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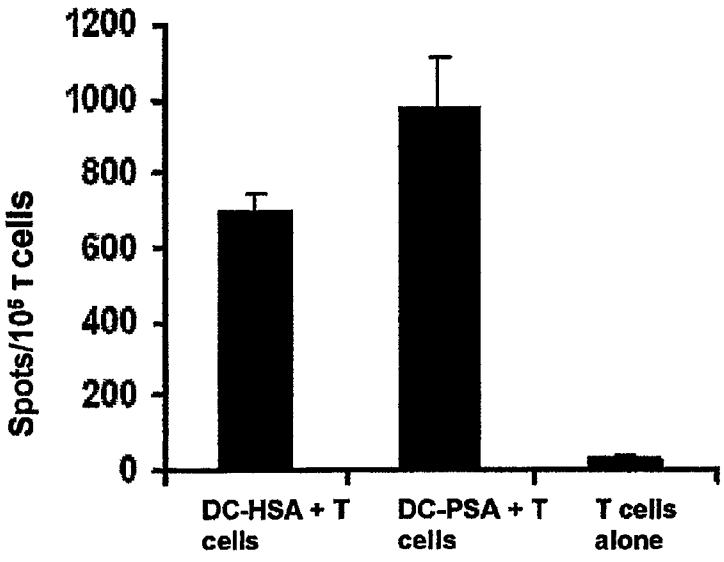
(54) **Title:** METHODS AND COMPOSITIONS RELATING TO A VACCINE AGAINST PROSTATE CANCER



(57) **Abstract:** An object of the invention is to provide methods and compositions relating to a vaccine against prostate cancer which includes a non- human -primate PSA for administration to humans to provide an immune response against human PSA. More generally, an object of the invention is to provide methods and compositions relating to using a non-human primate xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the non-human primate xenogeneic antigen that is used, there are relatively few interspecies differences between the non-human primate xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen.

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METHODS AND COMPOSITIONS RELATING TO A VACCINE AGAINST PROSTATE CANCER

Cross-Reference to Related Application

This application claims priority based upon copending United States Provisional Application Serial No. 60/692,238, filed 21 June 2005.

Technical Field

The present invention relates generally to methods and compositions relating to a vaccines and, more particularly, to methods and compositions relating to a vaccine against prostate cancer.

Background Art

Prior to a discussion of the background art, it is noted that the bracketed [] numbers in the discussion refer to the enumerated references in the Bibliographical References listed below at the end of the specification.

With respect to the background art, in the U. S. A., prostate cancer is the most frequently diagnosed form of cancer and the second leading cause of cancer death in males [2]. Current modalities of therapy for localized tumors include surgery and radiotherapy, and are generally successful. However, treatment for metastatic disease is not as beneficial, because current hormonal therapies work only transiently [3]. Therefore, new treatments for prostate cancer are needed.

Immunotherapy, based on CD8+ cytotoxic T lymphocytes (CTL) is one potential new avenue of therapy that holds much promise, especially for prevention and adjuvant treatment of metastatic disease [4, 5]. CTLs recognize antigen in the form of a short peptide (8-10 amino acids) in a complex with class I major histocompatibility complex (MHC) on the surface of target cells. The ability of CTL to directly lyse these cells makes them attractive for tumor immunotherapy.

Prostate-specific antigen (PSA) has been proposed as a tumor antigen for the specific destruction of prostate carcinoma cells by CTLs. Tight tissue specificity of expression to the prostate, continued expression by prostate carcinoma cells, and the wealth of biochemical, genetic, and cell biological data available all make PSA an excellent candidate for characterization as potential target for prostate cancer immunotherapy.

Several PSA-based vaccines were evaluated in recently conducted clinical trials for stimulating an immune response against PSA in patients with advanced prostate cancer. These vaccines represented a recombinant vaccinia virus expressing PSA (rV-PSA) [6-9], a recombinant PSA protein formulated in liposomes [10], and autologous dendritic cells (DCs) pulsed with recombinant PSA protein [11] or transfected with PSA-encoding RNA [12].

CD8+ T cells

The main biological function of CD8+ T cells is to eliminate pathogen-infected cells in the body. The mechanism responsible for T-cell recognition of infected cells is now well established at the molecular level and relies on interaction between a T-cell receptor complex (TCR) and an antigen-derived peptide bound to a major histocompatibility complex class I molecule (MHC I). All protein antigens produced by the cell are eventually degraded and the resulting peptides are presented by MHC I molecules on the cell surface.

Development of CD8+ T cells

Development of T cells occurs in the thymus, where TCR α and ß gene segments are rearranged such that each T cell clone eventually expresses a unique TCR [13]. Developing thymocytes that produce a surface TCR express CD4 and CD8 co-receptors and undergo a complex process of maturation, depending on the specificity and affinity of

their TCRs for self-peptide MHC ligands. Thymocytes that express TCRs with no affinity for self-peptide-MHC molecules die by a programmed cell death mechanism. Potentially harmful thymocytes that express TCRs with strong affinity for the self-peptide-MHC ligands expressed on cells in the thymus are eliminated via physical deletion [14], functional inactivation [15], or receptor editing [16]. Only thymocytes that express TCRs with a low but significant affinity for self-peptide-MHC ligands on thymic stromal cells survive thymic selection [17].

Recirculation and survival of naive CD8+ T cells

T cells that have not yet encountered a foreign peptide-MHC ligand for which their TCR has a high affinity are referred to as "naive" T cells. These cells account for the majority of T cells in the secondary lymphoid organs in healthy young adults. Naive T cells recirculate continuously through the secondary lymphoid organs, which include spleen, lymph nodes, and mucosal lymphoid organs (such as Peyer's patches of the intestines) [18, 19]. It is estimated that an individual naive T-cell will on average circulate through the secondary lymphoid organs for several months [20, 21]. Survival of naive CD8+ T cells during this normal lifespan is maintained by low-affinity TCR recognition of self-peptide-MHC complexes [22] and signaling through the IL-7 receptor [23, 24]. Although signals through the TCR and IL-7 receptor are required for the survival of naive T cells, these signals do not cause the T cells to proliferate in hosts containing normal numbers of T cells. In contrast, naive T cells proliferate when transferred into T-cell-deficient hosts. This "homeostatic" proliferation also depends on IL-7 [23, 24] and low-affinity TCR recognition of self-peptide-MHC complexes [25], but not IL-2 or the CD28 co-stimulatory receptor [26]. In young individuals, new naive T cells are constantly produced by the thymus and exported to the secondary lymphoid organs to replace

senescent naive T cells. In contrast, in older individuals whose thymic output is reduced or absent, senescent cells may be replaced by proliferation of remaining naive T cells.

Activation of CD8+ T cells

Naive CD8+ T cells migrating through the T-cell areas of secondary lymphoid organs encounter a dense network of large, irregular shaped dendritic cells (DCs) that constitutively express the highest levels of MHC molecules of any cell in the body [27]. In the absence of infection or tissue damage, all DC populations in the secondary lymphoid organs exist in a resting state characterized by low expression of co-stimulatory molecules such as CD80 and CD86 [28]. In this state, DCs most likely play an important role in the presentation of low-affinity self-peptide-MHC ligands that maintains survival of naive T cells.

In the case of infection, various viral or bacterial products are recognized by pattern recognition receptors [29], for example, Toll-like receptors (TLRs) on cells of the innate immune system, including DCs. TLR signaling causes activation of DCs, which results in expression of higher levels of co-stimulatory molecules (CD80 and CD86) and production of inflammatory cytokines [30]. Activated DCs then function by presenting pathogen-derived peptide-MHC class I complexes to naive CD8+ T cells. In addition to a signal through TLR, naive CD8+ T cells also require additional signals through the co-stimulatory CD28 receptor and the IL-12 receptor to proliferate maximally and differentiate into cytotoxic effector cells [31-33]. All these signals can be provided to naive CD8+ T cells by activated DCs [34].

Naive CD8+ T cells show signs of DNA replication and cell division as early as 48 hours after exposure to antigen *in vivo* [35-37]. These events are followed by an

exponential increase in the number of antigen-specific T cells over the next several days. Depending on the stimulus, the number of antigen-specific CD8+ T cells reaches its highest level in the secondary lymphoid organs, 7 to 15 days after activation with an antigen (Fig. 2.3) [35, 38-43].

In vitro experiments indicate that cell division by naive, antigen-stimulated T cells is driven by autocrine production of IL-2 [44]. Surprisingly, however, antigen-driven proliferation of naive T cells is minimally dependent on IL-2 *in vivo* [45-49]. Therefore, in addition to IL-2, other signals or growth factors must be also capable of driving T-cell proliferation *in vivo*.

In vivo T-cell proliferation is tightly regulated by co-stimulatory signals from DCs. The proliferation of antigen-stimulated CD8+ T cells is reduced dramatically in mice in which CD28 cannot interact with its ligands CD80 and CD86 [37, 45, 50]. CD40 ligand deficiency has a similar effect on T-cell expansion, which may be related to the fact that CD40 signaling induces CD80 and CD86 on antigen-presenting cells [51]. Co-stimulatory signals regulate T-cell proliferation by enhancing growth factor production. Antigen-driven IL-2 production is greatly impaired when CD28 signaling is eliminated [45].

Effector CD8+ T cells

Antigen-specific CD8+ T cells at the peak of immune response express effector functions, and thus are sometimes referred to as "effector cells" [52]. Effector cells express a characteristic set of adhesion receptors. Unlike naive cells they express perforin and granzymes, which contribute to their defining feature, that is, the ability to directly kill target cells that display the appropriate peptide-MHC class I complexes.[53]. The effector T cells migrate out of the T-cell areas and into many nonlymphoid tissues, particularly inflamed sites of antigen deposition. The migration of effector CD8+ T

cells with cytolytic potential into nonlymphoid organs is an effective way of eliminating cells that display peptide-MHC class I complexes from all parts of the body.

The number of effector T cells in the secondary lymphoid organs falls dramatically after the peak of proliferation [35, 38-43]. The molecular basis for death of effector T cells varies depending on the nature of the antigenic stimulus. In the case of a T cell response after a single administration of antigen, the death is Fas-independent and Bcl-2 sensitive [54] and occurs most likely due to deprivation of growth factors [55]. If antigen is presented chronically, TCR-mediated activation-induced cell death (AICD) may occur [56]. This type of apoptosis is dependent of Fas and is poorly inhibited by Bcl-2 [55].

IL-2 is playing a role in the AICD by preventing the activation of FLICE inhibitor protein, which normally inhibits Fas signaling [57]. The death of effector CD8+ T cells is regulated by inflammation. In the absence of inflammation, the loss of antigen-specific T cells from the secondary lymphoid and nonlymphoid organs after the peak of proliferation is nearly complete [58]. In contrast, many more cells survive the loss phase after injection of antigen together with adjuvants such as LPS or IL-1 [35, 58, 59].

