGLDSVELAHYDVLLSYPNKTHPNYISIINEDG
NEIFNTSLFEPPPPGYENVSDIVPPFSAFSPQGMPEGDLVYVNYARTEDFFKLERDMK
INCSGKIVIARYGKVFRGNKVKNAQLAGAKGVILYSDPADYFAPGVKSYPDGWNLPG
GGVQRGNILNLNGAGDPLTPGYPANEYAYRRGIAEAVGLPSIPVHPIGYYDAQKLLEK
MGGSAPPDSSWRGSLKVPYNVGPGFTGNFSTQKVKMHIHSTNEVTRIYNVIGTLRGA
VEPDRYVILGGHRDSWVFGGIDPQSGAAVVHEIVRSFGTLKKEGWRPRRTILFASWD
AEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLMYSLVHNLTKE
LKSPDEGFEGKSLYESWTKKSPSPEFSGMPRISKLGSGNDFEVFFQRLGIASGRARY
TKNWETNKFSGYPLYHSVYETYELVEKFYDPMFKYHLTVAQVRGGMVFELANSIVLP
FDCRDYAVVLRKYADKIYSISMKHPQEMKTYSVSFDSLFSAVKNFTEIASKFSERLQD
FDKSNPIVLRMMNDQLMFLERAFIDPLGLPDRPFYRHVIYAPSSHNKYAGESFPGIYD
ALFDIESKVDPSKAWGEVKRQIYVAAFTVQAAAETLSEVA

SEQ ID NO: 14. NUCLEOTIDE SEQUENCE ENCODING AMINO ACID SEQUENCE OF THE SECRETED PSMA ANTIGEN OF SEQ ID NO:13

atggctagcgaaaccgacactttgttgttgtgggtgcttttgctttgggtacccggatctactggtgatgctgctaaatcctcca
atgaagctactaacattactccaaagcataatatgaaagcatttttggatgaattgaaagctgagaacatcaagaagttct
tatataattttacacagataccacatttagcaggaacagaacaaaactttcagcttgcaaagcaaattcaatcccagtgg
aaagaatttggcctggattctgttgagctagcacattatgatgtcctgttgtcctacccaaataagactcatcccaactacat
ctcaataattaatgaagatggaaatgagattttcaacacatcattatttgaaccacctcctccaggatatgaaaatgtttcgg
atattgtaccacctttcagtgctttctctcctcaaggaatgccagagggcgatctagtgtatgttaactatgcacgaactgaa
gacttctttaaattggaacgggacatgaaaatcaattgctctgggaaaattgtaattgccagatatgggaaagttttcagag
gaaataaggttaaaaatgcccagctggcaggggccaaaggagtcattctctactccgaccctgctgactactttgctcct
ggggtgaagtcctatccagatggttggaatcttcctggaggtggtgtccagcgtggaaatatcctaaatctgaatggtgca
ggagaccctctcacaccaggttacccagcaaatgaatatgcttataggcgtggaattgcagaggctgttggtcttccaagt
attcctgttcatccaattggatactatgatgcacagaagctcctagaaaaaatgggtggctcagcaccaccagatagcag
ctggagaggaagtctcaaagtgccctacaatgttggacctggctttactggaaacttttctacacaaaaagtcaagatgc
acatccactctaccaatgaagtgacaagaatttacaatgtgataggtactctcagaggagcagtggaaccagacagat
atgtcattctgggaggtcaccgggactcatgggtgtttggtggtattgaccctcagagtggagcagctgttgttcatgaaatt
gtgaggagctttggaacactgaaaaaggaagggtggagacctagaagaacaattttgtttgcaagctgggatgcagaa
gaatttggtcttcttggttctactgagtgggcagaggagaattcaagactccttcaagagcgtggcgtggcttatattaatgct
gactcatctatagaaggaaactacactctgagagttgattgtacaccgctgatgtacagcttggtacacaacctaacaaa
agagctgaaaagccctgatgaaggctttgaaggcaaatctctttatgaaagttggactaaaaaaagtccttccccagagt
tcagtggcatgcccaggataagcaaattgggatctggaaatgattttgaggtgttcttccaacgacttggaattgcttcagg

cagagcacggtatactaaaaattgggaaacaaacaaattcagcggctatccactgtatcacagtgtctatgaaacatat
gagttggtggaaaagttttatgatccaatgtttaaatatcacctcactgtggcccaggttcgaggagggatggtgtttgagct
agccaattccatagtgctccctttgattgtcgagattatgctgtagttttaagaaagtatgctgacaaaatctacagtatttcta
tgaaacatccacaggaaatgaagacatacagtgtatcatttgattcacttttttctgcagtaaagaattttacagaaattgctt
ccaagttcagtgagagactccaggactttgacaaaagcaacccaatagtattaagaatgatgaatgatcaactcatgttt
ctggaaagagcatttattgatccattagggttaccagacaggccttttataggcatgtcatctatgctccaagcagccaca
acaagtatgcaggggagtcattcccaggaatttatgatgctctgtttgatattgaaagcaaagtggacccttccaaggcct
ggggagaagtgaagagacagatttatgttgcagccttcacagtgcaggcagctgcagagactttgagtgaagtagcc

SEQ ID NO: 15. AMINO ACID SEQUENCE OF THE FULL LENGTH HUMAN PSA

MASWVPVVFLTLSVTWIGAAPLILSRIVGGWECEKHSQPWQVLVASRGRAVCGGVLV
HPQWVLTAAHCIRNKSVILLGRHSLFHPEDTGQVFQVSHSFPHPLYDMSLLKNRFLRP
GDDSSHDLMLLRLSEPAELTDAVKVMDLPTQEPALGTTCYASGWGSIEPEEFLTPKK
LQCVDLHVISNDVCAQVHPQKVTKFMLCAGRWTGGKSTCSGDSGGPLVCNGVLQGI
TSWGSEPCALPERPSLYTKVVHYRKWIKDTIVANP

SEQ ID NO: 16. NUCLEOTIDE SEQUENCE ENCODING AMINO ACID SEQUENCE OF THE FULL LENGTH HUMAN PSA OF SEQ ID NO: 15

atggctagctgggtcccggttgtcttcctcaccctgtccgtgacgtggattggcgctgcgcccctcatcctgtctcggattgtg
ggaggctgggagtgcgagaagcattcccaaccctggcaggtgcttgtggcctctcgtggcagggcagtctgcggcggt
gttctggtgcacccccagtgggtcctcacagctgcccactgcatcaggaacaaaagcgtgatcttgctgggtcggcaca
gcttgtttcatcctgaagacacaggccaggtatttcaggtcagccacagcttcccacacccgctctacgatatgagcctcct
gaagaatcgattcctcaggccaggtgatgactccagccacgacctcatgctgctccgcctgtcagagcctgccgagctc
acggatgctgtgaaggtcatggacctgcccacccaggagccagcactggggaccacctgctacgcctcaggctgggg
cagcattgaaccagaggagttcttgaccccaaagaaacttcagtgtgtggacctccatgttatttccaatgacgtgtgtgcg
caagttcaccctcagaaggtgaccaagttcatgctgtgtgctggacgctggacaggggcaaaagcacctgctcgggt
gattctgggggcccacttgtctgtaatggtgtgcttcaaggtatcacgtcatggggcagtgaaccatgtgccctgcccgaa
aggccttccctgtacaccaaggtggtgcattaccggaagtggatcaaggacaccatcgtggccaacccc

