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(56) Related Art
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LEMIALE FRANCK et al Enhanced mucosal immunoglobulin A response of intranasal adenoviral vector HIV vaccine and localisation in the CNS. Journal of Virology 77/18
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(54) Title: VACCINES AGAINST AIDS COMPRISING CMV/R-NUCLEIC ACID CONSTRUCTS

(57) Abstract: The present disclosure provides compositions for eliciting an immune response, including a prophylactic immune response, against human immunodeficiency virus. The composition includes nucleic acid constructs encoding HIV antigenic polypeptides of multiple clades or strains. Methods for eliciting an immune response by administering the composition to a subject are also provided.

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VACCINE CONSTRUCTS AND COMBINATIONS OF VACCINES DESIGNED TO IMPROVE THE BREADTH OF THE IMMUNE RESPONSE TO DIVERSE STRAINS AND CLADES OF HIV

CROSS REFERENCE TO RELATED APPLICATION

[001] This application is an Australian national phase filing of International Patent Application No. PCT/US2005/025219 (publication No. WO 2006/020071) filed on July 15, 2005, which claims priority from USSN 60/588,378, filed July 16, 2004, PCT/US2004/030284, filed September 15, 2004 and PCT/US2005/12291, filed April 12, 2005. The contents of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

[002] This application relates to the field of vaccines. More specifically, this application relates to a multi-plasmid vaccine for the prevention of human immunodeficiency virus (HIV).

BACKGROUND

[004] More than 40 million people are infected worldwide with HIV-I and an estimated 14,000 new infections occur every day. Over 25 million people have died of HIV/AIDS since the first cases of AIDS were identified in 1981 (CDC5 MMWR Morb. Mortal Wkly. Rep., 52:1145-1148, 2003; UNAIDS, 2003 Report on the Global AIDS Epidemic Executive Summary, 2004). Development of a globally relevant HIV-I vaccine is critical for controlling the HIV/AIDS pandemic.

[005] The combination of a high transcriptional error rate and frequent recombination results in a remarkable amount of genetic diversity among HIV-I strains and presents a challenge for selecting viral antigens. The other potential

impact of HIV genetic variation is the high rate of mutation within each individual, which creates the opportunity for viral escape from epitope-specific immune responses and poses particular challenges for T cell based vaccine approaches (Altfield et al., *J. Virol.*, 77:12764-12772, 2002; Bhardwaj et al., *Nat. Med.*, 9:13-14, 2003; Brander et al., *Curr. Opin. Immunol.*, 11:451-459, 1999; Letvin et al., *Nat. Med.*, 9:861-866, 2003). A variety of vaccine strategies to elicit effective immunity to HIV-1 have been explored. Among them, immunization by plasmid DNA encoding genes for HIV protein antigens is a promising vaccine approach (Mascola et al., *Curr. Opin. Immunol.*, 13:489-494, 2001; Nabel, G.J., *Nature*, 410:1002-1007, 2001). Gene-based immunization promotes host cell synthesis and expression of the viral antigen and physiologic post-translational processing and folding in the cell cytoplasm. Therefore, DNA immunization elicits both $CD4^+$ and $CD8^+$ T lymphocyte responses with a variety of immunogens in animal models (Graham, B.S., *Annu. Rev. Med.*, 53:207-221, 2002; Rollman et al., *Gene Ther.*, 11:1146-1154, 2004; Barouch et al., *Science*, 290:486-492, 2000; Subbramanian et al., *J. Virol.*, 77:10113-10118, 2003; Mascola et al., *J. Virol.*, 79:771-779, 2005).

[006] Delivering viral antigens by DNA plasmid vaccine vectors has potential advantages over other vector delivery systems, notably the lack of anti-vector immunity. However, DNA immunization has shown only limited immunogenicity in humans, despite many examples of vaccine-induced protection in mice and nonhuman primates (Rollman et al., *Gene Ther.*, 11:1146-1154, 2004; Donnelly et al., *Nat. Med.*, 1:583-587, 1995). The first DNA vaccine demonstrated to be immunogenic in antigen-naïve humans was a construct expressing the circumsporozoite antigen from *Plasmodium falciparum* delivered by Biojector®. In this study, $CD8^+$ CTL responses were detected only after in vitro expansion of effectors (Wang et al., *Science*, 282:476-480, 1998). Another report described a DNA plasmid expressing the Hepatitis B surface antigen delivered by a different needleless injection device, Powderject™, induced antibody as well as vaccine-specific T cell responses in antigen-naïve humans (Roy et al., *Vaccine*, 19:764-778, 2000). A DNA plasmid vaccine expressing the HIV-1 Env and Rev proteins tested in both HIV-infected and HIV-uninfected subjects (MacGregor et al., *J. Infect. Dis.*,

178:92-100, 1998) was not associated with adverse events, but only sporadic lymphoproliferative and antibody responses were observed (MacGregor et al., *J. Infect. Dis.*, 181:406, 2000; MacGregor et al., *AIDS*, 16:2137-2143, 2002).