Memory CD8+ T cells

The vast majority of effector cells die after the peak of proliferation, nevertheless, a stable population of antigen-experienced T cells survive for long periods of time if the antigen was initially presented in an inflammatory context [52]. In many ways, memory cells can be thought of as effector cells that have returned to a basal activation state. Indeed, several lines of evidence suggest that effector cells are precursors of memory cells [60, 61].

Unlike naive CD8+ T cells, memory CD8+ T cells do not depend on MHC-class I molecules for survival [62]. Whereas most memory CD8+ T cells are not cycling, a small fraction of the memory population is proliferating in an MHC class I-independent fashion at all times [47, 62]. This proliferation is balanced by death since the total number of antigen-specific memory CD8+ T cells remains unchanged over time. Several observations suggest that IL-15 plays a role in this process. The antigen-independent proliferation of memory CD8+ T cells is accelerated by injection of IL-15 [63] and blocked by injection of antibodies against IL-15 [47]. In addition, memory CD8+ T cells are diminished in IL-15-deficient mice [64]. Since IL-15 is produced by non-T cells during the innate immune response, it is possible that memory CD8+ T cells are maintained as a consequence of IL-15 produced in response to other infections [63, 65].

Prostate-specific antigen (PSA)

Prostate-specific antigen (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 [66-68]. PSA is secreted into the lumina of the prostatic ducts and is present in the seminal plasma at rather high concentrations ranging from approximately 0.5 to 5 mg/ml [69]. Physiologically, PSA functions in seminal plasma to cleave the major gel-forming proteins semenogelin I and II, and fibronectin, resulting in increased sperm motility [67, 70, 71]. PSA is translated as an inactive 261 amino acid preproPSA precursor. PreproPSA has 24 additional residues that constitute the pre-region (the signal peptide) and the propeptide. Release of the propeptide results in the 237-amino acid, mature extracellular form, which is enzymatically active. Human glandular kallikrein 2 (hKLK2), which like PSA is preferentially expressed in the prostate tissue, is responsible for the activation of

proPSA [72]. PSA has been shown to contain an N-linked oligosaccharide attached to asparagine-69 [73].

PSA is also released into the blood at low concentrations. In healthy males without clinical evidence of prostate cancer, the concentration of PSA detected in the serum is usually less than 4ng/ml [74-76]. Enzymatically active PSA is inactivated in the blood by forming covalently linked complexes with α_1-antichymotrypsin (ACT) [77, 78]. Enzymatically inactive (internally clipped) PSA is incapable of forming complexes with protease inhibitors and circulates as a free, uncomplexed form in the blood [79].

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 [66, 80]. Normal prostate epithelial cells and BPH tissue actually produce more PSA protein than malignant prostate tissue [81, 82]. Therefore, PSA is not a traditional tumor marker that is produced in higher quantities by tumor cells, but rather abnormalities in the prostate gland architecture resulting from trauma or disease can lead to increased "leakage" of the enzyme into the stroma and then into the bloodstream via capillaries and lymphatics.

The most common use of PSA in the clinic is for monitoring prostatic cancer therapy. If a patient undergoes a radical prostatectomy, serum PSA levels should decrease to undetectable concentrations because all of the source tissue has been removed [83, 84]. Increasing PSA concentrations after surgery, indicate a recurrence of the disease [83, 85, 86]. PSA also reflects the success of radiotherapy and anti-androgen (hormonal) therapy in prostate cancer patients [87-89].

Plasmid DNA vaccines against cancer

In recent years a number of tumor vaccination strategies have been developed. Most of them rely on

identification of tumor antigens that can be recognized by the immune system. DNA vaccination represents one such approach for the induction of both humoral and cellular immune responses against tumor antigens. Studies in animal models demonstrated the feasibility of using DNA vaccination for eliciting protective anti-tumor immune responses. However, most tumor antigens expressed by cancer cells in humans are weakly immunogenic, which requires development of strategies to potentiate DNA vaccine efficacy in the clinical setting. Recent advances in understanding the immunology of DNA vaccines and strategies used to increase DNA vaccine potency with respect to CTL activity are discussed below.

Immunology of DNA vaccines

A DNA vaccine usually represents a simple plasmid DNA expression vector. It contains cDNA encoding a desired antigen inserted between a eukaryotic promotor and a polyadenylation sequence, bacterial antibiotic resistance gene and a bacterial origin of replication. The eukaryotic promotor and polyadenylation sequence are required for proper antigen expression in mammalian cells, and the antibiotic resistance gene and origin of replication allow production of the vector in bacteria.

After administration of the naked plasmid DNA by intramuscular (i.m.) or intradermal (i.d.) inoculation, host cells take up the DNA and produce the encoded antigen, which then serves as a target for the immune response [90-93]. The expression of the antigen *in vivo* is commonly achieved by using strong viral promotors, which are ubiquitously active and will drive antigen production in a wide range of cell types. The human cytomegalovirus immediate early enhancer-promotor (known as the CMV promotor) is often the promotor of choice [94]. DNA vaccination results in generation of adaptive immune responses comprising of regulatory components such as: induction of antigen-specific CD4+ helper T cells; and

effector components such as: production of antibodies recognizing native antigen, and effector CD8+ cytotoxic T lymphocytes (CTLs). The latter are directed against antigen-derived peptides presented by class I major histocompatibility molecules (MHC class I) on the cell surface.

The potential of DNA encoding a protein antigen to generate CTL responses has attracted a lot of attention, since immunization with purified recombinant proteins does not efficiently induce CTLs (reviewed in [95, 96]). Studies in mice of the underlying mechanism revealed that induction of helper CD4+ T cells and direct activation of antigen-presenting cells (APCs) by DNA molecules contributes to the successful CTL priming by DNA vaccines. The latter requirement was suggested to be somewhat redundant (see below).

Here we summarize the key findings, which are starting to elucidate the observed immunogenicity of DNA vaccines.

The CD8+ T-cell response after DNA vaccination was shown to be initiated by bone marrow-derived APCs, such as dendritic cells (DCs) [97-99]. The relevant APCs can be directly transfected with plasmid DNA, which then leads to antigen production within the cell, or they may pick up antigen expressed and released by other cells (the latter mechanism is referred to as cross-presentation/cross-priming) [100-102]. In both cases, the antigen is processed by proteolytic digestion inside the APCs and the resulting peptides are presented by MHC class I molecules on the cell surface for priming of naive CD8+ T cells. Which of these two mechanisms is the predominant one *in vivo* is still a matter of a debate and may vary among different DNA administration methods [102-104].

Nevertheless, certain modifications of the antigens (including linkage with ubiquitin [105] or heat shock proteins [106, 107]) may improve their targeting to the

conventional or cross-priming MHC class I presentation pathway (reviewed in [108]).

The backbone of plasmid DNA was shown to contain immunostimulatory nucleotide sequences, which are composed of unmethylated CpG dinucleotides, with particular flanking nucleotides (referred to as CpG motifs) [109-111]. Due to differences in frequency of utilization and methylation pattern of CpG dinucleotides in eukaryotes versus prokaryotes, such sequences are approximately 20 times more common in bacterial then in mammalian DNA [112, 113]. The CpG motifs were shown to act through Toll-like receptor 9 (TLR9) [114], which is expressed in mice on macrophages, DCs and B cells, but in humans only on plasmacytoid DCs and B cells [115-117]. The direct interaction of TLR9 and CpG-containing plasmid DNA was shown to result in upregulation of co-stimulatory molecules on APCs and induction of the proinflammatory cytokines IL-12, IL-6, IL-18, TNFα, IFNα/ß and IFNγ, secreted by various cells of innate immune system [118-121].

Activation of APCs is known to be important for efficient priming of naive CD8+ T cells and thus presence of certain CpG motifs in the backbone of DNA vaccines was suggested to contribute to CTL induction [122]. Surprisingly, repeated DNA immunization of mice with deficiency in the TLR9 signaling pathway (TLR9-/- or MyD88-/- mice) results in development of normal CTL responses, similar to those in wild-type mice, despite the fact that no direct stimulation of APCs by plasmid DNA could be observed in these mice [123, 124]. This finding suggests that activation of APCs by CpG-motifs might be redundant in the context of DNA vaccines, and necessary activation of APCs *in vivo* can possibly occur indirectly, through induction of helper CD4+ T cells (reviewed in [125]). In fact, DNA immunization experiments in mice either depleted of CD4+ T cells or having deficiency in CD4+ T cell compartment (CD4 -/- or MHC class II -/-

knockouts) demonstrated that the presence of CD4+ T cells is a critical requirement for generation of effector CTL responses [126-128].

DNA vaccines against cancer in animal models

The utility of DNA vaccines in developing protective anti-tumor responses was first demonstrated with model tumor antigens in mice. DNA immunization with plasmids encoding the SV40 large T-antigen [146], ß-galactosidase [147], human carcinoembryonic antigen (CEA) [148], human papillomavirus E7 [149] or human PSA [150] were shown to protect mice from lethal challenge with syngeneic tumor cells expressing the corresponding antigen. Depletion studies provided evidence for the role of CD8+ cytotoxic T lymphocytes in the tumor rejection [147, 149]. Altogether these studies demonstrate the feasibility of using DNA vaccines for inducing antigen-specific immune responses targeting tumor cells. However, all of the antigens used in these studies were in fact foreign proteins which typically are much more immunogenic than the "regular" tumor antigens which represent self-antigens.

Several murine models were established to allow testing of DNA vaccine potency against tumor antigens that more closely resemble those that would be encountered clinically. These approaches rely on the use of transgenic mice expressing model tumor antigens in a tissue specific manner [151, 152], or testing DNA vaccines that target the murine counterparts of human tumor antigens [153, 154].

DNA immunization against the P815A antigen, a murine equivalent of human tumor-specific antigens belonging to the MAGE family [155], was shown to induce CTLs and protect mice from lethal tumor challenge [153]. This finding suggested that the T cells could be readily induced against natural tumor-specific antigens, which are silent in most normal tissues.

In contrast, naturally occurring tumor-associated antigens were shown to have low intrinsic immunogenicity. While a DNA vaccine encoding human proto-oncogene Her2 readily induced an antibody response in wild-type mice, the same vaccine induced only a modest antibody response in Her2 transgenic mice and provided weak tumor protection [152]. Similar results were also obtained for CTL responses in Her2/neu transgenic mice. Immunization with the rat *neu* DNA vaccine induced protective CTL responses in wild-type mice, but was not effective in transgenic animals where no CTL response was observed [156]. The ability of the rat *neu* DNA vaccine to induce CTL responses in wild-type mice could probably be explained by the differences in the amino acid sequence between the *neu*-derived CTL epitope and the corresponding sequence of the murine Her2 counterpart (c-erbB-2) [156, 157]. Thus, CD8+ T cells capable of recognizing the *neu*-derived epitope are present in wild-type mice, but are most likely deleted during thymic selection or anergized in the periphery in *neu*-transgenic animals.