SEQ ID NO: 17. AMINO ACID SEQUENCE OF A CYTOSOLIC PSA ANTIGEN

MASIVGGWECEKHSQPWQVLVASRGRAVCGGVLVHPQWVLTAAHCIRNKSVILLGR
HSLFHPEDTGQVFQVSHSFPHPLYDMSLLKNRFLRPGDDSSHDLMLLRLSEPAELTD
AVKVMDLPTQEPALGTTCYASGWGSIEPEEFLTPKKLQCVDLHVISNDVCAQVHPQK
VTKFMLCAGRWTGGKSTCSGDSGGPLVCNGVLQGITSWGSEPCALPERPSLYTKVV
HYRKWIKDTIVANP

SEQ ID NO: 18. NUCLEOTIDE SEQEUNCE ENCODING AMINO ACID SEQUENCE OF THE CYTOSOLIC PSA ANTIGEN OF SEQ ID NO: 17

atggctagcattgtgggaggctgggagtgcgagaagcattcccaaccctggcaggtgcttgtggcctctcgtggcaggg
cagtctgcggcggtgttctggtgcacccccagtgggtcctcacagctgcccactgcatcaggaacaaaagcgtgatcttg
ctgggtcggcacagcttgtttcatcctgaagacacaggccaggtatttcaggtcagccacagcttcccacacccgctctac
gatatgagcctcctgaagaatcgattcctcaggccaggtgatgactccagccacgacctcatgctgctccgcctgtcaga
gcctgccgagctcacggatgctgtgaaggtcatggacctgcccacccaggagccagcactggggaccacctgctacg
cctcaggctggggcagcattgaaccagaggagttcttgaccccaaagaaacttcagtgtgtggacctccatgttatttcca
atgacgtgtgtgcgcaagttcaccctcagaaggtgaccaagttcatgctgtgtgctggacgctggacaggggcaaaa
gcacctgctcgggtgattctgggggcccacttgtctgtaatggtgtgcttcaaggtatcacgtcatggggcagtgaaccatg
tgccctgcccgaaaggccttccctgtacaccaaggtggtgcattaccggaagtggatcaaggacaccatcgtggccaa
cccc

SEQ ID NO: 19. AMINO ACID SEQUENCE OF A MEMBRANE-BOUND PSA ANTIGEN

MASARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSNEATNITPGIVGGWECEKHSQP
WQVLVASRGRAVCGGVLVHPQWVLTAAHCIRNKSVILLGRHSLFHPEDTGQVFQVS
HSFPHPLYDMSLLKNRFLRPGDDSSHDLMLLRLSEPAELTDAVKVMDLPTQEPALGT
TCYASGWGSIEPEEFLTPKKLQCVDLHVISNDVCAQVHPQKVTKFMLCAGRWTGGK
STCSGDSGGPLVCNGVLQGITSWGSEPCALPERPSLYTKVVHYRKWIKDTIVANP

SEQ ID NO:20. NUCLEOTIDE SEQUENCE ENCODING AMINO ACID SEQUENCE OF THE MEMBRANE-BOUND PSA ANTIGEN OF SEQ ID NO:19

atggctagcgcgcgccgcccgcgctggctgtgcgctggggcgctggtgctggcgggtggcttctttctcctcggcttcctctt
cgggtggtttataaaatcctccaatgaagctactaacattactccaggaattgtgggaggctgggagtgcgagaagcatt
cccaaccctggcaggtgcttgtggcctctcgtggcagggcagtctgcggcggtgttctggtgcacccccagtgggtcctc
acagctgcccactgcatcaggaacaaaagcgtgatcttgctgggtcggcacagcttgtttcatcctgaagacacaggcc
aggtatttcaggtcagccacagcttcccacacccgctctacgatatgagcctcctgaagaatcgattcctcaggccaggt
gatgactccagccacgacctcatgctgctccgcctgtcagagcctgccgagctcacggatgctgtgaaggtcatggacc
tgcccacccaggagccagcactggggaccacctgctacgcctcaggctggggcagcattgaaccagaggagttcttg
accccaaagaaacttcagtgtgtggacctccatgttatttccaatgacgtgtgtgcgcaagttcaccctcagaaggtgacc
aagttcatgctgtgtgctggacgctggacaggggcaaaagcacctgctcgggtgattctgggggcccacttgtctgtaat
ggtgtgcttcaaggtatcacgtcatggggcagtgaaccatgtgccctgcccgaaaggccttccctgtacaccaaggtggt
gcattaccggaagtggatcaaggacaccatcgtggccaaccccctga

SEQ ID NO: 21. AMINO ACID SEQUENCE OF THE FULL LENGTH HUMAN PSCA

MASKAVLLALLMAGLALQPGTALLCYSCKAQVSNEDCLQVENCTQLGEQCWTARIRA
VGLLTVISKGCSLNCVDDSQDYYVGKKNITCCDTDLCNASGAHALQPAAAILALLPAL
GLLLWGPGQL

SEQ ID NO: 22. NUCLEOTIDE SEQUENCE ENCODING AMINO ACID SEQUENCE OF THE FULL LENGTH HUMAN PSCA OF SEQ ID NO: 21

atggctagcaaggctgtgctgcttgccctgttgatggcaggcttggccctgcagccaggcactgccctgctgtgctactcct
gcaaagcccaggtgagcaacgaggactgcctgcaggtggagaactgcacccagctgggggagcagtgctggaccg
cgcgcatccgcgcagttggcctcctgaccgtcatcagcaaaggctgcagcttgaactgcgtggatgactcacaggacta
ctacgtgggcaagaagaacatcacgtgctgtgacaccgacttgtgcaacgccagcggggcccatgccctgcagccgg
ctgccgccatccttgcgctgctccctgcactcggcctgctgctctggggacccggccagcta