[007] This disclosure describes vaccine compositions that elicit broad spectrum immunity against HIV, by providing robust expression of HIV antigens corresponding to important immunogenic epitopes of multiple clades and strains of human immunodeficiency virus 1. The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

SUMMARY

[008] This disclosure relates to nucleic acid constructs that encode HIV antigens. These nucleic acid constructs are capable of eliciting an immune response against multiple variants of HIV, and are suitable for therapeutic (for example, prophylactic) administration. In the context of an immunogenic composition, multiple nucleic acids are combined, each of which encodes an HIV antigenic polypeptide, for example different HIV antigenic polypeptides (such as Gag, Pol, and Nef). A single immunogenic composition includes nucleic acid constructs that encode antigenic polypeptides of multiple clades or strains of HIV for example multiple clades or strains of Gag, Pol or Nef, or multiple clades or strains on Gag, Pol and Nef.. Thus, when administered to a subject, the composition elicits an immune response against multiple clades or strains prevalent in human populations.

[009] Methods of using the compositions are also described. Such methods involve administering compositions including the disclosed nucleic acid constructs to a subject, for example, for the purpose of eliciting an immune response against multiple clades or strains of HIV. The compositions can be administered alone or in combination with additional immunogenic compositions.

[010] The foregoing and other objects, features, and advantages of the invention will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[011] FIG. 1 is a schematic representation of a multi-clade, multi-valent HIV vaccine composition.

[012] FIG. 2 is a schematic representation of the plasmid VRC 4401.

[013] FIG. 3 is a schematic representation of the plasmid VRC 4409.

[014] FIG. 4 is a schematic representation of the plasmid VRC 4404.

[015] FIG. 5 is a schematic representation of the plasmid VRC 5736.

[016] FIG. 6 is a schematic representation of the plasmid VRC 5737.

[017] FIG. 7 is a schematic representation of the plasmid VRC 5738.

[018] FIG. 8A schematically represents antigenic expression constructs with different transcription regulatory sequences. FIG. 8B is an image of a Western blot showing relative expression of the various constructs.

[019] FIGS. 9A and B are bar graphs illustrating $CD4^+$ and $CD8^+$ T cell responses in mice immunized with expression plasmids with different transcription regulatory sequences.

[020] FIGS. 10A, B and C are bar graphs illustrating relative immune responses against HIV Gag, Pol and Nef antigens in mice immunized with nucleic acid constructs having either a CMV/R transcription control sequence or a CMV IE transcription control sequence.

[021] FIGS. 11A, B and C are bar graphs illustrating relative immune responses against HIV Gag, Pol, Nef and Env antigens in cynomolgous macaques immunized with different vaccine compositions.

[022] FIGS. 12A, B and C are bar graphs illustrate the time course of development of the immune response against HIV antigens following immunization of cynomolgous macaques with different vaccine compositions.

[023] FIG. 13 is a series of bar graphs illustrating the cellular immune response measured by intracellular cytokine staining (ICS) in humans immunized with VRC-HIVDNA016-00-VP.

BRIEF DESCRIPTION OF THE SEQUENCE LISTING

[024] SEQ ID NOs:1-6 represent the VRC-HIVDNA016-00-VP plasmids 4401, 4409, 4404, 5736, 5737, and 5738, respectively. Each of these plasmids is a nucleic acid construct for expressing a single HIV antigenic polypeptide.

[025] SEQ ID NOs:7-15 represent chimeric Env plasmids.

[026] SEQ ID NOs:16-19 represent adenovirus vectors

[027] SEQ ID NOs:20-25 represent exemplary Gag, Pol, Nef, clade A Env, clade B Env and clade C Env polypeptides, respectively.

[028] SEQ ID NO:26 represents the CMV/R transcription regulatory sequence.

DETAILED DESCRIPTION

[029] The present disclosure relates to a nucleic acid constructs suitable for use as a preventive vaccine for HIV-1. Specific examples of compositions disclosed herein provide two significant advances with respect to prior HIV vaccine candidates. Such compositions exhibit increased expression and immunogenicity, and are capable of eliciting an immune response against multiple divergent strains of HIV. The vaccine includes a mixture of different nucleic acid constructs, and is designed to produce Gag, Pol, Nef and Env HIV-1 proteins to elicit broad immune responses against multiple HIV-1 subtypes isolated in human infections. Most typically, the nucleic acids are incorporated into a plasmid vector. An exemplary clinical embodiment of the multi-plasmid vaccine is designated VRC-HIVDNA016-00-VP.