In line with these findings, DNA immunization against murine melanocyte differentiation antigens TRP-1, TRP-2 (tyrosinase-related proteins), and gp100 were also unsuccessful [154, 158, 159]. Interestingly, the same studies demonstrated that immunization of mice with the xenogeneic (human) DNA encoding TRP-1, TRP-2, or gp100 resulted in induction of immune responses and protection from syngeneic tumor challenge with B16 mouse melanoma cells. The anti-tumor immunity was mediated by antibodies upon vaccination with human TRP-1, and by CD8+ T cells in the case of human TRP-2 and gp100 (reviewed in [160]) A significant conclusion of these observations is that immunization with syngeneic (mouse) genes does not induce T-cell or antibody responses, while immunization with xenogeneic (human) genes can lead to the generation of antibodies and CTLs capable of recognizing both the human and mouse proteins. For CTL responses, the mechanism

underlying such cross-reactivity was shown, in case of gp100, to represent the random creation of a heteroclitic epitope in the human sequence with better binding capacity to a MHC class I antigen [161]. Thus, a DNA vaccine encoding human gp100 induces CD8+ T cells that are directed against this "human" epitope and are also capable of recognizing the corresponding murine endogenous sequence ("murine" epitope) [159, 162]. For cross-reactive antibody responses, the presence of strong helper epitopes within the xenogeneic sequence was suggested [163]. To this end, research on DNA vaccines in animal models have shown some promising results regarding tumor protection. Challenges remain, however, for the use of DNA vaccines as a therapeutic tool, which is more reflecting the clinical setting. Further understanding of the mechanisms underlying the formation of the T cell repertoire during T cell maturation in the thymus and exact mapping of epitope specificity for "self" tumor antigen reactive CTLs, should provide further help for the rational design of DNA vaccines capable of inducing more potent immune responses particularly against tumor-associated antigens.

Enhancing potency of DNA vaccines

Studies in mice have demonstrated that the frequencies of antigen-specific CTLs induced by DNA vaccines are around 10-fold lower when compared to virally induced responses, and the primary effector CTL response after a single DNA immunization is slightly delayed, peaking at 12-15 days after immunization [164, 165]. These qualitative differences in primary CTL responses could be in part attributed to the minute amounts of antigen produced after plasmid DNA administration [90] and inefficient targeting of APCs *in vivo*, which altogether is not sufficient to ensure robust priming and expansion of naive T cells.

Several approaches for DNA delivery have been developed which provide elevated amounts of antigen produced and/or improved targeting of APCs *in vivo*, when compared to the commonly used i.m. or i.d. injection of DNA in saline. These techniques include biolistic inoculation of DNA-coated gold particles into the skin, targeting resident antigen presenting Langerhans cells (also referred to as "gene-gun" technique) [91, 102], the use of cationic poly(DL-lactide-co-glycolide) (PLG) microparticles with DNA adsorbed onto the surface [166, 167], or application of pulsed electrical fields (also referred to as electroporation *in vivo*) at the injection site either after i.m. or i.d. DNA administrations [168-171]. It is worthwhile to note here that direct injection of naked DNA into a peripheral lymph node was shown to induce strong CTL responses, which were qualitatively and quantitatively superior to that achieved by conventional i.m. or i.d. inoculation routes [172]. This finding suggests that efficacy of priming of naive T cells after DNA immunization correlates with the strength and duration of antigenic stimulus in secondary lymphoid organs.

The immunogenicity of DNA vaccines can also be enhanced by various modifications of the plasmid-encoded antigens. Codon optimization of the encoding DNA sequences has been shown to increase antigen expression resulting in superior antibody and CTL responses after DNA vaccination [173, 174]. Linking of the antigen to a ubiquitin monomer [105] or heat shock proteins [106, 175] enhanced antigen-specific CTL responses, presumably via improved targeting of these fusion proteins to the conventional or cross-priming MHC class I presentation pathways.

Another strategy to optimize induction of immune responses by DNA vaccines is based on the fact that induction of helper CD4+ T cells significantly contributes to the generation of effector CTL and antibody responses (see section 4.1). Providing CD4+ T cell help by means of

linkage of a tumor antigen with a microbial or viral antigen, containing strong helper epitopes, was shown to result in enhanced antibody and CTL responses against the tumor antigen after DNA vaccination (reviewed in [176]).

It is important to mention that design of such tumor antigen - "helper" antigen fusion constructs, with the aim to enhance tumor antigen-specific CTL responses, requires an additional consideration. A naturally occurring focusing of CTL responses onto a very few peptide epitopes from a large antigen, known as the phenomenon of immunodominance, is observed also with DNA vaccines [177, 178]. Thus, in order to ensure that the CTL response develops against tumor antigen-derived epitopes rather than "helper" antigen-derived ones, all potential CTL epitopes in the "helper" portion of the fusion should be removed. [179, 180].

Although, recent experiments in TLR9-/- and MyD88-/- mice have demonstrated that activation of APCs by the plasmid DNA backbone is not absolutely required for induction of immune responses [123, 124], the CpG-mediated stimulation of APCs could provide certain adjuvant effects for DNA vaccines. The CpG motifs provided in the form of synthetic oligodeoxynucleotides (CpG-ODNs) were shown to act as adjuvants promoting better antibody and CTL responses after DNA vaccination (reviewed in [181]). The adjuvant effect of CpG-ODNs is very profound in combination with low DNA vaccine doses, but only modest with higher doses of DNA vaccine [182]. It is important to emphasize, that the CpG-ODNs providing optimal immunostimulatory activity in mice differ in sequence from those functioning in primates [183].

Several other strategies for enhancing the potency of DNA vaccines have focused on the use of various immunostimulatory molecules including cytokines and costimulatory molecules (reviewed in [184, 185]). These adjuvants can be administered in the form of recombinant proteins or as a separate plasmid encoding the selected

molecule. The rationale behind such approaches is commonly based on facilitating priming of T cells by providing additional signals through cytokine/costimulatory molecules, which otherwise might not be optimal when using plasmid DNA vaccines alone. Examples of successful application of this approach include enhanced antibody and CTL responses leading to better protection against tumor challenge in mice immunized with CEA-encoding plasmid together with IL-12 expressing plasmid [186], and enhanced antibody/CTL responses after co-administration of an antigen-encoding DNA vaccine and plasmid expressing murine granulocyte-macrophage colony-stimulating factor (GM-CSF) [187], [188].

While all of the above-mentioned strategies were generally shown to increase immunogenicity of DNA vaccines encoding model antigens, no selected strategy is yet firmly established to provide better priming of CTL or antibody responses after DNA immunization against poorly immunogenic "self" tumor antigens in appropriate murine models and more importantly in clinical settings.

DNA vaccines against cancer in clinical trials

Here we discuss several recently conducted Phase I clinical trials on DNA vaccination targeting tumor-associated antigens in patients with HPV-associated anal dysplasia [213], metastatic colorectal carcinoma [212], B-cell lymphoma [214], metastatic melanoma [215, 216] and prostate cancer [211, 217]. A number of different DNA delivery techniques and adjuvants were employed in these studies, which well represent current advances within the DNA vaccination field.

A standard dose escalation scheme was followed in most of these trials, with no DNA vaccine dose escalation in individual patients. DNA vaccination was applied as monotherapy and the patients had not undergone any other form of therapy within at least 3 weeks prior to entering

trials, except for the studies in prostate cancer, where patients were concurrently receiving a hormonal therapy [217].

Due to the limited numbers of patients enrolled in these trials, the main objectives in all of the studies were to evaluate the safety of plasmid DNA administration, to monitor immune responses induced by the vaccines in a dose-dependent manner, and to assess correlation between vaccine-induced immune responses and the clinical benefits.

Collectively, these trials have shown that repetitive DNA administrations were well tolerated with no dose-limiting toxicities observed even with DNA doses reaching up to 2 mg per injection [212], demonstrating that repetitive immunizations with DNA is a safe procedure.

With regard to induction of immune responses, the "foreign" antigens were shown to be more immunogenic than the "self" tumor-associated antigens. Immunization with DNA vaccine encoding human papillomavirus E7-derived CTL epitope(s) induced T cell responses detected by IFNγ ELISPOT assay in 10 of 12 subjects [213]. A dual expression plasmid encoding CEA and hepatitis B surface antigen (HbsAg - included in the study as a control "foreign" antigen) induced HbsAg-specific antibody responses in 6 of 8 patients that were immunized repeatedly [212]. Lymphoproliferative or antibody responses against murine immunoglobulin (Ig) constant regions were also observed in 8 of 12 patients vaccinated with plasmid DNA encoding chimeric Ig molecules [214]. In contrast the rates of immune responses against autologous tumor-associated antigens were relatively low. In above-mentioned studies, CEA-specific antibody responses were not observed and only 4 of 17 patients developed lymphoproliferative responses to CEA, which showed no clear relationship to the dose or schedule of plasmid DNA immunization [212]. Similarly, only 1 of 12 patients

immunized with chimeric Ig molecules developed a transient T cell response against autologous tumor-derived idiotypic (Id) determinant [214]. No CTL responses were detected against gp100-derived HLA-A2 restricted CTL epitopes in melanoma patients that were immunized with DNA encoding modified gp100 antigen [215], despite the fact that a recombinant fowl poxvirus encoding the same DNA construct was shown to induce CTL activity in 4 of 14 patients in previously performed study [218]. Transient CTL responses against a novel tyrosinase-derived HLA-A2 restricted epitope were observed overall in 11 of 24 melanoma patients, which received plasmid DNA encoding this epitope by infusions into a lymph node [216].

In the study combining repetitive administrations of a DNA vaccine and a recombinant adenovirus expressing PSMA, all patients eventually developed positive DTH response to a PSMA plasmid DNA injection, suggesting an induction of cellular immune response against PSMA, but these results were not further confirmed by other conventional *in vitro* assays [217].

In our recent clinical trial of DNA vaccination in patients with hormone-refractory prostate cancer, PSA-specific T cell immune responses were observed in 2 of 9 patients, with both responders being in the cohort receiving the highest DNA dose tested. [211]. A trend towards dose-dependent induction of T cell immune responses against tumor-associated antigens were observed in several of these studies [211, 214], although the epitope specificities of the reactive T cells have yet to be determined in order to firmly demonstrate presence of CTLs.