SEQ ID NO:23. NUCLEOTIDE SEQUENCE OF PLASMID 5166

GGCGTAATGCTCTGCCAGTGTTACAACCAATTAACCAATTCTGATTAGAAAAACTC
ATCGAGCATCAAATGAAACTGCAATTTATTCATATCAGGATTATCAATACCATATTT
TTGAAAAAGCCGTTTCTGTAATGAAGGAGAAAACTCACCGAGGCAGTTCCATAGG
ATGGCAAGATCCTGGTATCGGTCTGCGATTCCGACTCGTCCAACATCAATACAAC
CTATTAATTTCCCCTCGTCAAAAATAAGGTTATCAAGTGAGAAATCACCATGAGTG
ACGACTGAATCCGGTGAGAATGGCAAAAGCTTATGCATTTCTTTCCAGACTTGTTC
AACAGGCCAGCCATTACGCTCGTCATCAAAATCACTCGCATCAACCAAACCGTTA
TTCATTCGTGATTGCGCCTGAGCGAGACGAAATACGCGATCGCTGTTAAAAGGAC
AATTACAAACAGGAATCAAATGCAACCGGCGCAGGAACACTGCCAGCGCATCAAC
AATATTTTCACCTGAATCAGGATATTCTTCTAATACCTGGAATGCTGTTTTCCCGG
GGATCGCAGTGGTGAGTAACCATGCATCATCAGGAGTACGGATAAAATGCTTGAT
GGTCGGAAGAGGCATAAATTCCGTCAGCCAGTTTAGTCTGACCATCTCATCTGTA
ACATCATTGGCAACGCTACCTTTGCCATGTTTCAGAAACAACTCTGGCGCATCGG
GCTTCCCATACAATCGATAGATTGTCGCACCTGATTGCCCGACATTATCGCGAGC
CCATTTATACCCATATAAATCAGCATCCATGTTGGAATTTAATCGCGGCCTCGAGC
AAGACGTTTCCCGTTGAATATGGCTCATAACACCCCTTGTATTACTGTTTATGTAA
GCAGACAGGTCGACAATATTGGCTATTGGCCATTGCATACGTTGTATCTATATCAT
AATATGTACATTTATATTGGCTCATGTCCAATATGACCGCCATGTTGACATTGATTA
TTGACTAGTTATTAATAGTAATCAATTACGGGGTCATTAGTTCATAGCCCATATATG
GAGTTCCGCGTTACATAACTTACGGTAAATGGCCCGCCTGGCTGACCGCCCAAC
GACCCCCGCCCATTGACGTCAATAATGACGTATGTTCCCATAGTAACGCCAATAG
GGACTTTCCATTGACGTCAATGGGTGGAGTATTTACGGTAAACTGCCCACTTGGC
AGTACATCAAGTGTATCATATGCCAAGTCCGCCCCCTATTGACGTCAATGACGGT

AAATGGCCCGCCTGGCATTATGCCCAGTACATGACCTTACGGGACTTTCCTACTT
GGCAGTACATCTACGTATTAGTCATCGCTATTACCATGGTGATGCGGTTTTGGCA
GTACACCAATGGGCGTGGATAGCGGTTTGACTCACGGGGATTTCCAAGTCTCCAC
CCCATTGACGTCAATGGGAGTTTGTTTTGGCACCAAAATCAACGGGACTTTCCAA
AATGTCGTAATAACCCCGCCCCGTTGACGCAAATGGGCGGTAGGCGTGTACGGT
GGGAGGTCTATATAAGCAGAGCTCGTTTAGTGAACCGTCAGATCGCCTGGAGAC
GCCATCCACGCTGTTTTGACCTCCATAGAAGACACCGGGACCGATCCAGCCTCC
GCGGCCGGGAACGGTGCATTGGAACGCGGATTCCCCGTGCCAAGAGTGACTCA
CCGTCCGGATCTCAGCAAGCAGGTATGTACTCTCCAGGGTGGGCCTGGCTTCCC
CAGTCAAGACTCCAGGGATTTGAGGGACGCTGTGGGCTCTTCTCTTACATGTACC
TTTTGCTTGCCTCAACCCTGACTATCTTCCAGGTCAGGATCCCAGAGTCAGGGGT
CTGTATTTTCCTGCTGGTGGCTCCAGTTCAGGAACAGTAAACCCTGCTCCGAATA
TTGCCTCTCACATCTCGTCAATCTCCGCGAGGACTGGGGACCCTGTGACGAACAT
GGCTAGCGCGCGCCGCCCGCGCTGGCTGTGCGCTGGGGCGCTGGTGCTGGCG
GGTGGCTTCTTTCTCCTCGGCTTCCTCTTCGGGTGGTTTATAAAATCCTCCAATGA
AGCTACTAACATTACTCCAAAGCATAATATGAAAGCATTTTTGGATGAATTGAAAG
CTGAGAACATCAAGAAGTTCTTATATAATTTTACACAGATACCACATTTAGCAGGA
ACAGAACAAAACTTTCAGCTTGCAAAGCAAATTCAATCCCAGTGGAAAGAATTTGG
CCTGGATTCTGTTGAGCTGGCACATTATGATGTCCTGTTGTCCTACCCAAATAAGA
CTCATCCCAACTACATCTCAATAATTAATGAAGATGGAAATGAGATTTTCAACACAT
CATTATTTGAACCACCTCCTCCAGGATATGAAAATGTTTCGGATATTGTACCACCT
TTCAGTGCTTTCTCTCCTCAAGGAATGCCAGAGGGCGATCTAGTGTATGTTAACTA
TGCACGAACTGAAGACTTCTTTAAATTGGAACGGGACATGAAAATCAATTGCTCTG
GGAAAATTGTAATTGCCAGATATGGGAAAGTTTTCAGAGGAAATAAGGTTAAAAAT
GCCCAGCTGGCAGGGGCCAAAGGAGTCATTCTCTACTCCGACCCTGCTGACTAC
TTTGCTCCTGGGGTGAAGTCCTATCCAGATGGTTGGAATCTTCCTGGAGGTGGTG
TCCAGCGTGGAAATATCCTAAATCTGAATGGTGCAGGAGACCCTCTCACACCAGG
TTACCCAGCAAATGAATATGCTTATAGGCGTGGAATTGCAGAGGCTGTTGGTCTT
CCAAGTATTCCTGTTCATCCAATTGGATACTATGATGCACAGAAGCTCCTAGAAAA
AATGGGTGGCTCAGCACCACCAGATAGCAGCTGGAGAGGAAGTCTCAAAGTGCC
CTACAATGTTGGACCTGGCTTTACTGGAAACTTTTCTACACAAAAAGTCAAGATGC
ACATCCACTCTACCAATGAAGTGACAAGAATTTACAATGTGATAGGTACTCTCAGA
GGAGCAGTGGAACCAGACAGATATGTCATTCTGGGAGGTCACCGGGACTCATGG
GTGTTTGGTGGTATTGACCCTCAGAGTGGAGCAGCTGTTGTTCATGAAATTGTGA
GGAGCTTTGGAACACTGAAAAAGGAAGGGTGGAGACCTAGAAGAACAATTTTGTT