[030] The rationale in development of the exemplary vaccine disclosed herein is to separate the *gag, pol* and *nef* genes into separate nucleic acid constructs, such as, plasmids, rather than having one construct that produces a fusion protein immunogen, as was the case with previously developed HIV vaccines. In exemplary embodiments, the nucleic acid construct has been modified to increase production of immunogenic protein products *in vivo*. The modifications include: 1) a change in the promoter incorporated into these plasmids and/or 2) a 68 amino acid addition to the *gag* gene (for example, in the VRC 4401 (Gag protein only) plasmid). Whereas previous HIV vaccine plasmids have most commonly utilized the cytomegalovirus (CMV) immediate early promoter to regulate transcription of the polynucleotide sequence encoding the antigenic polypeptide, in the nucleic acid constructs disclosed herein, the polynucleotide sequence encoding the immunogenic HIV polypeptides is operably linked to a promoter designated CMV/R. The CMV/R promoter was previously described in published US patent application no. 20040259825, the disclosure of which is incorporated herein in its entirety.

[031] The nucleic acid constructs disclosed herein can incorporate polynucleotide sequences encoding essentially any HIV antigenic polypeptide, so long as antigens corresponding to multiple clades and/or strains are included. The compositions are described in detail with respect to a specific example of the nucleic acid constructs collectively designated the VRC-HIVDNA016-00-VP vaccine composition. This exemplary embodiment is illustrated in FIG. 1.

[032] The vaccine composition VRC-HIVDNA016-00-VP includes six closed circular plasmid DNA macromolecules, VRC 4401, VRC 4409, VRC 4404, VRC 5736, VRC 5737 and VRC 5738, which can, for example, be combined in equal concentrations (mg/mL). VRC 4401 encodes the clade B HIV-1 Gag structural core protein that encapsidates the viral RNA and exhibits highly conserved domains. VRC 4409 encodes for clade B polymerase (Pol), which is also highly conserved, and VRC 4404 encodes for clade B Nef, an accessory protein against which a vigorous T-cell response is mounted in natural infection. The DNA plasmid expressing HIV-1 Pol has been modified to reduce potential toxicity through the incorporation of changes in the regions affecting the protease, reverse transcriptase,

and integrase activities. Two amino acids in the myristoylation site in the HIV-1 *nef* gene were deleted to abrogate MHC class I and CD4+ down-regulation by the Nef protein. No modifications were made to the amino acid sequence of Gag. The other three plasmids express synthetic versions of modified, truncated envelope glycoproteins (gp145) from three strains of HIV-1: VRC 5736 (clade A), VRC 5737 (clade B) and VRC 5738 (clade C). The sequences used to create the DNA plasmids encoding Env are derived from three HIV-1 CCR5-tropic strains of virus. These genes have been modified to improve immunogenicity, which has been demonstrated in mice and monkeys. The vaccine is designed to elicit immune responses to a broad range of HIV-1 strains.

[033] In particular examples, plasmids containing Gag, Pol, Nef and Env complementary DNAs (cDNAs) were used to subclone the relevant inserts into plasmid DNA expression vectors that use the CMV/R promoter and the bovine growth hormone polyadenylation sequence. All the plasmids expressing the HIV-1 genes were made synthetically with sequences designed to disrupt viral RNA structures that limit protein expression by using codons typically found in humans, thereby increasing gene expression. The translational enhancer region of the CMV immediate early region 1 enhancer was substituted with the 5′-untranslated HTLV-1 R-U5 region of the human T-cell leukemia virus type 1 (HTLV-1) long terminal repeat (LTR) to further optimize gene expression.

[034] The DNA plasmids are typically produced in bacterial cell cultures containing a kanamycin selection medium. In all such cases, bacterial cell growth is dependent upon the cellular expression of the kanamycin resistance protein encoded by a portion of the plasmid DNA. Following growth of bacterial cells harboring the plasmid, the plasmid DNA is purified from cellular components. In a particular example, the Gag plasmid (VRC 4401) is 5886 nucleotide pairs in length and has an approximate molecular weight of 3.9 MDa; the Pol plasmid (VRC 4409) is 7344 nucleotide pairs in length and has an approximate molecular weight of 4.8 MDa; the Nef plasmid (VRC 4404) is 5039 nucleotide pairs in length and has an approximate molecular weight of 3.3 MDa; the clade A, B, and C Env plasmids (VRC 5736,

5737, and 5738) are 6305, 6338 and 6298 nucleotides in length, respectively, and have an approximate molecular weight of 4.2 MDa.

[035] Thus, one aspect of the present disclosure relates to compositions capable of eliciting an immune response against HIV. For example, the compositions can be capable of eliciting a protective immune response against HIV when administered alone or in combination with at least one additional immunogenic compositions. It will be understood by those of skill in the art, the ability to produce an immune response after exposure to an antigen is a function of complex cellular and humoral processes, and that different subjects have varying capacity to respond to an immunological stimulus. Accordingly, the compositions disclosed herein are capable of eliciting an immune response in an immunocompetent subject, that is a subject that is physiologically capable of responding to an immunological stimulus by the production of a substantially normal immune response, e.g., including the production of antibodies that specifically interact with the immunological stimulus, and/or the production of functional T cells ($CD4^+$ and/or $CD8^+$ T cells) that bear receptors that specifically interact with the immunological stimulus. It will further be understood, that a particular effect of infection with HIV is to render a previously immunocompetent subject immunodeficient. Thus, with respect to therapeutic methods discussed below, it is generally desirable to administer the compositions to a subject prior to exposure to HIV (that is, prophylactically, e.g., as a vaccine) or therapeutically at a time following exposure to HIV during which the subject is nonetheless capable of developing an immune response to a stimulus, such as an antigenic polypeptide.