Clinical benefits of DNA vaccination as monotherapy were only modest and included: one patient with B-cell lymphoma experienced the tumor regression in bone marrow [214], three subjects with high-grade anogenital dysplasia achieved a partial histological response [213], two patients with prostate cancer exhibited stabilization of

disease as judged by a decrease in serum PSA levels [211] and superior survival of the eleven melanoma patients who had detectable immune responses against tyrosinase compared with the thirteen patients who had no immune response [216]. The correlation of clinical benefits with vaccine induced-immune responses was observed only in the two latter studies [211, 216].

In summary, repetitive DNA vaccinations have shown a good safety profile in clinical settings even at high DNA doses (at 1 mg range), which seem to be required for induction of T cell immune responses in humans. The low frequency of responses may have resulted in part from the compromised immune status of the advanced stage patients enrolled in these trials. Future clinical trials can focus on patients during a remission phase or with minimal residual disease, where more pronounced clinical benefits of DNA vaccines are more likely to occur.

Xenogeneic vaccines

It is naturally easier to induce an immune response to a foreign antigen than it is to a self antigen. For that reason, it is helpful to make an antigen as foreign as possible and still induce an immunity to the self protein. One strategy for doing this is to attach a foreign protein to a native self protein. A commonly used protein for this is keyhole lymphet cyanogen. Induction of an immune response to KLH often induces an immune response to the attached protein.

Another strategy is to use proteins similar to the native self protein but taken from another species of animals. This is called a xenogeneic protein. This has been done with a prostate antigen called prostate specific membrane antigen (PSMA). Wolchok et al used human PSMA in mice and induced a good immune response in mice to the mouse PSMA. There is currently a clinical trial using rodent xenogeneic PSMA in humans.

The strategy of using xenogeneic protein has been used in other species. Human tyrosinase was used to immunize dogs with melanoma. In general, the species have been chosen with wide differences between the species.

Publications describe the use of xenogeneic or xenogeneic antigens to induce an immune response. This includes the accidental but unrecognized use of xenoantigens such as when human PSA is used in mice. It also includes the deliberate use of xenoantigens. An example of the deliberate use of xenoantigens is the immunization of dogs with human antigens for vaccines against melanoma (Bergman et al, 2003, Long-term survival of dogs with advanced malignant melanoma after DNA vaccination with xenogeneic human tyrosinase: a phase 1 trial, Clinical Cancer Research, 9:1284-1290). The publications do not describe the use of xenogeneic proteins with minimal interspecies differences between the xenogeneic protein and the native protein to induce an optimal immune response to the native self antigen.

The human protein PSA was discovered and characterized in the 1970's. The PSA protein was first purified in 1979. Anti-rabbit serum was prepared from the protein and tissues analyzed. The human PSA was only found in prostatic tissues and not other tissues. Wang et al Purification of a human prostate specific antigen 1979, Invest. Urol. 17:159-63. Others have found human PSA in smaller amounts in other tissues. It is expressed at low levels in other epithelial like cells in lung and breast tumors. Zarghami et al Frequency of expression of prostate-specific antigen mRNA in lung tumors, 1997 Am J Clin Pathol 108(2): 184-90. Smith et al Prostate-specific antigen messenger RNA is expressed in non-prostate cells: implications for detection of micrometastases 1995 Cancer Res. 55(12): 2640-44.

The gene for human prostate-specific antigen was sequenced in 1989. Digby et al Human prostate specific antigen (PSA) gene: structure and linkage to kallifrein-

like gene 1989 Nucleic Acids Research, 17(5): 2137. Klobeck et al, Genome sequence of human prostate specific antigen, 1989 nucleic Acids Research 17(10):3981

The cDNA sequence of Homo Sapiens PSA is recorded in Genebank. One sequence is listed in Genebank Accession Number AJ459783. Another was published in 1988 and submitted as Genebank Accession Number X07730 (Schultz et al. Sequence of a cDNA clone encompassing the complete mature human Prostate Specific Antigen (PSA) and an unspliced leader sequence. 1988 Nucleic Acids Research 16(13):6226. Still another human cDNA human sequence is listed as Genebank Accession Number BC056665.

The cDNA sequence of the non-human primate Cynomolgus monkey (Macaca fasicularis) prostate specific antigen precursor cDNA is published as Genebank Accession Number AY647976.

In addition, the cDNA sequence of the Rhesus monkey (Macaca mulatta) prostate specific antigen is published as Genebank Accession Number X73560.

A comparison of the preceding three genes shows that there are 30 base pair differences between human PSA and either rhesus or Cynolomogus PSA cDNA. This is a 3.8% difference. The resulting amino acid difference is 9.9% for the rhesus monkey PSA compared to human PSA and 10.7% for the Cynamologus monkey PSA compared to human.

The attached three page DNA Sequence Comparison (in FIGs. 1A, 1B, and 1C) shows the homology among the cDNA gene sequence for human PSA (cDNA on Genebank Accession # BC056665), the cDNA gene sequence for Maccaca mulatto PSA, and the cDNA gene sequence for Macca fascicula PSA.

Aside from the scientific literature discussed above, a review of published and issued patents reveal the following relevant patents and published patent application.

United States Published Application 20040141958 discloses novel methods for therapeutic vaccination and discusses the use of self peptides or proteins with

foreign peptides representing CTL epitopes. This would be a chimeric protein. It does not address the use of entire foreign proteins to induce a cross reactive immunity to native proteins.

U. S. Patent No. 5,925,362 discloses a method to elicit an antitumor response with human prostate specific antigen. This patent describes a prostate cancer vaccine requiring two parts. One is human PSA and the other is an expression system for producing the human PSA in situ. This is a DNA vaccine expressing human PSA. It does not describe the use of a xenogeneic PSA DNA vaccine.

U. S. Patent No. 6,165,460 discloses the generation of immune responses to human prostate specific antigen (PSA). This patent describes a PSA DNA vaccine. One claim describes a pox virus vector used for expressing PSA. It does not specifically state human PSA but xenogeneic PSA is not mentioned. Another claim teaches the use of PSA (or PSA CTL epitope) followed by a second administration of additional PSA. This is a traditional vaccine boost strategy that includes boosting with a different PSA expressing vector or with PSA protein itself. A third claim mentions the use of a CTL eptiope only. Although the animal model used to evaluate the vaccine was a rhesus monkey model using human PSA, there was no mention of the opposite approach of using of rhesus monkey PSA in humans.

U. S. Patent Nos. 6,818,751; 6,800,746; 6,759,515; 6,664,377; 6,657,056; 6,630,305; 6,620,922; 6,613,872; 6,329,505; 6,262,245; 6,261,562; 5,854,206 all describe the use of prostate specific peptides for diagnosis of prostate cancer, generation of monoclonal antibodies against the peptides, and immunotherapy of prostate cancer. They do not discuss the use of xenogeneic PSA as an immunogen.

U. S. Patent No. 6,699,483 discloses cancer treatments which employ the use of three human prostate cancer cell lines in a prostate cancer vaccine. The cell

lines are human and represent a broad range of antigens. It does not describe the use of xenogeneic cell lines, xenogeneic PSA or the use of DNA vaccines.

From the above discussion, a wide variety of approaches have been discussed in the scientific literature relating to vaccines, including xenogeneic approaches.

For purposes of the present invention, a brief review of relevant points is provided.

It is known that when a non-human antigen is introduced into a human, a human immune response produces antibodies against the non-human antigen.

It is believed that, in certain limited specific cases, when a specific-case non-human antigen is introduced into a human, a human immune response produces antibodies against a similar specific-case human antigen.

Only primates have prostate specific antigen (PSA). Humans have human-PSA, and non-human primates have non-human-primate-PSA. Species such as mice and dogs have serine proteases that are kallikrien proteins, but they are different enough from PSA so they are not considered to be PSA.

Non-human primates include the rhesus monkey and the chimpanzee, among others.

Human-PSA is comprised of a sequence of approximately 260 amino acids (See FIG. 2, section "huPSA"). Rhesusy-monkey-PSA is comprised of a sequence of approximately 260 amino acids (See FIG. 2, section "rhPSA"). Approximately 10% of the amino acids in the rhesus-monkey-PSA amino acid sequence differ from the amino acids in the human-PSA amino acid sequence.

Though there are similarities between human-PSA and xenogeneic-PSA, such as Rhesus-monkey-PSA, the differences between the human-PSA and the Rhesus-monkey-PSA are so significant that laboratory tests for detection of human-PSA will not detect xenogeneic-PSA such as Rhesus-monkey-PSA.

Turning specifically to prostate cancer in humans, treatment of human prostate cancer involves surgically removing the entire prostate gland. Further treatment of prostate cancer involves trying to destroy prostate cells that escaped surgical removal. In this respect, an anti-prostate vaccine should be designed to kill all prostate cells that escaped surgical removal.

Human prostate cells produce human-PSA, and a vaccine against human prostate cancer should cause triggering a human immune response that brings about the killing of human cells that produce human-PSA. In this way, prostate cells that escaped surgery would be killed as a result of vaccination with the vaccine against human prostate cancer.

In view of the prior art, it is an insight of the present inventors, resulting in the present invention, that it would be desirable to use a xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the xenogeneic antigen that is used, there are relatively few interspecies differences between the xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen.

Another insight of the present inventors, resulting in the present invention, is that it would be desirable to use a non-human primate xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the non-human primate xenogeneic antigen that is used, there are relatively few interspecies differences between the non-human primate xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen.

A more specific insight of the present inventors, resulting in the present invention, is that it would be desirable to use a non-human primate xenogeneic PSA antigen in a human, wherein, with respect to the non-human primate xenogeneic PSA antigen that is used, there are relatively few interspecies differences between the non-

human primate xenogeneic PSA antigen and the human self PSA antigen in order to induce an optimal immune response in the human to its native self PSA antigen.

An even more specific insight of the present inventors, resulting in the present invention, is that it would be desirable to provide a method for inducing an immune response against human PSA in humans using a non-human PSA having an amino acid homology $\geq$88% and $\leq$98% (or a 2 to 12% difference) with respect to the human PSA.

More specifically, the subject method includes obtaining PSA isolated from non-human primates and molecularly altering the non-human-primate PSA to adjust the amino acid homology to an optimal homology balance with respect to the human PSA. More specifically, it is desirable to provide an optimal homology balance such that the amino acid sequence in the non-human-primate PSA has a homology that is different enough from the amino acid sequence of the human PSA to induce an immune response to the non-human-primate PSA in the human but similar enough to produce an immune response in the human to human PSA.

The present invention also includes a DNA sequence whereby expression of that sequence produces a protein with an amino acid sequence with 88 to 98% homology to human PSA. It also includes the use of the DNA sequence in a polynucleotide vaccine such as a DNA or RNA vaccine.

A rationale for using non-human primate PSA rather than artificially made PSA is that all of the changes in the natural selection of a protein that maintains serine protease activity selects proteins with similar conformation. This means that immune responses to areas of the protein that are conformationally dependent are more likely to be similar or the same among the human and primate xenogeneic PSA.