TGCAAGCTGGGATGCAGAAGAATTTGGTCTTCTTGGTTCTACTGAGTGGGCAGAG
GAGAATTCAAGACTCCTTCAAGAGCGTGGCGTGGCTTATATTAATGCTGACTCAT
CTATAGAAGGAAACTACACTCTGAGAGTTGATTGTACACCGCTGATGTACAGCTT
GGTACACAACCTAACAAAAGAGCTGAAAAGCCCTGATGAAGGCTTTGAAGGCAAA
TCTCTTTATGAAAGTTGGACTAAAAAAAGTCCTTCCCCAGAGTTCAGTGGCATGCC
CAGGATAAGCAAATTGGGATCTGGAAATGATTTTGAGGTGTTCTTCCAACGACTTG
GAATTGCTTCAGGCAGAGCACGGTATACTAAAAATTGGGAAACAAACAAATTCAG
CGGCTATCCACTGTATCACAGTGTCTATGAAACATATGAGTTGGTGGAAAAGTTTT
ATGATCCAATGTTTAAATATCACCTCACTGTGGCCCAGGTTCGAGGAGGGATGGT
GTTTGAGCTGGCCAATTCCATAGTGCTCCCTTTTGATTGTCGAGATTATGCTGTAG
TTTTAAGAAAGTATGCTGACAAAATCTACAGTATTTCTATGAAACATCCACAGGAAA
TGAAGACATACAGTGTATCATTTGATTCACTTTTTTCTGCAGTAAAGAATTTTACAG
AAATTGCTTCCAAGTTCAGTGAGAGACTCCAGGACTTTGACAAAAGCAACCCAATA
GTATTAAGAATGATGAATGATCAACTCATGTTTCTGGAAAGAGCATTTATTGATCC
ATTAGGGTTACCAGACAGGCCTTTTTATAGGCATGTCATCTATGCTCCAAGCAGC
CACAACAAGTATGCAGGGGAGTCATTCCCAGGAATTTATGATGCTCTGTTTGATAT
TGAAAGCAAAGTGGACCCTTCCAAGGCCTGGGGAGAAGTGAAGAGACAGATTTAT
GTTGCAGCCTTCACAGTGCAGGCAGCTGCAGAGACTTTGAGTGAAGTAGCCTAAA
GATCTGGGCCCTAACAAAACAAAAAGATGGGGTTATTCCCTAAACTTCATGGGTTA
CGTAATTGGAAGTTGGGGGACATTGCCACAAGATCATATTGTACAAAAGATCAAA
CACTGTTTTAGAAAACTTCCTGTAAACAGGCCTATTGATTGGAAAGTATGTCAAAG
GATTGTGGGTCTTTTGGGCTTTGCTGCTCCATTTACACAATGTGGATATCCTGCCT
TAATGCCTTTGTATGCATGTATACAAGCTAAACAGGCTTTCACTTTCTCGCCAACT
TACAAGGCCTTTCTAAGTAAACAGTACATGAACCTTTACCCCGTTGCTCGGCAAC
GGCCTGGTCTGTGCCAAGTGTTTGCTGACGCAACCCCCACTGGCTGGGGCTTGG
CCATAGGCCATCAGCGCATGCGTGGAACCTTTGTGGCTCCTCTGCCGATCCATAC
TGCGGAACTCCTAGCCGCTTGTTTTGCTCGCAGCCGGTCTGGAGCAAAGCTCATA
GGAACTGACAATTCTGTCGTCCTCTCGCGGAAATATACATCGTTTCGATCTACGTA
TGATCTTTTTCCCTCTGCCAAAAATTATGGGGACATCATGAAGCCCCTTGAGCATC
TGACTTCTGGCTAATAAAGGAAATTTATTTTCATTGCAATAGTGTGTTGGAATTTTT
TGTGTCTCTCACTCGGAAGGAATTCTGCATTAATGAATCGGCCAACGCGCGGGGA
GAGGCGGTTTGCGTATTGGGCGCTCTTCCGCTTCCTCGCTCACTGACTCGCTGC
GCTCGGTCGTTCGGCTGCGGCGAGCGGTATCAGCTCACTCAAAGGCGGTAATAC
GGTTATCCACAGAATCAGGGGATAACGCAGGAAAGAACATGTGAGCAAAAGGCC
AGCAAAAGGCCAGGAACCGTAAAAAGGCCGCGTTGCTGGCGTTTTTCCATAGGC

TCCGCCCCCCTGACGAGCATCACAAAAATCGACGCTCAAGTCAGAGGTGGCGAA
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SEQ ID NO:24. NUCLEOTIDE SEQUENCE OF PLASMID 5259

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SEQ ID NO:25. NUCLEOTIDE SEQUENCE OF PLASMID 5297

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SEQ ID NO:26. NUCLEOTIDE SEQUENCE OF PLASMID 460

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SEQ ID NO:27. NUCLEOTIDE SEQUENCE OF PLASMID 451

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SEQ ID NO:28. NUCLEOTIDE SEQUENCE OF PLASMID 454

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SEQ ID NO:29. NUCLEOTIDE SEQUENCE OF PLASMID 5300

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SEQ ID NO:30. NUCLEOTIDE SEQUENCE OF PLASMID 449

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SEQ ID NO:31. NUCLEOTIDE SEQUENCE OF PLASMID 603

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SEQ ID NO:32. NUCLEOTIDE SEQUENCE OF PLASMID 455

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SEQ ID NO:33. NUCLEOTIDE SEQUENCE OF PLASMID 456

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SEQ ID NO:34. NUCLEOTIDE SEQUENCE OF PLASMID 457

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SEQ ID NO:35. NUCLEOTIDE SEQUENCE OF PLASMID 458

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SEQ ID NO:36. NUCLEOTIDE SEQUENCE OF PLASMID 459

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TTTACAGAAATTGCTTCCAAGTTCAGTGAGAGACTCCAGGACTTTGACAAAAGCAA
CCCAATAGTATTAAGAATGATGAATGATCAACTCATGTTTCTGGAAAGAGCATTTA
TTGATCCATTAGGGTTACCAGACAGGCCTTTTTATAGGCATGTCATCTATGCTCCA
AGCAGCCACAACAAGTATGCAGGGGAGTCATTCCCAGGAATTTATGATGCTCTGT
TTGATATTGAAAGCAAAGTGGACCCTTCCAAGGCCTGGGGAGAAGTGAAGAGACA
GATTTATGTTGCAGCCTTCACAGTGCAGGCAGCTGCAGAGACTTTGAGTGAAGTA
GCCTAAAGATCTGACCCCCTAACGTTACTGGCCGAAGCCGCTTGGAATAAGGCC
GGTGTGCGTTTGTCTATATGTTATTTTCCACCATATTGCCGTCTTTTGGCAATGTG
AGGGCCCGGAAACCTGGCCCTGTCTTCTTGACGAGCATTCCTAGGGGTCTTTCC
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TGGAAGCTTCTTGAAGACAAACAACGTCTGTAGCGACCCTTTGCAGGCAGCGGAA
CCCCCCACCTGGCGACAGGTGCCTCTGCGGCCAAAAGCCACGTGTATAAGATAC
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ACAGGCCAGGTATTTCAGGTCAGCCACAGCTTCCCACACCCGCTCTACGATATGA
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CCTGCCCACCCAGGAGCCAGCACTGGGGACCACCTGCTACGCCTCAGGCTGGG
GCAGCATTGAACCAGAGGAGTTCTTGACCCCAAAGAAACTTCAGTGTGTGGACCT
CCATGTTATTTCCAATGACGTGTGTGCGCAAGTTCACCCTCAGAAGGTGACCAAG
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AACAAACCACCGCTGGTAGCGGTGGTTTTTTTGTTTGCAAGCAGCAGATTACGCG
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AGTGGAACGAAAACTCACGTTAAGGGATTTTGGTCATGAGATTATCAAAAAGGATC
TTCACCTAGATCCTTTTAAATTAAAAATGAAGTTTTAAATCAATCTAAAGTATATATG
AGTAAACTTGGTCTGACAGTTACCAATGCTTAATCAGTGAGGCACCTATCTCAGC
GATCTGTCTATTTCGTTCATCCATAGTTGCCTGACTC