[036] The compositions include a plurality of (that is two, three, four, five, six or even more) different nucleic acid constructs. Multiple copies of each of the different nucleic acid constructs are typically present. Each of the different nucleic acid constructs includes a polynucleotide sequence encoding an HIV antigenic polypeptide operably linked to a transcription regulatory sequence capable of directing its expression in the cells of a subject following systemic or localized administration. Included among the nucleic acid constructs are polynucleotide sequences that encode antigenic polypeptides of more than one (multiple) clades or

strains of HIV. Thus, the composition includes multiple nucleic acid constructs, at least two of which incorporate polynucleotide sequences that encode HIV antigenic polypeptides from different clades or strains. Frequently, the composition includes nucleic acid constructs that encode HIV antigenic polypeptides from at least three different clades or strains.

[037] In one embodiment, the composition includes multiple separate nucleic acid constructs, each of which includes a polynucleotide sequence encoding an HIV antigenic polypeptide operably linked to a CMV/R transcription control sequence. In one example, the CMV/R transcription control sequence has the sequence of SEQ ID NO:26. In another embodiment, the composition includes multiple separate nucleic acid constructs, each of which includes a polynucleotide sequence encoding a single HIV antigenic polypeptide. In certain embodiments, the nucleic acid constructs are plasmids.

[038] The compositions typically include a first nucleic acid construct that includes a polynucleotide sequence that encodes an HIV Gag polypeptide, a second nucleic acid construct that includes a polynucleotide sequence that encodes an HIV Pol polypeptide, a third nucleic acid construct comprising a polynucleotide sequence that encodes an HIV Nef polypeptide, and at least one additional nucleic acid construct that includes a polynucleotide sequence that encodes an HIV Env polypeptide. The composition can also include one or more additional nucleic acid constructs that include a polynucleotide sequence that encodes an Env polypeptide of a different HIV clade or strain.

[039] For example, the first nucleic acid construct can include a polynucleotide sequence that encodes a clade B Gag polypeptide, the second nucleic acid construct can include a polynucleotide sequence that encodes a clade B Pol polypeptide, and the third nucleic acid construct can include a polynucleotide sequence that encodes a clade B Nef polypeptide. Alternatively, the first, second and third nucleic acid constructs can include polynucleotide sequences that encode Gag, Pol and Nef polypeptides of a different clade, such as clade A or clade C, etc. For example, the composition can include a nucleic acid construct that include a polynucleotide

sequence that encodes a Gag polypeptide with at least about 95% sequence identity to SEQ ID NO:20; a nucleic acid construct that includes a polynucleotide sequence that encodes a Pol polypeptide with at least about 95% sequence identity to SEQ ID NO:21 and/or a nucleic acid construct that includes a polynucleotide sequence that encodes a Nef polypeptide with at least about 95% sequence identity to SEQ ID NO:22. In one embodiment, the immunogenic composition includes a first nucleic acid construct with a polynucleotide sequence that encodes the Gag polypeptide of SEQ ID NO:20, a second nucleic acid construct with a polynucleotide sequence that encodes the Pol polypeptide of SEQ ID NO:21; and a third nucleic acid construct with a polynucleotide sequence that encodes the Nef polypeptide of SEQ ID NO:22. For example, the composition can include a nucleic acid construct that include a polynucleotide sequence with at least 95% sequence identity to positions 1375-2883 of SEQ ID NO:1; a nucleic acid construct that include a polynucleotide sequence with at least 95% sequence identity to positions 1349-4357 of SEQ ID NO:2 and/or a nucleic acid construct that include a polynucleotide sequence with at least 95% sequence identity to positions 1392-2006 of SEQ ID NO:3, or differing from the reference sequence by the substitution of one or more degenerate condons. In one embodiment, the composition includes the nucleic acid constructs represented by SEQ ID NO:1, SEQ ID NO:2 and SEQ ID NO:3 (plasmids VRC 4401, VRC 4409 and VRC 4404), or constructs having at least 95% sequence identity thereto.