In accordance with the present invention, delivery of the vaccine can be by a variety of methods including injection with or without chemical enhancers of

transfection, biolistic methods, or electroporation for example.

Thus, while the foregoing body of prior art indicates it to be well known to use xenogeneic antigens for eliciting some immune responses in non-human animal models, the prior art described above does not teach or suggest methods and compositions relating to a vaccine against prostate cancer which has the following combination of desirable features: (1) an anti-prostate vaccine which is designed to kill prostate cells that have escaped surgical removal; (2) causes a triggering of a human immune response that brings about the killing of human cells that produce human-PSA; (3) is not limited to hormonal therapies; (4) uses a xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the xenogeneic antigen that is used, there are relatively few interspecies differences between the xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen; (5) uses a non-human primate xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the non-human primate xenogeneic antigen that is used, there are relatively few interspecies differences between the non-human primate xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen; and (6) uses a non-human-primate xenogeneic PSA antigen in a human, wherein, with respect to the non-human-primate xenogeneic PSA antigen that is used, there are relatively few interspecies differences between the non-human-primate xenogeneic PSA antigen and the human self PSA antigen in order to induce an optimal immune response in the human to its native self PSA antigen. The foregoing desired characteristics are provided by the unique methods and compositions relating to a vaccine against prostate cancer of the present invention as will be made apparent from the following description thereof. Other advantages of the

present invention over the prior art also will be rendered evident.

Disclosure of Invention

An object of the present invention is to provide new and improved methods and compositions relating to a vaccine against prostate cancer which is designed to kill all prostate cells that escaped surgical removal.

Still another object of the present invention is to provide new and improved methods and compositions relating to a vaccine against prostate cancer that causes a triggering of a human immune response that brings about the killing of human cells that produce human-PSA.

Yet another object of the present invention is to provide new and improved methods and compositions relating to a vaccine against prostate cancer which is not limited to hormonal therapies.

Even another object of the present invention is to provide new and improved methods and compositions relating to a vaccine against prostate cancer that uses a xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the xenogeneic antigen that is used, there are relatively few interspecies differences between the xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen.

Still a further object of the present invention is to provide new and improved methods and compositions relating to a vaccine against prostate cancer which uses a non-human primate xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the non-human primate xenogeneic antigen that is used, there are relatively few interspecies differences between the non-human primate xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen.

Yet another object of the present invention is to provide new and improved methods and compositions relating to a vaccine against prostate cancer that uses a non-human-primate xenogeneic PSA antigen in a human, wherein, with respect to the non-human-primate xenogeneic PSA antigen that is used, there are relatively few interspecies differences between the non-human-primate xenogeneic PSA antigen and the human self PSA antigen in order to induce an optimal immune response in the human to its native self PSA antigen.

In accordance with one aspect of the invention, a composition of matter is provided which includes non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans.

In accordance with another aspect of the invention, a vaccine is provided for humans which is comprised of non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans.

In accordance with another aspect of the invention, a vaccine is provided wherein the non-human-primate-PSA triggers a human immune response which produces antibodies against human-PSA.

In accordance with another aspect of the invention, the use of non-human-primate PSA is provided for the preparation of a vaccine for administration to humans to provide an immune response against human PSA.

In accordance with another aspect of the invention, a vaccine is provided wherein a human immune response results in cytotoxic, cell-mediated immunity against human cells which contain human-PSA.

In accordance with another aspect of the invention, a method of treating humans includes steps for introducing a non-human-primate-DNA sequence into a human for providing non-human-primate-PSA in the human.

In accordance with another aspect of the invention, the use of a non-human-primate DNA sequence is provided for providing an antigen, for the preparation of a vaccine

for administration to humans to provide an immune response to the antigen in humans. In accordance with another aspect of the invention, the use of a non-human-primate DNA sequence for PSA is provided for the preparation of a vaccine for administration to humans to provide an immune response against human PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA into a human for triggering a human immune response which produces antibodies against human-PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA into a human, wherein a human immune response results in production of antibodies against human-PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA into a human for triggering an immune response which includes cytotoxic, cell-mediated immunity against cells containing human-PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA into a human, wherein a human immune response results in cytotoxic, cell-mediated immunity against cells containing human-PSA.

In accordance with another aspect of the invention, a method of delivering a nucleic acid vaccine expressing a non-human-primate antigen into human cells is provided which includes the steps of administering a quantity of the nucleic acid vaccine to human tissue, and applying electrical fields to the human tissue, whereby the nucleic acid vaccine, expressing non-human-primate antigen, is delivered into cells in the human tissue.

In accordance with another aspect of the invention, a method of delivering a nucleic acid vaccine expressing a non-human-primate PSA into human cells is provided which includes the steps of administering a quantity of the nucleic acid vaccine to human tissue, and applying electrical fields to the human tissue, whereby the nucleic acid vaccine, expressing non-human-primate PSA, is delivered into cells in the human tissue.

In accordance with another aspect of the invention, a DNA vaccine for humans includes is provided which includes a gene sequence derived from a gene of non-human-primate PSA.

In accordance with another aspect of the invention, a method of inducing an immune response against human PSA in humans is provided which includes the step of introducing a non-human PSA into the human, wherein the non-human PSA comprises an amino acid homology to human PSA in a range of equal to or greater than 88% to less than or equal to 98%.

In accordance with another aspect of the invention, a method of inducing an immune response against human PSA in humans is provided which includes the step of introducing a gene sequence derived from a gene of non-human PSA into the human. The non-human PSA gene sequence is expressed as a non-human PSA in the human. The introduced non-human gene sequence comprises a base pair homology to a gene sequence derived from a gene of human PSA, and the homology is in a range of equal to or greater than 88% to less than or equal to 98%. Preferably, the method of claim 18. The homology is in a range of equal to or greater than 92% to less than or equal to 99%.

In accordance with another aspect of the invention, the use of a vector expressing a non-human-primate antigen is provided for the preparation of a vaccine for administration to humans to provide an immune response against a human antigen. In one respect, the vector is

can be a DNA vector. In another respect, the vector can be an RNA vector.

In accordance with another aspect of the invention, the use of a vector expressing a non-human-primate PSA, for the preparation of a vaccine for administration to humans is provided to provide an immune response against human PSA. In one respect, the vector is can be a DNA vector. In another respect, the vector can be an RNA vector.

These together with still other objects of the invention, along with the various features of novelty which characterize the invention, are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be had to the accompanying drawings and descriptive matter in which there are illustrated preferred embodiments of the invention.

Brief Description of Drawings

The invention will be better understood and the above objects as well as objects other than those set forth above will become more apparent after a study of the following detailed description thereof. Such description makes reference to the annexed drawing wherein:

FIGs. 1A, 1B, and 1C set forth cDNA comparisons, derived from the Prior Art, between the cDNA of human PSA, the cDNA of non-human-primate PSA of the Rhesus monkey (Macaca mulatta), and the cDNA of non-human-primate PSA of Cynomolgus monkey (Macaca fasicularis).

FIG. 2 shows that human-PSA is comprised of a sequence of 261 amino acids (in the first section "huPSA"); that Rhesus-monkey-PSA is comprised of a sequence of 261 amino acids (in the first section

"rhPSA"). FIG. 2 also shows that the DNA sequence of human-PSA is comprised of a sequence of 786 nucleotides (in the second section "huPSA", Genebank Accession # X73560); that the DNA sequence of Rhesus-monkey-PSA is comprised of a sequence of 786 (in the second section "rhPSA", Genebank Accession # X07730).

FIG. 3 shows the expression of rhesus PSA in human dendritic cells transduced with pVAX/rhPSA (a plasmid expressing rhesus PSA) and a control plasmid (pVAX).

FIG. 4 shows the response of human T cells to stimulation by pVAX/rhPSA transfected monocyte derived human dendritic cells.

Modes for Carrying Out the Invention

Methods and apparatus are provided for use of a xenogeneic antigen (e. g. protein) in a human, wherein, with respect to the xenogeneic antigen that is used, there are relatively few interspecies differences between the xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen.

Relevant interspecies differences are illustrated in FIGs. 1A, 1B, 1C, and 2.

In accordance with one aspect of the invention, a composition of matter is provided which includes non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans. See Example 1 below.

In accordance with another aspect of the invention, a vaccine is provided for humans which is comprised of non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans. See Example 1 below.

Example 1

Here is a description of steps for making a vaccine

formulation containing recombinant non-human primate PSA.

A vaccine formulation containing recombinant non-human primate PSA can be formulated using standard vaccine adjuvants. One formulation can contain 90 mg antigen (recombinant rhesus PSA), 0.7 mg/ml aluminum, and 140 mM sodium chloride. This formulation can be made by the following method.

Three solutions are first made.

First, a 2.1 mg/ml Aluminum hydroxide mixture is made by diluting Alhydrogel (from Accurate Chemical and Scientific Corporation, Westbury NY) to 10 mM MOPS buffer (pH 7.4) to a provide a final aluminum concentration of 2.1%. The volume of Alhydrogel used in the latter mixture is determined by referring to the insert accompanying the Alhydrogel.

Second, recombinant rhesus PSA is diluted to a final concentration of 270 mg/ml in 10 millimolar MOPS buffer.

Third, a solution of 3% sodium chloride (420 millimolar) in water is prepared.

The first and second solutions (alhydrogel and recombinant rhesus PSA solutions) are mixed in equal volumes (e. g. 1 ml each). The mixture is gently mixed at 4 degrees centigrade by end to end inversion for 30 minutes.

Finally, a volume of sodium chloride equal to the volume of the Alhydrogel solution (e. g. 1 ml) in the mixture is added to dilute the vaccine mixture and to bring the sodium chloride concentration to 140 millimolar. The finally obtained vaccine mixture thus made provides a composition of matter which includes non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans.

The production of the recombinant rhesus PSA employed in Example 1 is obtained by expression of recombinant rhesus PSA protein in insect cells. Briefly,

a rhPSA gene sequence is cloned into Baculovirus as a fusion gene together with a sequence for a his-tag and a protease signal cleavage site. Recombinant rhPSA protein is produced by transcription and translation.

The recombinant rhPSA protein used in the formulation is purified from Baculovirus-infected insect cell lysates using affinity chromatography, followed by protease cleavage of the his-tag, size exclusion chromatography, and refolding by sequential dialysis. The sequential dialysis can be carried out in decreasing urea concentration buffers.

In accordance with another aspect of the invention, a vaccine is provided wherein the non-human-primate-PSA triggers a human immune response which produces antibodies against human-PSA. See Example 1 above.

In accordance with another aspect of the invention, the use of non-human-primate PSA is provided for the preparation of a vaccine for administration to humans to provide an immune response against human PSA. See Example 1 above.