SEQ ID NO:37. NUCLEOTIDE SEQUENCE OF PSHUTTLE IRES

CATCATCAATAATATACCTTATTTTGGATTGAAGCCAATATGATAATGAGGGGGTG
GAGTTTGTGACGTGGCGCGGGGCGTGGGAACGGGGCGGGTGACGTAGTAGTGT
GGCGGAAGTGTGATGTTGCAAGTGTGGCGGAACACATGTAAGCGACGGATGTGG
CAAAAGTGACGTTTTTGGTGTGCGCCGGTGTACACAGGAAGTGACAATTTTCGCG
CGGTTTTAGGCGGATGTTGTAGTAAATTTGGGCGTAACCGAGTAAGATTTGGCCA
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ATAGCGCGTAATACTGTAATAGTAATCAATTACGGGGTCATTAGTTCATAGCCCAT
ATATGGAGTTCCGCGTTACATAACTTACGGTAAATGGCCCGCCTGGCTGACCGCC
CAACGACCCCCGCCCATTGACGTCAATAATGACGTATGTTCCCATAGTAACGCCA
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GCAGTACATCAATGGGCGTGGATAGCGGTTTGACTCACGGGGATTTCCAAGTCTC
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CAAAATGTCGTAACAACTCCGCCCCATTGACGCAAATGGGCGGTAGGCGTGTAC
GGTGGGAGGTCTATATAAGCAGAGCTGGTTTAGTGAACCGTCAGATCCGCTAGA
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ACAGAGAAAGAGCCAAGAACAAAATTGCAAAGGAAACCAACAATAAGAAGAAAGA
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TGAGATCGTCATAGGCCATTTTTACAAAGCGCGGGCGGAGGGTGCCAGACTGCG
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CTGATGCAATGCGGCGGCTGCATACGCTTGATCCGGCTACCTGCCCATTCGACC
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GGAAGGGAAGAAAGCGAAAGGAGCGGGCGCTAGGGCGCTGGCAAGTGTAGCGG
TCACGCTGCGCGTAACCACCACACCCGCGCGCTTAATGCGCCGCTACAGGGCGC
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SEQ ID NO:38. Amino acid sequence of Her-2 antigen:

MASELAALCRWGLLLALLPPGAASTQVCTGTDMKLRLPASPETHLDMLRHLYQGCQ
VVQGNLELTYLPTNASLSFLQDIQEVQGYVLIAHNQVRQVPLQRLRIVRGTQLFEDNY
ALAVLDNGDPLDSVAPAAGATPGGLQELQLRSLTEILKGGVLIRRSPQLCHQDTVLWE
DVFRKNNQLALVLMDTNRSRACHPCAPMCKANHCWGESSQDCQTLTRTICTSACAR
CKAPLPTDCCHEQCAAGCTGPKHSDCLACLHFNHSGICELHCPALVTYNTDTFESMP

NPEGRYTFGASCVTACPYNYLSTDVGSCTLVCPLHNQEVTAEDGTQRCEKCSKPCA
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LQVFETLEEITGYLYISAWPDSFPNLSVFQNLRVIRGRILHNGAYSLTLQGLGISWLGL
RSLQELGSGLALVHRNARLCFVHTVPWDQLFRNPHQALLHSGNRPEEDCVGEGFVC
YSLCAHGHCWGPGPTQCVNCSHFLRGQECVEECRVLQGLPREYVNARHCLPCHPE
CQPQNGSVTCFGPEADQCVACAHYKDPPFCVARCPSGVKPDLSYMPIWKFPDEEG
ACQPCPINCTHSCVDLDDKGCPAEQRASPLTSIISAVVGILLVVVLGVVFGILIKRRQQK
IRKYTMRRNEDLGPSSPMDSTFYRSLLEDEDMGELVDAEEYLVPQQGFFCPDPTPGT
GSTAHRRHRSSSARNGGGDLTLGMEPSGEGPPRSPRAPSEGTGSDVFDGDLAVGV
TKGLQSLSPQDLSPLQRYSEDPTLPLPSETDGKVAPLSCSPQPEFVNQSDVQPKSPL
TPEGPPSPARPTGATLERAKTLSPGKNGVVKDVFTFGGAVENPEFLAPREGTASPPH
PSPAFSPAFDNLFFWDQNSSEQGPPPSNFEGTPTAENPEFLGLDVPV

(signal sequence underlined)

SEQ ID NO:39. Nucleic acid sequence encoding the Her-2 antigen amino acid sequence of SEQ ID NO: 38

ATGGCTAGCGAGCTGGCCGCCCTGTGTAGATGGGGACTGCTGCTGGCTCTGCTG
CCTCCTGGAGCCGCTTCTACACAGGTCTGCACCGGCACCGACATGAAGCTGAGA
CTGCCCGCCAGCCCCGAGACACACCTGGACATGCTGCGGCACCTGTACCAGGG
CTGCCAGGTGGTCCAGGGGAATCTGGAACTGACCTACCTGCCCACCAACGCCAG
CCTGAGCTTCCTGCAGGACATCCAGGAAGTGCAGGGCTACGTCCTGATCGCCCA
CAACCAGGTCCGCCAGGTGCCCCTGCAGCGGCTGAGAATCGTGCGGGGCACCC
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CAGGGCCTGGGAATCAGCTGGCTGGGCCTGCGGAGCCTGCAGGAACTGGGATC
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CGGCCACTGTTGGGGACCTGGCCCTACCCAGTGCGTGAACTGCAGCCACTTCCT
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ATGGCAGCGTGACCTGCTTCGGACCCGAGGCCGATCAGTGTGTGGCCTGCGCC
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AGGACCTGTCCCCCCTGCAGAGATACAGCGAGGACCCCACCCTGCCCCTGCCCA
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AGCCCTGCCAGACCTACCGGCGCCACCCTGGAAAGAGCCAAGACCCTGAGCCC
CGGCAAGAACGGCGTGGTGAAAGACGTGTTCACCTTCGGAGGCGCCGTGGAAAA
CCCCGAGTTCCTGGCCCCCAGAGAGGGCACAGCCAGCCCTCCACACCCCAGCC
CAGCCTTCTCCCCCGCCTTCGACAACCTGTTCTTCTGGGACCAGAACAGCAGCGA

GCAGGGCCCACCCCCCAGCAATTTCGAGGGCACCCCCACCGCCGAGAATCCTGA
GTTCCTGGGCCTGGACGTGCCCGTGTGA

SEQ ID NO:40. Amino acid sequence of heavy chain of the anti-CD40 antibody CP870,893:

MDWTWRILFLVAAATGAHSQVQLVQSGAEVKKPGASVKVSCKASGYTFTGYYMHW
VRQAPGQGLEWMGWINPDSGGTNYAQKFQGRVTMTRDTSISTAYMELNRLRSDDT
AVYYCARDQPLGYCTNGVCSYFDYWGQGTLVTVSSASTKGPSVFPLAPCSRSTSES
TAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSNFGT
QTYTCNVDHKPSNTKVDKTVERKCCVECPPCPAPPVAGPSVFLFPPKPKDTLMISRT
PEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVVSVLTVVHQD
WLNGKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLV
KGFYPSDIAVEWESNGQPENNYKTTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSC
SVMHEALHNHYTQKSLSLSPGK.

SEQ ID NO:41. Acid sequence of the light chain of the anti-CD40 antibody CP870,893:

MRLPAQLLGLLLLWFPGSRCDIQMTQSPSSVSASVGDRVTITCRASQGIYSWLAWYQ
QKPGKAPNLLIYTASTLQSGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCQQANIFPL
TFGGGTKVEIKRTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNAL
QSGNSQESVTEQDSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNR
GEC.