[040] Additionally, the composition can include multiple nucleic acid constructs that encode Env polypeptides from different clades or strains. For example, the composition can include a first additional nucleic acid construct including a polynucleotide sequence that encodes a clade A Env polypeptide, a second additional nucleic acid construct including a polynucleotide sequence that encodes a clade B Env polypeptide, and a third additional nucleic acid construct including a polynucleotide sequence that encodes a clade C Env polypeptide. Generally, clade A, clade B and clade C Env polypeptides will be utilized as clades A, B and C collectively account for the highest proportion of HIV infections worldwide. However, one of skill in the art will recognize that compositions can be produced that include Env polypeptides from any combination of HIV clades or strains. In

certain embodiments, the immunogenic compositions include a first additional nucleic acid construct that includes a polynucleotide sequence that encodes a clade A Env polypeptide with at least 95% sequence identity to SEQ ID NO:23; a second additional nucleic acid construct that includes a polynucleotide sequence that encodes a clade B Env polypeptide with at least 95% sequence identity to SEQ ID NO:24; and/or a third additional nucleic acid construct that includes a polynucleotide sequence that encodes a clade C Env polypeptide with at least 95% sequence identity to SEQ ID NO:25. In one embodiment, the composition includes a first additional nucleic acid construct with a polynucleotide sequence that encodes the clade A Env polypeptide of SEQ ID NO:23; a second additional nucleic acid construct with a polynucleotide sequence that encodes the clade B Env polypeptide of SEQ ID NO:24; and a third additional nucleic acid construct with a polynucleotide sequence that encodes the clade C Env polypeptide of SEQ ID NO:25. For example, the immunogenic composition can include a nucleic acid construct with a polynucleotide sequence that is at least about 95% identical to positions 1392-3272 of SEQ ID NO:4; a nucleic acid construct with a polynucleotide sequence that is at least about 95% identical to positions 1384-3312 of SEQ ID NO:5 and/or a nucleic acid construct with a polynucleotide sequence that is at least about 95% identical to positions 1392-3272 of SEQ ID NO:6. In an embodiment, the immunogenic compositions includes nucleic acid constructs represented by SEQ ID NO:4; SEQ ID NO:5 and SEQ ID NO:6 (plasmids VRC 5736, 5737 and 5738, respectively), or constructs having at least 95% sequence identity thereto, or constructs differing from the reference sequence by the substitution of degenerate codons.

[041] Thus, in certain embodiments, the immunogenic composition includes a first nucleic construct with a polynucleotide sequence encoding a Gag polypeptide, a second nucleic acid construct with polynucleotide sequence encoding a Pol polypeptide, a third nucleic acid construct with a polynucleotide sequence encoding a Nef polypeptide, a fourth nucleic acid construct with a polynucleotide sequence encoding a clade A Env polypeptide, a fifth nucleic acid construct with a polynucleotide sequence encoding a clade B Env polypeptide, and a sixth nucleic

acid construct with a polynucleotide sequence encoding a clade C Env polypeptide. In one such an embodiment, the first nucleic acid construct encodes a polypeptide with at least 95% sequence identity to SEQ ID NO:20, the second nucleic acid construct encodes a polypeptide with at least 95% sequence identity to SEQ ID NO:21; the third nucleic acid construct encodes a polypeptide with at least 95% sequence identity to SEQ ID NO:22; the fourth nucleic acid construct encodes a polypeptide with at least 95% sequence identity to SEQ ID NO:23; the fifth nucleic acid construct encodes a polypeptide with at least 95% sequence identity to SEQ ID NO:24 and the sixth nucleic acid construct encodes a polypeptide with at least 95% sequence identity to SEQ ID NO:25. In an embodiment, the immunogenic composition includes six nucleic acid constructs, of which one or more are at least 95% identical to positions 1375-2883 of SEQ ID NO:1; positions 1349-4357 of SEQ ID NO:2; positions 1392-2006 of SEQ ID NO:3; positions 1392-3272 of SEQ ID NO:4; positions 1384-3312 of SEQ ID NO:5 and positions 1392-3272 of SEQ ID NO:6. For example, the composition can include six nucleic acid constructs with the polynucleotide sequences represented by SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:5 and SEQ ID NO:6 (plasmids VRC 4401, VRC 4409, VRC 4404, VRC 5736, VRC 5737 and VRC 5738, respectively), or constructs having at least 95% sequence identity thereto, or constructs differing from the reference sequences by the substitution of degenerate codons. When combined in an immunogenic composition, the nucleic acid constructs can be combined in a substantially equal ratio by weight (that is an approximately 1:1:1:1:1:1 ratio).

[042] In some cases, the compositions include nucleic acid constructs that each encode an HIV antigenic polypeptide of a single clade or strain. In other cases, it can be useful to include nucleic acid constructs that incorporate polynucleotide sequences that encode a chimeric Env polypeptide. Thus, in certain embodiments, the nucleic acid construct can encode a chimeric Env polypeptide with at least 95% identity to a polypeptide encoded by one of SEQ ID NOs:7-15.

[043] Typically, when formulated for administration to a subject, the compositions also include a pharmaceutically acceptable carrier or excipient, for example, an aqueous carrier, such as phosphate buffered saline (PBS) or another neutral

physiological salt solution. The composition can also include an adjuvant or other immunostimulatory molecule. The composition can be administered one or more times to a subject to elicit an immune response. For example, the composition can be administered multiple times at intervals of at least about 28 days, or at different intervals as dictated by logistical or therapeutic concerns.