In accordance with another aspect of the invention, a vaccine is provided wherein a human immune response results in cytotoxic, cell-mediated immunity against human cells which contain human-PSA. See Example 1 above.

In accordance with another aspect of the invention, a method of treating humans includes a step for introducing a vector containing a non-human-primate-DNA sequence into a human for providing expression of non-human-primate-PSA in the human. The vector can be a DNA or RNA vector. Examples of vectors are mammalian expression plasmids, viral RNA or DNA, messenger RNA or other nucleic acid constructs that when introduced into mammalian cells result in the expression of non-human-primate PSA. See Example 2 below.

Example 2

In one method, a DNA vaccine is prepared that contains a plasmid that expresses non-human-primate PSA under the control of a CMV promoter. The plasmid contains other DNA sequences essential to production of the plasmid, such as a bacterial origin of replication and an antibiotic resistance gene such as a Kanamycin resistance gene. The plasmid is mixed at a concentration of 0.5 to five micrograms per microliter in a suitable carrier such as half strength phosphate buffered saline. For administration, the plasmid mixture is loaded into a tuberculin type syringe with a half inch, 27 gauge needle. Twenty to fifty microliters of the plasmid mix are injected intradermally into skin above the deltoid muscle or on the forearm.

Then, an electrode with two parallel rows of needles (0.3 mm diameter needles, 4 mm distance between rows, 1 mm distance between needles in a row, four needles in a row and needle length of 3 mm) is inserted 2-3 mm deep into the skin with a row of needles on each side of the injection site. Electroporation pulses are then applied to the inserted electrode. One pulse protocol consists of two pulses of 1125 V/cm, 50 microsecond duration and 0.125 seconds between pulses followed 0.5 seconds later by eight pulses of 275 V/cm, 10 millisecond duration and 0.125 seconds between pulses.

In accordance with another aspect of the invention, the use of a vector containing a non-human-primate DNA sequence is provided for the preparation of a vaccine for administration to humans to provide an immune response to the antigen in humans. See Example 2 above.

In accordance with another aspect of the invention, the use of vector containing a non-human-primate DNA sequence is provided for the preparation of a vaccine for administration to humans to provide an immune response against human PSA. See Example 2 above.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided

which includes the step of introducing non-human-primate-PSA into a human for triggering a human immune response which produces antibodies against human-PSA. See Examples 1 and 2 above for a non-human-primate-PSA and vectors that express non-human-PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA or vectors that express non-human-PSA into a human, wherein a human immune response results in production of antibodies against human-PSA. See Examples 1 and 2 above for a non-human-primate-PSA and vectors that express non-human-PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA or vectors that express non-human-PSA into a human for triggering an immune response which includes cytotoxic, cell-mediated immunity against cells containing human-PSA. See Examples 1 and 2 above for a non-human-primate-PSA and vectors that express non-human-PSA.

In accordance with another aspect of the invention, a method of treating prostate cancer in humans is provided which includes the step of introducing non-human-primate-PSA or vectors that express non-human-PSA into a human, wherein a human immune response results in cytotoxic, cell-mediated immunity against cells containing human-PSA. See Examples 1 and 2 above for a non-human-primate-PSA and vectors that express non-human-PSA.

In accordance with another aspect of the invention, a method of delivering a nucleic acid vaccine expressing a non-human-PSA into human cells is provided which includes the steps of administering a quantity of the nucleic acid vaccine to human tissue, and applying electrical fields to the human tissue, whereby the nucleic acid vaccine, expressing non-human-primate antigen, is delivered into

cells in the human tissue. See Example 2 above and Example 3 below.

Example 3

Application of electrical fields can be implemented by conducting electroporation techniques. Suitable electroporation techniques are disclosed in U. S. Patent Nos. 6,010,613, 6,603,998, and 6,713,291, all of which are incorporated herein by reference.

In accordance with another aspect of the invention, a method of delivering a nucleic acid vaccine expressing a non-human-primate PSA into human cells is provided which includes the steps of administering a quantity of the nucleic acid vaccine to human tissue, and applying electrical fields to the human tissue, whereby the nucleic acid vaccine, expressing non-human-primate PSA, is delivered into cells in the human tissue. See Examples 2 and 3 above.

In accordance with another aspect of the invention, a DNA vaccine for humans is provided which includes a gene sequence derived from a gene of non-human-primate PSA.

In accordance with another aspect of the invention, a method of inducing an immune response against human PSA in humans is provided which includes the step of introducing a non-human PSA into the human, wherein the non-human PSA comprises an amino acid homology to human PSA in a range of equal to or greater than 88% to less than or equal to 98%. See Example 1 above for a non-human PSA.

In accordance with another aspect of the invention, a method of inducing an immune response against human PSA in humans is provided which includes the step of introducing a gene sequence derived from a gene of non-human PSA into the human. The non-human PSA gene sequence is expressed as a non-human PSA in the human. The introduced non-human gene sequence comprises a base pair

homology to a gene sequence derived from a gene of human PSA, and the homology is in a range of equal to or greater than 88% to less than or equal to 98%. Preferably, the homology is in a range of equal to or greater than 92% to less than or equal to 99%. See Example 2 above.

In accordance with another aspect of the invention, the use of a vector expressing a non-human-primate antigen is provided for the preparation of a vaccine for administration to humans to provide an immune response against a human antigen. In one respect, the vector can be a DNA vector. In another respect, the vector can be an RNA vector. See Example 2 above.

In accordance with another aspect of the invention, the use of a vector expressing a non-human-primate PSA, for the preparation of a vaccine for administration to humans is provided to provide an immune response against human PSA. In one respect, the vector is can be a DNA vector. In another respect, the vector can be an RNA vector. See Example 2 above.

The utility of non-human primate PSA (e. g. rhesus PSA) in the stimulation of the human immune system for attacking human cells that produce human PSA is proved by the evidence illustrated in FIGs. 3 and 4.

FIG. 4 shows the response of human T cells to stimulation by pVAX/rhPSA transfected monocyte derived human dendritic cells. Immature human monocyte dendritic cells were prepared by growth of human monocytes in cytokines. Human monocyte derived dendritic cells were transduced with pVAX/rhPSA. The cells were matured by incubation in medium with poly I:C. After maturation, the cells were used to stimulate autologous human T cells in an in vitro immunization. After two re-stimulations, human PSA specificity was assessed using IFNgamma ELISPOT assay. Specific T cells were compared to T cells stimulated using a control human serum albumin (HSA). The response shows a human PSA specific T cell response in cells stimulated with the rhesus PSA transduced human

dendritic cells. This shows that in an in vitro immunization, the human T cells, stimulated by rhesus PSA, respond in a way indicative of attacking human cells which contain human PSA.

For the above transfection of the human dendritic cells, to demonstrate that in fact the transfected cells were expressing rhesus PSA, a Western blot was done. More specifically, FIG. 3 shows the expression of rhesus PSA in human dendritic cells transduced with pVAX/rhPSA (a plasmid expressing rhesus PSA) and a control plasmid (pVAX). The Western blot shows expression of the expected 30 kilodalton protein for rhesus PSA. For the expression, pVAX/rhPSA and the control plasmid were transduced into immature human dendritic cells by electroporation . Cells were analyzed 24 hours later by Western blot, and the rhesus PSA was detected as a band at 30 kilodaltons.

As to the manner of usage and operation of the instant invention, the same is apparent from the above disclosure, and accordingly, no further discussion relative to the manner of usage and operation need be provided.

It is apparent from the above that the present invention accomplishes all of the objects set forth by providing new and improved methods and compositions relating to a vaccine against prostate cancer which may advantageously be used to kill prostate cells in a human that have escaped surgical removal of the prostate. With the invention, methods and compositions relating to a vaccine against prostate cancer are provided which cause a triggering of a human immune response that brings about the killing of human cells that produce human-PSA. With the invention, methods and compositions relating to a vaccine against prostate cancer are provided which is not limited to hormonal therapies. With the invention, methods and compositions relating to a vaccine against prostate cancer are provided which use a xenogeneic antigen (e. g. a protein) in a human, wherein, with

respect to the xenogeneic antigen that is used, there are relatively few interspecies differences between the xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen. With the invention, methods and compositions relating to a vaccine against prostate cancer are provided which use a non-human primate xenogeneic antigen (e. g. a protein) in a human, wherein, with respect to the non-human primate xenogeneic antigen that is used, there are relatively few interspecies differences between the non-human primate xenogeneic antigen and the human self antigen in order to induce an optimal immune response in the human to its native self antigen. With the invention, methods and compositions relating to a vaccine against prostate cancer are provided which use a non-human-primate xenogeneic PSA antigen in a human, wherein, with respect to the non-human-primate xenogeneic PSA antigen that is used, there are relatively few interspecies differences between the non-human-primate xenogeneic PSA antigen and the human self PSA antigen in order to induce an optimal immune response in the human to its native self PSA antigen.

Thus, while the present invention has been shown in the drawings and fully described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiment(s) of the invention, it will be apparent to those of ordinary skill in the art that many modifications thereof may be made without departing from the principles and concepts set forth herein, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use.

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Claims

What is claimed is:

1. A composition of matter which includes non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans.

2. The composition of matter of claim 1, wherein said composition of matter is a vaccine for humans comprising non-human-primate-PSA and a pharmaceutically acceptable carrier for administration to humans.

3. The composition of matter of claim 1, wherein said composition of matter is a vaccine, and wherein the non-human-primate-PSA triggers a human immune response which produces antibodies against human-PSA.

4. The composition of matter of claim 1, wherein said composition of matter is a vaccine, and wherein a human immune response results in production of antibodies against human-PSA.

5. The composition of matter of claim 1, wherein said composition of matter is a vaccine, and wherein a human immune response results in cytotoxic, cell-mediated immunity against human cells which contain human-PSA.

6. The use of non-human-primate PSA for the preparation of a vaccine for administration to humans to provide an immune response against human PSA.

7. The use of a non-human-primate DNA sequence for an antigen, for the preparation of a vaccine for administration to humans to provide an immune response to the antigen in humans.

8. The use of a non-human-primate DNA sequence for PSA, for the preparation of a vaccine for administration to humans to provide an immune response against human PSA.

9. A method of treating humans, comprising steps for introducing a non-human-primate-DNA sequence into a human for providing non-human-primate-PSA in the human.

10. A method of treating prostate cancer in humans, comprising the step of introducing non-human-primate-PSA into a human for triggering a human immune response.

11. The method of claim 10 for treating prostate cancer in humans, comprising the step of introducing non-human-primate-PSA into a human, wherein a human immune response results in production of antibodies against human-PSA.

12. The method of claim 10 for treating prostate cancer in humans, comprising the step of introducing non-human-primate-PSA into a human for triggering an immune response which includes cytotoxic, cell-mediated immunity against cells containing human-PSA.