SEQ ID NO:42. Acid sequence of the heavy chain of the anti-CTLA-4 antibody Tremelimumab

QVQLVESGGGVVQPGRSLRLSCAASGFTFSSYGMHWVRQAPGKGLEWVAVIWYDG
SNKYYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCARDPRGATLYYYYYGM
DVWGQGTTVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNS
GALTSGVHTFPAVLQSSGLYSLSSVVTVPSSNFGTQTYTCNVDHKPSNTKVDKTVER
KCCVECPPCPAPPVAGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQFNWY
VDGVEVHNAKTKPREEQFNSTFRVVSVLTVVHQDWLNGKEYKCKVSNKGLPAPIEKT
ISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYK
TTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK

SEQ ID NO:43. Acid sequence of the light chain of the anti-CTLA-4 antibody Tremelimumab

DIQMTQSPSSLSASVGDRVTITCRASQSINSYLDWYQQKPGKAPKLLIYAASSLQSGV
PSRFSGSGSGTDFTLTISSLQPEDFATYYCQQYYSTPFTFGPGTKVEIKRTVAAPSVFI
FPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTY
SLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

SEQ ID NO:44. Nucleotide sequence of CpG 7909

5' TCGTCGTTTTGTCGTTTTGTCGTT3'

SEQ ID NO:45. Nucleotide sequence of CpG 24555

5' TCGTCGTTTTTCGGTGCTTTT3'

SEQ ID NO:46. Nucleotide sequence of CpG 10103

5' TCGTCGTTTTTCGGTCGTTTT3'

SEQ ID NO:47. Amino acid sequence of eGFP

MVSKGEELFTGVVPILVELDGDVNGHKFSVSGEGEGDATYGKLTLKFICTTGKLPVP
WPTLVTTLTYGVQCFSRYPDHMKQHDFFKSAMPEGYVQERTIFFKDDGNYKTRAEV
KFEGDTLVNRIELKGIDFKEDGNILGHKLEYNYNSHNVYIMADKQKNGIKVNFKIRHNIE
DGSVQLADHYQQNTPIGDGPVLLPDNHYLSTQSALSKDPNEKRDHMVLLEFVTAAGI
TLGMDELYK

SEQ ID NO:48. Amino acid sequence of HBV core antigen

MDIDPYKEFGATVELLSFLPSDFFPSVRDLLDTASALYREALESPEHCSPHHTALRQAI
LCWGELMTLATWVGNNLEDPASRDLVVNYVNTNMGLKIRQLLWFHISCLTFGRETVL
EYLVSFGVWIRTPPAYRPPNAPILSTLPETTVVRRRGRGRSPRRRTPSPRRRRSQSP
RRRRSQSRESQC

SEQ ID NO:49. Amino acid sequence of HBV surface antigen

MENITSGFLGPLLVLQAGFFLLTRILTIPQSLDSWWTSLNFLGGSPVCLGQNSQSPTS
NHSPTSCPPICPGYRWMCLRRFIIFLFILLLCLIFLLVLLDYQGMLPVCPLIPGSTTTSTG
PCKTCTTPAQGNSMFPSCCCTKPTDGNCTCIPIPSSWAFAKYLWEWASVRFSWLSLL
VPFVQWFVGLSPTVWLSAIWMMWYWGPSLYSIVSPFIPLLPIFFCLWVYI

SEQ ID NO:50. Amino acid sequence of Rhesus PSMA ECD protein:

MASETDTLLLWVLLLWVPGSTGDAAHHHHHHKSSSEATNITPKHNMKAFLDELKAENI
KKFLHNFTQIPHLAGTEQNFQLAKQIQSQWKEFGLDSVELTHYDVLLSYPNKTHPNYI
SIINEDGNEIFNTSLFEPPPAGYENVSDIVPPFSAFSPQGMPEGDLVYVNYARTEDFFK
LERDMKINCSGKIVIARYGKVFRGNKVKNAQLAGATGVILYSDPADYFAPGVKSYPDG

WNLPGGGVQRGNILNLNGAGDPLTPGYPANEYAYRRGIAEAVGLPSIPVHPIGYYDA
QKLLEKMGGSASPDSSWRGSLKVPYNVGPGFTGNFSTQKVKMHIHSTSEVTRIYNVI
GTLRGAVEPDRYVILGGHRDSWVFGGIDPQSGAAVVHEIVRSFGTLKKEGWRPRRTI
LFASWDAEEFGLLGSTEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLMYSL
VYNLTKELESPDEGFEGKSLYESWTKSPSPEFSGMPRISKLGSGNDFEVFFQRLGIAS
GRARYTKNWETNKFSSYPLYHSVYETYELVEKFYDPMFKYHLTVAQVRGGMVFELA
NSVVLPFDCRDYAVVLRKYADKIYNISMKHPQEMKTYSVSFDSLFSAVKNFTEIASKFS
ERLRDFDKSNPILLRMMNDQLMFLERAFIDPLGLPDRPFYRHVIYAPSSHNKYAGESF
PGIYDALFDIESKVDPSQAWGEVKRQISIATFTVQAAAETLSEVA

SEQ ID NO:51. Amino acid sequence of rat Her-2 p66 peptide (H-2d T cell epitope)

TYVPANASL

SEQ ID NO:52. Amino acid sequence of rat Her-2 p169 peptide (H-2d T cell epitope)

DMVLWKDVFRKNNQL

SEQ ID NO:53. Amino acid sequence of HBV core antigen p87 peptide

SYVNTNMGL

SEQ ID NO:54. Amino acid sequence of a Rat Her-2 Antigen (rHer-2):

MASELAAWCRWGFLLALLPPGIAGTQVCTGTDMKLRLPASPETHLDMLRHLYQGCQ
VVQGNLELTYVPANASLSFLQDIQEVQGYMLIAHNQVKRVPLQRLRIVRGTQLFEDKY
ALAVLDNRDPQDNVAASTPGRTPEGLRELQLRSLTEILKGGVLIRGNPQLCYQDMVL
WKDVFRKNNQLAPVDIDTNRSRACPPCAPACKDNHCWGESPEDCQILTGTICTSGC
ARCKGRLPTDCCHEQCAAGCTGPKHSDCLACLHFNHSGICELHCPALVTYNTDTFES
MHNPEGRYTFGASCVTTCPYNYLSTEVGSCTLVCPPNNQEVTAEDGTQRCEKCSKP
CARVCYGLGMEHLRGARAITSDNVQEFDGCKKIFGSLAFLPESFDGDPSSGIAPLRPE
QLQVFETLEEITGYLYISAWPDSLRDLSVFQNLRIIRGRILHDGAYSLTLQGLGIHSLGL
RSLRELGSGLALIHRNAHLCFVHTVPWDQLFRNPHQALLHSGNRPEEDCGLEGLVCN
SLCAHGHCWGPGPTQCVNCSHFLRGQECVEECRVWKGLPREYVSDKRCLPCHPEC
QPQNSSETCFGSEADQCAACAHYKDSSSCVARCPSGVKPDLSYMPIWKYPDEEGIC
QPCPINCTHSCVDLDERGCPAEQRASPVTFIIATVVGVLLFLILVVVVGILIKRRRQKIRK
YTMRRNEDLGPSSPMDSTFYRSLLEDDDMGDLVDAEEYLVPQQGFFSPDPTPGTGS
TAHRRHRSSSTRSGGGELTLGLEPSEEGPPRSPLAPSEGAGSDVFDGDLAMGVTKG