[044] Thus, a feature of the disclosure includes pharmaceutical compositions or medicaments for the therapeutic or prophylactic treatment of an HIV infection. The use of the compositions disclosed herein in the production of medicament for the therapeutic or prophylactic treatment of HIV is also expressly contemplated. Any of the limitations or formulations disclosed above with respect to compositions are applicable to their use in or as medicaments for the treatment of an HIV infection.

[045] Another aspect of the disclosure relates to methods for eliciting an immune response against HIV by administering the compositions described above to a human subject. When administered to an immunocompetent subject, the composition is capable of eliciting an immune response against multiple clades or strains of HIV. For example, in one embodiment the method involves administering a composition that includes multiple different nucleic acid constructs, each of which includes a polynucleotide sequence encoding an HIV antigenic polypeptide operably linked to a CMV/R transcription control sequence. In another embodiment, the method involves administering a composition that includes multiple different nucleic acid constructs, each of which includes a polynucleotide sequence encoding a single HIV antigenic polypeptide. In certain embodiments, the administered nucleic acid constructs are plasmids. Indeed, any of the above described compositions are suitable for administration to human subjects in the methods disclosed herein.

[046] One dose or multiple doses of the composition can be administered to a subject to elicit an immune response with desired characteristics, including the production of HIV specific antibodies, or the production of functional T cells that react with HIV. In certain embodiments, the composition is administered intramuscularly, for example, using a needleless delivery device. Alternatively, the

composition is administered by other routes, such as intravenous, transdermal, intranasal, oral (or via another mucosa).

[047] In some embodiments, the methods also involve administering viral vectors that encode HIV antigenic polypeptides, instead of, or in combination with one or more of the nucleic acid constructs already described. In some cases, the viral vectors are adenoviral vectors (for example a replication deficient adenoviral vectors). For example, one or more doses of a "primer" composition, such as those disclosed above, can be administered to a subject, followed by administration of one or more doses of a "booster" composition including multiple adenoviral vectors encoding HIV antigenic polypeptides. In certain embodiments, the adenoviral vectors encode one or more HIV antigenic polypeptide that is identical to an HIV antigenic polypeptide previously administered in the primer composition. Exemplary recombinant adenoviral vectors are represented by SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18 and SEQ ID NO:19. Of course, alternative adenoviral vectors, for example, that encode polypeptides with at least about 95% sequence identity to a polypeptide encoded by one of these sequences, or that share at least about 95% sequence identity to one of these sequences, can also be used.

[048] In another aspect, the disclosure concerns isolated or recombinant nuclei acids that include a polynucleotide sequence that encodes an HIV antigenic polypeptide operably linked to a CMV/R transcription regulatory sequence. For example, such a nucleic acid can be a plasmid or a viral vector. The polynucleotide sequence can encode an HIV Gag polypeptide, an HIV Pol polypeptide, an HIV Nef polypeptide or an HIV Env polypeptide. In some examples, the HIV polypeptide encoded by the nucleic acid construct is the only HIV antigen encoded by the isolated or recombinant nucleic acid. Exemplary polypeptides encoded by these nucleic acids are represented by SEQ ID NOs:20-25, and include sequences that are at least 95% identical to the amino acid sequences of SEQ ID NOs:20-25. For example, such a nucleic acid can include a polynucleotide sequence that is at least 95% identical to: positions 1375-2883 of SEQ ID NO:1; positions 1349-4357 of SEQ ID NO:2; positions 1392-2006 of SEQ ID NO:3; positions 1392-3272 of SEQ ID NO:4; positions 1384-3312 of SEQ ID NO:5 or positions 1392-3272 of SEQ ID

NO:6, any of which can be operably linked to a CMV/R transcription regulatory sequence. For example, the CMV/R transcription control sequence can be a polynucleotide sequence with at least 95% sequence identity to SEQ ID NO:26. Exemplary embodiments of such nucleic acids include the plasmids VRC 4401, VRC 4409, VRC 4404, VRC 5736, VRC 5737 and VRC 5738 represented by SEQ ID NOs:1-6, respectively.

[049] In other embodiments, the nucleic acids include a polynucleotide sequence that encodes a chimeric HIV polypeptide that incorporates at least a subsequence of multiple HIV clades or strains. For example, the chimeric HIV polypeptide can be a chimeric Env polypeptide that includes subsequences of different HIV clades or strains. Examples of such nucleic acids include SEQ ID NOs:7-15, as well as substantially similar polynucleotide sequences, such as those having at least about 95% sequence identity to one of SEQ ID NOs:7-15, or polynucleotide sequences in which one or more degenerate codons have been substituted for each other. Alternatively, the nucleic acids can include a polynucleotide sequence that encodes a chimeric HIV Env polypeptide operably linked to a transcription regulatory sequence other than the CMV/R transcription regulatory region (for example, the CMV immediate early promoter enhance or other promoter and/or enhancer as discussed below). Chimeric Env polypeptides are also a feature of this disclosure.