13. The method of claim 10 for treating prostate cancer in humans, comprising the step of introducing non-human-primate-PSA into a human, wherein a human immune response results in cytotoxic, cell-mediated immunity against cells containing human-PSA.

14. A method of delivering a nucleic acid vaccine expressing a non-human-primate antigen into human cells, comprising the steps of:

administering a quantity of the nucleic acid vaccine to human tissue, and

applying electrical fields to the human tissue, whereby the nucleic acid vaccine, expressing non-human-

primate antigen, is delivered into cells in the human tissue.

15. A method of delivering a nucleic acid vaccine expressing a non-human-primate PSA into human cells, comprising the steps of:

administering a quantity of the nucleic acid vaccine to human tissue, and

applying electrical fields to the human tissue, whereby the nucleic acid vaccine, expressing non-human-primate PSA, is delivered into cells in the human tissue.

16. A DNA vaccine for humans, comprising a gene sequence derived from a gene of non-human-primate PSA.

17. A method of inducing an immune response against human PSA in humans, comprising the step of introducing a non-human PSA into the human, wherein non-human PSA comprises an amino acid homology to human PSA in a range of equal to or greater than 88% to less than or equal to 98%.

18. A method of inducing an immune response against human PSA in humans, comprising the step of introducing a gene sequence derived from a gene of non-human PSA into the human, wherein the non-human PSA gene sequence is expressed as a non-human PSA in the human, wherein the introduced non-human gene sequence comprises a base pair homology to a gene sequence derived from a gene of human PSA, and wherein the homology is in a range of equal to or greater than 88% to less than or equal to 98%.

19. The method of claim 18, wherein the homology is in a range of equal to or greater than 92% to less than or equal to 99%.

20. The use of a vector expressing a non-human-primate antigen, for the preparation of a vaccine for

administration to humans to provide an immune response against a human antigen.

21. The use of a vector as described in claim 20, wherein said vector is a DNA vector.

22. The use of a vector as described in claim 20, wherein said vector is an RNA vector.

23. The use of a vector expressing a non-human-primate PSA, for the preparation of a vaccine for administration to humans to provide an immune response against human PSA.

24. The use of a vector as described in claim 23, wherein said vector is a DNA vector.

25. The use of a vector as described in claim 23, wherein said vector is an RNA vector.

DNA Sequence Comparison

		10		20		30		40	
Human PSA	ggggg	agccc	caagc	ttacc	acctg	caccc	ggaga	gctgt	40
Mmulatta P			c	tcacc	gcctg	caccc	ggaca	gctgt	26
Mfascicula			gc	tcacc	gcctg	cacct	ggaca	gctgt	27
Consensus			gC	TcACC	gCCTG	CACCt	GGAcA	GCTG T	

		50		60		70		80	
Human PSA	gtcac	catgt	gggtc	ccggt	tgtct	tcctc	accct	gtccg	80
Mmulatta P	gtcac	catgt	gggtt	ctggt	tgtct	tcctc	accct	gtccg	66
Mfascicula	gtcac	catgt	gggtt	ctggt	tgtct	tcctc	accct	gtccg	67
Consensus	GTCA C	CATGT	GGGTt	CtGGT	TGTCT	TCCTC	ACCCT	GTCC G	

↑start

		90		100		110		120	
Human PSA	tgacg	tggat	tggtg	ctgca	ccccc	catcc	tgtct	cggat	120
Mmulatta P	tgacg	tggat	tggcg	ctgca	ccccc	catcc	tgtct	cggat	106
Mfascicula	tgacg	tggat	tggcg	ctgca	ccccc	catcc	tgtct	cggat	107
Consensus	TGAC G	TGGAT	TGGcG	CTGCA	CCCCT	CATCC	TGTCT	CGGA T	

Human PSA	tgtgg	gaggc	tggga	gtgcg	agaag	cattc	ccaac	cctgg	160
Mmulatta P	tgtgg	gaggc	tggga	gtgcg	agaag	cattc	ccaac	cctgg	146
Mfascicula	tgtgg	gaggc	tggga	gtgcg	agaag	cattc	ccaac	cctgg	147
Consensus	TGTG G	GAGG C	TGGG A	GTGC G	AGAA G	CATTC	CCAA C	CCTG G	

		170		180		190		200	
Human PSA	caggt	gcttg	tggcc	tctcg	tggca	gggca	gtctg	cggcg	200
Mmulatta P	caggt	gcttg	tggcc	tctcg	tggca	gggca	gtctg	cgggg	186
Mfascicula	caggt	gcttg	tggcc	tctca	tggca	gggca	gtctg	cgggg	187
Consensus	CAGG T	GCTTG	TGGC C	TCTCg	TGGC A	GGGC A	GTCTG	CGGg G	

		210		220		230		240	
Human PSA	gtgtt	ctggt	gcacc	cccag	tgggt	cctca	cagct	gccca	240
Mmulatta P	gtgtt	ctggt	gcacc	cccag	tgggt	cctca	cagct	gccca	226
Mfascicula	gtgtt	ctggt	gcacc	cccag	tgggt	gctca	cagct	gccca	227
Consensus	GTGTT	CTGGT	GCAC C	CCCA G	TGGG T	cCTCA	CAGCT	GCCC A	

		250		260		270		280	
Human PSA	ctgca	tcagg	aacaa	aagcg	tgatc	ttgct	gggtc	ggcac	280
Mmulatta P	ctgca	tcagg	agcaa	cagcg	tgatc	ttgct	gggtc	ggcac	266
Mfascicula	ctgca	tcagg	agcca	cagcg	tgatc	ttgct	gggtc	ggcac	267
Consensus	CTGC A	TCAG G	AgCaA	cAGCG	TGATC	TTGCT	GGGT C	GGCA C	

		290		300		310		320	
Human PSA	agcct	gtttc	atcct	gaaga	cacag	gccag	gtatt	tcagg	320
Mmulatta P	aaccc	gtatt	atcct	gaaga	cacgg	gccag	gtgtt	tcagg	306
Mfascicula	aaccc	gtatt	atcct	gaaga	cacgg	gccag	gtgtt	tcagg	307
Consensus	AaCCc	GTaTt	ATCCT	GAAG A	CACgG	GCCA G	GTgTT	TCAG G	

FIG. 1A

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DNA Sequence Comparison

		330		340		350		360	
Human PSA	tcagc	cacag	cttcc	cacac	ccgct	ctacg	atatg	agcct	360
Mmulatta P	tcagc	cacag	cttcc	cacac	ccgct	ctaca	atatg	agcct	346
Mfascicula	tcagc	cacag	cttcc	cacac	ccgct	ctaca	atatg	agcct	347
Consensus	TCAG C	CACA G	CTTCC	CACA C	CCGC T	CTACa	ATATG	AGCC T	

		370		380		390		400	
Human PSA	cctga	agaat	cgatt	cctca	ggcca	ggtga	tgact	ccagc	400
Mmulatta P	cctga	agaat	cgata	cctcg	ggcca	ggtga	tgact	ccagc	386
Mfascicula	cctga	agaat	cgata	cctcg	ggcca	ggtga	tgact	ccagc	387
Consensus	CCTG A	AGAAT	CGATa	CCTCg	GGCC A	GGTG A	TGACT	CCAG C	

		410		420		430		440	
Human PSA	cacga	cctca	tgctg	ctccg	cctgt	cagag	cctgc	cgagc	440
Mmulatta P	cacga	cctca	tgctg	ctccg	cctgt	cagag	cctgc	cgaga	426
Mfascicula	cacga	cctca	tgctg	ctccg	cctgt	cagag	cctgc	cgaga	427
Consensus	CACG A	CCTC A	TGCT G	CTCC G	CCTG T	CAGA G	CCTG C	CGAG a	

		450		460		470		480	
Human PSA	tcacg	gatgc	tgtga	aggtc	atgga	cctgc	ccacc	cagga	480
Mmulatta P	tcaca	gatgc	tgtgc	aggtc	ctgga	cctgc	ccacc	tggga	466
Mfascicula	tcaca	gatgc	tgtgc	aggtc	ctgga	cctgc	ccacc	tggga	467
Consensus	TCACa	GATG C	TGTGc	AGGT C	cTGGA	CCTG C	CCAC C	tgGG A	

		490		500		510		520	
Human PSA	gccag	cactg	gggac	cacct	gctac	gcctc	aggct	ggggc	520
Mmulatta P	gccag	agctg	gggac	cacgt	gctac	gcctc	aggct	ggggc	506
Mfascicula	gccag	agctg	gggac	cacgt	gctac	gcctc	aggct	ggggc	507
Consensus	GCCA G	agCTG	GGGA C	CACgT	GCTA C	GCCT C	AGGC T	GGG GC	

		530		540		550		560	
Human PSA	agcat	tgaac	cagag	gagtt	cttga	cccca	aagaa	acttc	560
Mmulatta P	agcat	cgaac	cagag	gaaca	cttga	ctcca	aagaa	acttc	546
Mfascicula	agcat	cgaac	cagag	gaaca	cttga	ctcca	aagaa	acttc	547
Consensus	AGCA T	cGAAC	CAGA G	GAaca	CTTGA	CtCCA	AAGA A	ACTT C	

		570		580		590		600	
Human PSA	agtgt	gtgga	cctcc	atgtt	atttc	caatg	acgtg	tgtgc	600
Mmulatta P	agtgt	gtgga	cctcc	atatt	atttc	caatg	atgtg	tgtgc	586
Mfascicula	agtgt	gtgga	cctcc	atatt	atttc	caatg	atgtg	tgtgc	587
Consensus	AGTG T	GTGG A	CCTC C	ATaTT	ATTTC	CAAT G	AtGTG	TGTG C	

		610		620		630		640	
Human PSA	gcaag	ttcac	cctca	gaagg	tgacc	aagtt	catgc	tgtgt	640
Mmulatta P	gcaag	ttcac	tctca	gaagg	tgacc	aagtt	catgc	tgtgt	626
Mfascicula	gcaag	ttcac	tctca	gaagg	tgacc	aagtt	catgc	tgtgt	627
Consensus	GCAA G	TTCAC	tCTCA	GAAG G	TGAC C	AAGTT	CATG C	TGTG T	

FIG. 1B

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DNA Sequence Comparison

		650		660		670		680	
Human PSA	gctgg	acgct	ggaca	ggggg	caaaa	gcacc	tgctc	gggtg	680
Mmulatta P	gctgg	acgct	ggatg	ggcgg	caaaa	gcacc	tgctc	gggtg	666
Mfascicula	gctgg	acgct	ggatg	ggcgg	caaaa	gcacc	tgctc	gggtg	667
Consensus	GCTG G	ACGC T	GGAtg	GGcG G	CAAAA	GCAC C	TGCTC	GGGT G	