LQSLSPHDLSPLQRYSEDPTLPLPPETDGYVAPLACSPQPEFVNQSEVQPQPPLTPE
GPLPPVRPAGATLERPKTLSPGKNGVVKDVFAFGGAVENPEFLVPREGTASPPHPSP
AFSPAFDNLFFWDQNSSEQGPPPSNFEGTPTAENPEFLGLDVPV

SEQ ID NO:55. Amino Acid Sequence of Rhesus PSMA antigen:

MASARRPRWLCAGALVLAGGFFLLGFLFGWFIKSSSEATNITPKHNMKAFLDELKAENIK
KFLHNFTQIPHLAGTEQNFQLAKQIQSQWKEFGLDSVELTHYDVLLSYPNKTHPNYISII
NEDGNEIFNTSLFEPPPAGYENVSDIVPPFSAFSPQGMPEGDLVYVNYARTEDFFKLERD
MKINCSGKIVIARYGKVFRGNKVKNAQLAGATGVILYSDPADYFAPGVKSYPDGWNLPGG
GVQRGNILNLNGAGDPLTPGYPANEYAYRRGIAEAVGLPSIPVHPIGYYDAQKLLEKMGG
SASPDSSWRGSLKVPYNVGPGFTGNFSTQKVKMHIHSTSEVTRIYNVIGTLRGAVEPDRY
VILGGHRDSWVFGGIDPQSGAAVVHEIVRSFGTLKKEGWRPRRTILFASWDAEEFGLLGS
TEWAEENSRLLQERGVAYINADSSIEGNYTLRVDCTPLMYSLVYNLTKELESPDEGFEGK
SLYESWTKKSPSPEFSGMPRISKLGSGNDFEVFFQRLGIASGRARYTKNWETNKFSSYPL
YHSVYETYELVEKFYDPMFKYHLTVAQVRGGMVFELANSVVLPFDCRDYAVVLRKYADKI
YNISMKHPQEMKTYSVSFDSLFSAVKNFTEIASKFSERLRDFDKSNPILLRMMNDQLMFL
ERAFIDPLGLPDRPFYRHVIYAPSSHNKYAGESFPGIYDALFDIESKVDPSQAWGEVKRQ
ISIATFTVQAAAETLSEVA

SEQ ID NO:56 Nucleotide sequence encoding the rhesus PSMA antigen of SEQ ID NO: 55"

ATGGCTAGCGCTAGAAGGCCCAGATGGCTGTGCGCTGGCGCCCTGGTGCTGGCTGGCGGATTCTT
CCTGCTGGGCTTCCTGTTCGGCTGGTTCATCAAGTCCTCCAGCGAGGCCACCAACATCACCCCCA
AGCACAACATGAAGGCCTTTCTGGACGAGCTGAAGGCCGAGAATATCAAGAAGTTCCTGCACAAC
TTCACCCAGATCCCCCACCTGGCCGGCACCGAGCAGAACTTCCAGCTGGCCAAGCAGATCCAGTC
CCAGTGGAAAGAGTTCGGCCTGGACTCCGTGGAACTGACCCACTACGACGTGCTGCTGTCCTACC
CCAACAAGACCCACCCCAACTACATCTCCATCATCAACGAGGACGGCAACGAAATCTTCAACACC
TCCCTGTTCGAGCCCCCACCAGCCGGCTACGAGAACGTGTCCGACATCGTGCCCCCATTCTCCGC
ATTCAGTCCACAAGGCATGCCCGAGGGCGACCTGGTGTACGTGAACTACGCCAGGACCGAGGACT
TCTTCAAGCTGGAAAGGGACATGAAGATCAACTGCTCCGGCAAGATCGTGATCGCCAGATACGGC
AAGGTGTTCAGGGGCAACAAAGTGAAGAACGCTCAGCTGGCTGGGGCCACCGGCGTGATCCTGTA
CTCTGACCCCGCCGACTACTTCGCCCCAGGCGTGAAGTCCTACCCCGACGGCTGGAACCTGCCAG
GTGGCGGAGTGCAGAGGGGCAACATCCTGAACCTGAACGGCGCTGGCGACCCCCTGACCCCAGGA
TACCCCGCCAACGAGTACGCCTACAGAAGAGGAATCGCCGAGGCCGTGGGCCTGCCCTCTATCCC
AGTGCACCCCATCGGCTACTACGACGCCCAGAAACTGCTGGAAAAGATGGGCGGCTCCGCCTCCC
CCGACTCCTCTTGGAGAGGCTCCCTGAAGGTGCCCTACAACGTGGGCCCAGGCTTCACCGGCAAC
TTCTCCACCCAGAAAGTGAAGATGCACATCCACTCCACCTCCGAAGTGACCAGGATCTACAACGT
GATCGGCACCCTGAGAGGCGCCGTGGAACCCGACAGATACGTGATCCTGGGCGGCCACAGGGACA
GCTGGGTGTTCGGCGGCATCGACCCACAGTCTGGCGCCGCTGTGGTGCACGAGATCGTGCGGTCC
TTCGGAACCCTGAAGAAAGAGGGATGGCGCCCCAGAAGGACAATCCTGTTCGCCTCCTGGGACGC
CGAGGAATTCGGCCTGCTGGGATCCACCGAGTGGGCCGAGGAAAACTCCAGGCTGCTGCAGGAAA
GGGGCGTCGCCTACATCAACGCCGACTCCTCCATCGAGGGCAACTACACCCTGAGGGTGGACTGC
ACCCCCCTGATGTACTCCCTGGTGTACAACCTGACCAAAGAGCTGGAATCCCCCGACGAGGGCTT
CGAGGGCAAGTCCCTGTACGAGTCCTGGACCAAGAAGTCCCCATCCCCCGAGTTCTCCGGCATGC
CCAGGATCTCCAAGCTGGGCTCCGGCAACGACTTCGAGGTGTTCTTCCAGAGGCTGGGAATCGCC
TCCGGCAGGGCCAGATACACCAAGAACTGGGAGACAAACAAGTTCTCCTCCTACCCCCTGTACCA
CTCCGTGTACGAAACCTACGAGCTGGTGGAAAAGTTCTACGACCCCATGTTCAAGTACCACCTGA
CCGTGGCCCAGGTCCGCGGAGGCATGGTGTTCGAGCTGGCCAACTCCGTGGTGCTGCCCTTCGAC
TGCAGAGACTATGCTGTGGTGCTGAGGAAGTACGCCGACAAAATCTACAACATCTCCATGAAGCA
CCCCCAGGAAATGAAGACCTACTCCGTGTCCTTCGACTCCCTGTTCTCCGCCGTGAAGAATTTCA

CCGAGATCGCCTCCAAGTTCTCCGAGAGGCTGAGGGACTTCGACAAGTCCAACCCCATCCTGCTG
AGGATGATGAACGACCAGCTGATGTTCCTGGAAAGGGCCTTCATCGACCCCCTGGGCCTGCCAGA
CAGGCCCTTCTACAGGCACGTGATCTACGCCCCATCCTCCCACAACAAATACGCCGGCGAGTCCT
TCCCCGGCATCTACGATGCCCTGTTCGACATCGAGTCCAAGGTGGACCCCTCCCAGGCTTGGGGC
GAAGTGAAGAGGCAGATCAGTATCGCCACATTCACAGTGCAGGCCGCTGCCGAAACCCTGTCCGA
GGTGGCC

CLAIMS

1. A multi-antigen DNA construct for expression of at least three separate immunogenic prostate-associated-antigen polypeptides comprising an immunogenic PSA polypeptide, an immunogenic PSCA polypeptide, and an immunogenic PSMA polypeptide, that comprises:

(a) at least one nucleotide sequence encoding the immunogenic PSA polypeptide;

(b) at least one nucleotide sequence encoding the immunogenic PSCA polypeptide; and

(c) at least one nucleotide sequence encoding the immunogenic PSMA polypeptide, wherein the immunogenic PSA polypeptide comprises amino acids 4 - 240 of SEQ ID NO:17, wherein the immunogenic PSCA polypeptide comprises the amino acid sequence of SEQ ID NO:21, and wherein the immunogenic PSMA polypeptide has at least 90% identity with amino acids 15-750 of the human PSMA of SEQ ID NO:1 and comprises the amino acids of at least 10 conserved T cell epitopes of the human PSMA at corresponding positions.