[050] Additional technical details are provided under the specific topic headings below. In order to facilitate review of the various embodiments of this disclosure, the following explanations of specific terms are provided:

Terms

[051] Unless otherwise explained, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. Definitions of common terms in molecular biology may be found in Benjamin Lewin, *Genes V*, published by Oxford University Press, 1994 (ISBN 0-19-854287-9); Kendrew *et al.* (eds.), *The Encyclopedia of Molecular Biology*, published by Blackwell Science Ltd., 1994 (ISBN 0-632-02182-9); and

Robert A. Meyers (ed.), *Molecular Biology and Biotechnology: a Comprehensive Desk Reference*, published by VCH Publishers, Inc., 1995 (ISBN 1-56081-569-8).

[052] The singular terms "a," "an," and "the" include plural referents unless context clearly indicates otherwise. Similarly, the word "or" is intended to include "and" unless the context clearly indicates otherwise. The term "plurality" refers to two or more. It is further to be understood that all base sizes or amino acid sizes, and all molecular weight or molecular mass values, given for nucleic acids or polypeptides are approximate, and are provided for description. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of this disclosure, suitable methods and materials are described below. The term "comprises" means "includes." The abbreviation, "e.g." is derived from the Latin *exempli gratia*, and is used herein to indicate a non-limiting example. Thus, the abbreviation "e.g." is synonymous with the term "for example."

[053] In order to facilitate review of the various embodiments of this disclosure, the following explanations of specific terms are provided:

[054] **Adjuvant:** A vehicle used to enhance antigenicity; such as a suspension of minerals (alum, aluminum hydroxide, aluminum phosphate) on which antigen is adsorbed; or water-in-oil emulsion in which antigen solution is emulsified in oil (MF-59, Freund's incomplete adjuvant), sometimes with the inclusion of killed mycobacteria (Freund's complete adjuvant) to further enhance antigenicity (inhibits degradation of antigen and/or causes influx of macrophages). Adjuvants also include immunostimulatory molecules, such as cytokines, costimulatory molecules, and for example, immunostimulatory DNA or RNA molecules, such as CpG oligonucleotides.

[055] **Antigen:** A compound, composition, or substance that can stimulate the production of antibodies or a T cell response in an animal, including compositions that are injected, absorbed or otherwise introduced into an animal. The term "antigen" includes all related antigenic epitopes. An "antigenic polypeptide" is a polypeptide to which an immune response, such as a T cell response or an antibody

response, can be stimulated. "Epitope" or "antigenic determinant" refers to a site on an antigen to which B and/or T cells respond. In one embodiment, T cells respond to the epitope when the epitope is presented in conjunction with an MHC molecule. Epitopes can be formed both from contiguous amino acids or noncontiguous amino acids juxtaposed by tertiary folding of an antigenic polypeptide. Epitopes formed from contiguous amino acids are typically retained on exposure to denaturing solvents whereas epitopes formed by tertiary folding are typically lost on treatment with denaturing solvents. An epitope typically includes at least 3, and more usually, at least 5, about 9, or about 8-10 amino acids in a unique spatial conformation. Methods of determining spatial conformation of epitopes include, for example, x-ray crystallography and multi-dimensional nuclear magnetic resonance spectroscopy.

[056] **Antibody:** Immunoglobulin molecules and immunologically active portions of immunoglobulin molecules, that is, molecules that contain an antigen binding site that specifically binds (immunoreacts with) an antigen. A naturally occurring antibody (for example, IgG, IgM, IgD) includes four polypeptide chains, two heavy (H) chains and two light (L) chains interconnected by disulfide bonds. The phrase "antibody response" refers to an immunological response against an antigen involving the secretion of antibodies specific for the antigen. An antibody response is a B cell mediated immune response initiated through the interaction of an antigen (or epitope) with a B cell receptor (membrane bound IgD) on the surface of a B cell. Following binding of the stimulation of the B cell receptor by its cognate antigen, the B cell differentiates into a plasma cell that secretes antigen specific immunoglobulin to produce an antibody response. "Neutralizing antibodies" are antibodies that bind to an epitope on a virus inhibiting infection and/or replication as measured, for example, in a plaque neutralization assay.

[057] **cDNA (complementary DNA):** A piece of DNA lacking internal, non-coding segments (introns) and regulatory sequences that determine transcription. cDNA is typically synthesized in the laboratory by reverse transcription from messenger RNA extracted from cells. In the context of preparing nucleic acid constructs including polynucleotide sequences that encode an HIV antigenic polypeptide, a cDNA can be prepared, for example by reverse transcription or

amplification (e.g., by the polymerase chain reaction, PCR) from an HIV RNA genome (or genome segment).

[058] Host cells: Cells in which a polynucleotide, for example, a polynucleotide vector or a viral vector, can be propagated and its DNA expressed. The cell may be prokaryotic or eukaryotic. The term also includes any progeny of the subject host cell. It is understood that all progeny may not be identical to the parental cell since there may be mutations that occur during replication. However, such progeny are included when the term "host cell" is used. Thus, the nucleic acid constructs described herein can be introduced into host cells where their polynucleotide sequences (including those encoding HIV antigenic polypeptides) can be expressed.