		690		700		710		720	
Human PSA	attct	ggggg	cccac	ttgtc	tgtaa	tggtg	tgctt	caagg	
Mmulatta P	attct	ggggg	cccac	tggtc	tgtga	cggtg	tgctt	caagg	720
Mfascicula	attct	ggggg	cccac	tggtc	tgtga	cggtg	tgctt	caagg	706
Consensus	ATTCT	GGGG G	CCCA C	TgGTC	TGTgA	cGGTG	TGCTT	CAAG G	707

		730		740		750		760	
Human PSA	tatca	cgtca	tgggg	cagtg	aacca	tgtgc	cctgc	ccgaa	760
Mmulatta P	tatca	cgtca	tgggg	cagtc	aacca	tgtgc	cctgc	cccga	746
Mfascicula	tatca	cgtca	tgggg	cagtc	aacca	tgtgc	cctgc	cccga	747
Consensus	TATCA	CGTC A	TGGG G	CAGTc	AACCA	TGTG C	CCTG C	CCcg A	

		770		780		790		800	
Human PSA	aggcc	ttccc	tgtac	accaa	ggtgg	tgcat	taccg	gaagt	800
Mmulatta P	aggcc	ttccc	tgtac	accaa	ggtgg	tgcgt	taccg	gaagt	786
Mfascicula	aggcc	ttccc	tgtac	accaa	ggtgg	tgcgt	taccg	gaagt	787
Consensus	AGGC C	TTCCC	TGTAC	ACCAA	GGTG G	TGCgT	TACC G	GAAG T	

		810		820		830		840	
Human PSA	ggatc	aagga	cacca	tcgtg	gccaa	ccccc	gagca	ccccc	840
Mmulatta P	ggatc	cagga	cacca	tcatg	gcaaa	ccccc	gagca	cccc-	825
Mfascicula	ggatc	cagga	cacca	tcatg	gcaaa	ccccc	gagca	cccc-	826
Consensus	GGAT C	cAGGA	CACC A	TCaTG	GCaAA	CCCC T	GAGC A	CCCC	

		850		860		870		880	
Human PSA	atcaa	ctccc	ta-tt	gtagt	-aaa-	-----	-----	-----	862
Mmulatta P	atcaa	ctccc	taatt	gtagc	gaaaa	aaaaa	agtcc	acctc	865
Mfascicula	atcaa	ctccc	tactt	gtagc	gaaaa	aaaaa	a-tcc	acctc	865
Consensus	ATCAA	CTCC C	TA TT	GTAGc	gAAAa	aaaaa	a tcc	acctc	

		890		900		910		920	
Human PSA	-----	-----	-----	-----	-----	-----	-----	----c	863
Mmulatta P	aagtt	ctigg	catca	tttgg	ctatt	ctaga	cacca	ggcac	905
Mfascicula	aagtt	ctg-g	catca	tttgg	ctatt	ctaga	cacca	ggcac	904
Consensus	aagtt	ct g	catca	tttgg	ctatt	ctaga	cacca	ggcaC	

		930		940		950		960	
Human PSA	ttgga	acctt	ggaaa	tgacc	aggcc	aagac	tcagg	cctcc	903
Mmulatta P	ttgga	acctt	ggaaa	tgacc	gggcc	aaggc	tcaag	cctcc	945
Mfascicula	ttgga	acctt	ggaaa	tgacc	gggcc	aaggc	tcaag	cctcc	944
Consensus	TTGGA	ACCTT	GGAA A	TGAC C	gGGC C	AAGgC	TCAaG	CCTC C	

FIG. 1C

Rhesus and Human PSA cDNA
Protein and DNA Sequence of huPSA and rhPSA
Protein sequence: 261 aa
DNA sequence: 786 nucleotides

rhPSA
1 mut compared to published (plus one silent in nucleotide sequence):
mwvlvvfltl svtwigaapl ilsrivggwe cekhsqpwqv lvasrgravc ggvlvhpqwv
ltaahcirsn svillgrhnp yypedtgqvf qvshsfphpl ynmsllknry lgpgddsshd
lmllrlsepa eltdavqvld lptwepelgt tcyasgwgsi epeehltpkk lqcvdlhiis
ndvcaqvhsq kvtefmlcag swmggkstcs gdsggplvcd gvlqgitswg sqpcalprrp
slytkvvryr kwiqdtiman p

huPSA
mwvpvvfltl svtwigaapl ilsrivggwe cekhsqpwqv lvasrgravc ggvlvhpqwv
ltaahcirnk svillgrhsl fhpedtgqvf qvshsfphpl ydmsllknrf lrpgddsshd
lmllrlsepa eltdavkvmd lptqepalgt tcyasgwgsi epeefltpkk lqcvdlhvis
ndvcaqvhpq kvtkfmlcag rwtggkstcs gdsggplvcn gvlqgitswg sepcalperp
slytkvvhyr kwikdtivan p

rhPSA Genebank Accession # X73560
ATGTGGGTTCTGGTTGTCTTCCTCACCCTGTCCGTGACGTGGATTGGCGCTGCACCCCT
CATCCTGTCTCGGATTGTGGGAGGCTGGGAGTGCGAGAAGCATTCCCAACCCTGGCAGGT
GCTTGTGGCCTCTCGTGGCAGGGCAGTCTGTGGGGGTGTTCTGGTGCACCCCCAGTGGGT
CCTCACAGCTGCCCACTGCATCAGGAGCAACAGCGTGATCTTGCTGGGTCGGCACAACCC
GTATTATCCTGAAGACACGGGCCAGGTGTTTCAGGTCAGCCACAGCTTCCCACACCCGCT
CTACAACATGAGCCTCCTGAAGAATCGATACCTCGGGCCAGGTGATGACTCCAGCCACGA
CCTCATGCTGCTCCGCCTGTCAGAGCCTGCCGAGATCACAGATGCTGTGCAGGTCCTGGA
CCTGCCCACCTGGGAGCCAGAGCTGGGGACCACGTGCTACGCCTCAGGCTGGGGCAGCAT
CGAACCGGAGGAACACTTGACTCCAAAGAAACTTCAGTGTGTGGACCTCCATATTATTTC
CAATGATGTGTGTGCGCAAGTTCACTCTCAGAAGGTGACCGAGTTCATGCTGTGTGCTGG
AAGCTGGATGGGCGGCAAAAGCACCTGCTCGGGTGATTCTGGGGGCCCACTGGTCTGTGA
CGGTGTGCTTCAAGGTATCACGTCATGGGGCAGTCAACCATGTGCCCTACCCCGAAGGCC
TTCCCTGTACACCAAGGTGGTGCGTTACCGGAAGTGGATCCAGGACACCATCATGGCAAA
CCCCTGA

huPSA Genebank Accession # X07730
ATGTGGGTCCCGGTTGTCTTCCTCACCCTGTCCGTGACGTGGATTGGTGCTGCACCCCTC
ATCCTGTCTCGGATTGTGGGAGGCTGGGAGTGCGAGAAGCATTCCCAACCCTGGCAGGTG
CTTGTGGCCTCTCGTGGCAGGGCAGTCTGCGGCGGTGTTCTGGTGCACCCCCAGTGGGTC
CTCACAGCTGCCCACTGCATCAGGAACAAAAGCGTGATCTTGCTGGGTCGGCACAGCCTG
TTTCATCCTGAAGACACAGGCCAGGTATTTCAGGTCAGCCACAGCTTCCCACACCCGCTC
TACGATATGAGCCTCCTGAAGAATCGATTCCTCAGGCCAGGTGATGACTCCAGCCACGAC
CTCATGCTGCTCCGCCTGTCAGAGCCTGCCGAGCTCACGGATGCTGTGAAGGTCATGGAC
CTGCCCACCCAGGAGCCAGCACTGGGGACCACCTGCTACGCCTCAGGCTGGGGCAGCATT
GAACCAGAGGAGTTCTTGACCCCAAAGAAACTTCAGTGTGTGGACCTCCATGTTATTTCC
AATGACGTGTGTGCGCAAGTTCACCCTCAGAAGGTGACCAAGTTCATGCTGTGTGCTGGA
CGCTGGACAGGGGGCAAAAGCACCTGCTCGGGTGATTCTGGGGGCCCACTTGTCTGTAAT
GGTGTGCTTCAAGGTATCACGTCATGGGGCAGTGAACCATGTGCCCTGCCCGAAAGGCCT
TCCCTGTACACCAAGGTGGTGCATTACCGGAAGTGGATCAAGGACACCATCGTGGCCAAC
CCCTGA

FIG. 2

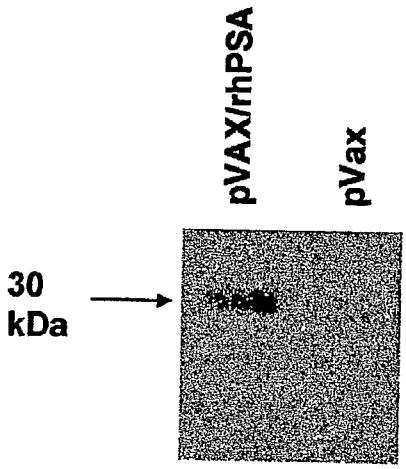

FIG. 3

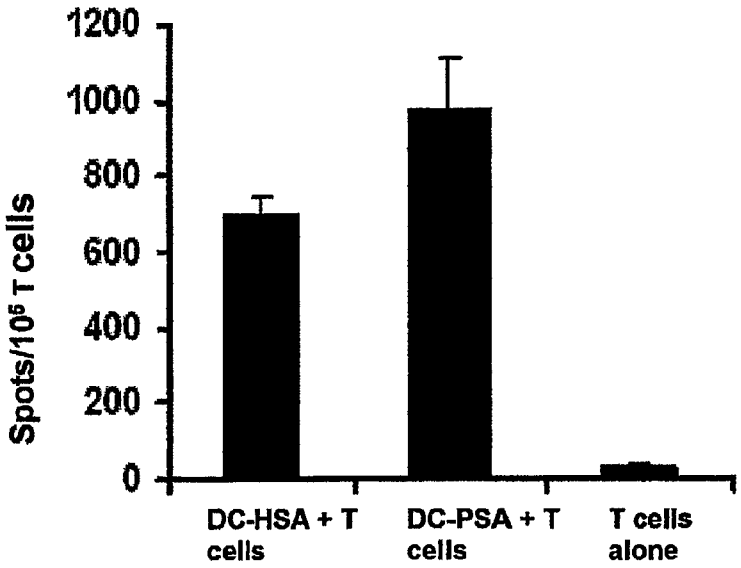
1200
1000
800
600
400
200
0
Spots/10⁵ T cells
DC-HSA + T cells
DC-PSA + T cells
T cells alone

FIG. 4