2. The multi-antigen DNA construct according to claim 1, wherein the immunogenic PSMA polypeptide is selected from the group consisting of:

1) a polypeptide comprising amino acids 15-750 of the amino acid sequence of SEQ ID NO: 1;

2) a polypeptide comprising the amino acid sequence of SEQ ID NO:3;

3) a polypeptide comprising the amino acid sequence of SEQ ID NO:5;

4) a polypeptide comprising the amino acid sequence of SEQ ID NO:7;

5) a polypeptide comprising the amino acids 4 – 739 of SEQ ID NO:9;

6) a polypeptide comprising the amino acids 4 – 739 of SEQ ID NO:3;

7) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO:5;

8) a polypeptide comprising the amino acids 4 - 739 of SEQ ID NO:7; and

9) a polypeptide comprising the amino acid sequence of SEQ ID NO: 9.

3. The multi-antigen DNA construct according to claim 2, wherein the nucleotide sequence encoding the immunogenic PSA polypeptide is set forth in SEQ ID NO:18, wherein the nucleotide sequence encoding the immunogenic PSCA polypeptide

is set forth in SEQ ID NO:22, and wherein the nucleotide sequence encoding the immunogenic PSMA polypeptide is selected from the group consisting of:

(1) a nucleotide sequence comprising nucleotides 43-2250 of the nucleotide sequence of SEQ ID NO:2;

(2) the nucleotide sequence of SEQ ID NO:4;

(3) the nucleotide sequence of SEQ ID NO:6;

(4) the nucleotide sequence of SEQ ID NO:8;

(5) the nucleotide sequence of SEQ ID NO:10;

(6) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:4;

(7) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:6;

(8) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:8; and

(9) a nucleotide sequence comprising nucleotides 10 – 2217 of SEQ ID NO:10.

4. The multi-antigen DNA construct according to claim 1, further comprising at least one nucleotide sequence encoding a 2A-like peptide sequence.

5. The multi-antigen DNA construct according to claim 4, wherein the 2A-like peptide sequence is selected from the group consisting of FMDV 2A peptide, TAV 2A peptide, EMCV 2A peptide, ERAV 2A peptide, and PTV 2A peptide.

6. The multi-antigen DNA construct according to claim 5, wherein:

(1) the FMDV 2A peptide comprises the amino acid sequence QTLNFDLLKLAGDVESNPGP;

(2) the TAV 2A peptide comprises the amino acid sequence EGRGSLLTCGDVEENPGP;

(3) the EMCV 2A peptide comprises the ámino acid sequence HYAGYFADLLIHDIETNPGP;

(4) the ERAV 2A peptide comprises the amino acid sequence QCTNYALL,KLAGDVESNPGP; and

(5) the PTV 2A peptide comprises the amino acid sequence ATNFSLLKQAGDVEENPGP.

7. The multi-antigen DNA construct according to claim 5, which comprises:

(1) a nucleotide sequence encoding a TAV 2A peptide sequence; and

(2) a nucleotide sequence encoding a FMDV 2A peptide sequence.

8. The multi-antigen DNA construct according to claim 7, wherein the order of the nucleotide sequences on the multi-antigen DNA construct is shown in formula (I):

PSA-T2A-PSCA-F2A-PSMA (I)

wherein in formula (I);

PSA is the nucleotide sequence encoding the immunogenic PSA polypeptide;

PSCA is the nucleotide sequence encoding the immunogenic PSCA polypeptide;

PSMA is the nucleotide sequence encoding the immunogenic PSMA polypeptide;

T2A is the nucleotide sequence encoding the TAV 2A peptide sequence; and

F2A is the nucleotide sequence encoding the FMDV 2A peptide sequence.

9. The multi-antigen construct according to claim 8, wherein the immunogenic PSMA polypeptide comprises amino acids 15-750 of the amino acid sequence of SEQ ID NO:1.

10. The multi-antigen construct according to claim 8, wherein the nucleotide sequence encoding the immunogenic PSMA polypeptide comprises nucleotides 43-2250 of the nucleotide sequence of SEQ ID NO:2.

11. A multi-antigen DNA construct comprising the nucleotide sequence of SEQ ID NO:35 or a degenerate variant of the nucleotide sequence of SEQ ID NO:35.

12. The multi-antigen DNA construct according to claim 11, which comprises the nucleotide sequence of SEQ ID NO:35.

13. The multi-antigen DNA construct according to claim 11, which is a degenerate variant of the nucleotide sequence of SEQ ID NO:35.

14. A vector comprising the multi-antigen DNA construct according to any one of claims 1-12.

15. The vector according to claim 14, which comprises a multi-antigen DNA construct comprising nucleotide sequence of SEQ ID NO:35 or a degenerate variant of the nucleotide sequence of SEQ ID NO:35.

16. A composition comprising the vector according to claim 14.

17. The composition according to claim 16 for use in the inhibition of-abnormal cell proliferation in a mammal.

18. The composition according to claim 16 for use in the elicitation of an immune response in a mammal.

19. The composition according to claim 18 for use in the treatment of prostate cancer in a human.

20. A composition comprising the multi-antigen DNA construct according to any one of claims 1 -13.

21. The composition according to claim 20, wherein the multi-antigen DNA construct comprises the nucleotide sequence of SEQ ID NO:35 or a degenerate variant of the nucleotide sequence of SEQ ID NO:35.

22. Composition according to any one of claims 1-13 for use in the inhibition of-abnormal cell proliferation in a mammal.

23. The composition according to claim 22, wherein the multi-antigen DNA construct comprises the nucleotide sequence of SEQ ID NO:35 or a degenerate variant of the nucleotide sequence of SEQ ID NO:35.

24. Composition according to any one of claims 1-13 for use in the elicitation of an immune response in a mammal.

25. The composition according to claim 24, wherein the multi-antigen DNA construct comprises the nucleotide sequence of SEQ ID NO:35 or a degenerate variant of the nucleotide sequence of SEQ ID NO:35.

26. Composition according to any one of claims 1-13 for use in the treatment of prostate cancer in a human.

27. The composition according to claim 26, wherein the multi-antigen DNA construct comprises the nucleotide sequence of SEQ ID NO:35 or a degenerate variant of the nucleotide sequence of SEQ ID NO:35.