[059] Immune response: A response of a cell of the immune system, such as a B cell, T cell, or monocyte, to a stimulus. In some cases, the response is specific for a particular antigen (that is, an "antigen-specific response"). In some cases, an immune response is a T cell response, such as a CD4+ response or a CD8+ response. Alternatively, the response is a B cell response, and results in the production of specific antibodies. A "protective immune response" is an immune response that inhibits a detrimental function or activity of a pathogen (such as HIV), reduces infection by the pathogen, or decreases symptoms (including death) that result from infection by the pathogen. A protective immune response can be measured, for example, by the inhibition of viral replication or plaque formation in a plaque reduction assay or ELISA-neutralization assay (NELISA), or by measuring resistance to viral challenge *in vivo* in an experimental system.

[060] Immunogenic composition: A composition comprising at least one epitope of a pathogenic organism, that induces a measurable CTL response, or induces a measurable B cell response (for example, production of antibodies that specifically bind the epitope), or both, when administered to an immunocompetent subject. Thus, an immunogenic composition is a composition capable of eliciting an immune response in an immunocompetent subject. For example, an immunogenic composition can include isolated nucleic acid constructs (such as plasmids or viral vectors) that encode one or more immunogenic epitopes of an HIV antigenic

polypeptide that can be used to express the epitope(s) (and thus be used to elicit an immune response against this polypeptide or a related polypeptide expressed by the pathogen). For *in vitro* use, the immunogenic composition can consist of the isolated nucleic acid, protein or peptide. For *in vivo* use, the immunogenic composition will typically include the nucleic acid or virus that expresses the immunogenic epitope in pharmaceutically acceptable carriers or excipients, and/or other agents, for example, adjuvants. An immunogenic polypeptide (such as an HIV antigen), or nucleic acid encoding the polypeptide, can be readily tested for its ability to induce a CTL or antibody response by art-recognized assays.

[061] Pharmaceutically acceptable carriers and/or **pharmaceutically acceptable excipients:** The pharmaceutically acceptable carriers or excipients of use are conventional. *Remington's Pharmaceutical Sciences*, by E. W. Martin, Mack Publishing Co., Easton, PA, 15th Edition (1975), describes compositions and formulations suitable for pharmaceutical delivery of the polypeptides and polynucleotides disclosed herein.

[062] In general, the nature of the carrier will depend on the particular mode of administration being employed. For instance, parenteral formulations usually comprise injectable fluids that include pharmaceutically and physiologically acceptable fluids such as water, physiological saline, balanced salt solutions, aqueous dextrose, glycerol or the like as a vehicle. For solid compositions (for example, powder, pill, tablet, or capsule forms), conventional non-toxic solid carriers can include, for example, pharmaceutical grades of mannitol, lactose, starch or magnesium stearate. In addition to biologically neutral carriers, pharmaceutical compositions to be administered can contain minor amounts of non-toxic auxiliary substances, such as wetting or emulsifying agents, preservatives, and pH buffering agents and the like, for example sodium acetate or sorbitan monolaurate.

[063] A "therapeutically effective amount" is a quantity of a composition used to achieve a desired effect in a subject. For instance, this can be the amount of the composition necessary to inhibit viral (or other pathogen) replication or to prevent or measurably alter outward symptoms of viral (or other pathogenic) infection. When

administered to a subject, a dosage will generally be used that will achieve target tissue concentrations (for example, in lymphocytes) that has been shown to achieve an *in vitro* effect.

[064] Inhibiting or treating a disease: Inhibiting infection by HIV refers to inhibiting the full development of disease caused by exposure to human immunodeficiency virus. For example, inhibiting an HIV infection refers to lessening symptoms resulting from infection by the virus, such as preventing the development of symptoms in a person who is known to have been exposed to the virus, or to reducing virus load or infectivity of a virus in a subject exposed to the virus. "Treatment" refers to a therapeutic or prophylactic intervention that ameliorates or inhibits or otherwise avoids a sign or symptom of a disease or pathological condition related to infection of a subject with a virus.

[065] Subject: Living multi-cellular vertebrate organisms, a category that includes both human and veterinary subjects, including human and non-human mammals. In a clinical setting with respect to HIV, a subject is usually a human subject. An immunocompetent subject is a subject that is able to produce a substantially normal immune response against an antigenic stimulus.

[066] T Cell: A white blood cell critical to the immune response. T cells include, but are not limited to, $CD4^+$ T cells and $CD8^+$ T cells. A $CD4^+$ T lymphocyte is an immune cell that carries a marker on its surface known as CD4, for example, a "helper" T cell. These cells, also known as helper T cells, help orchestrate the immune response, including antibody responses as well as killer T cell responses. $CD8^+$ T cells carry the CD8 marker, and include T cells with cytotoxic or "killer" effector function.

[067] Transduced or Transfected: A transduced cell is a cell into which a nucleic acid molecule has been introduced, for example, by molecular biology techniques. As used herein, the term introduction or transduction encompasses all techniques by which a nucleic acid molecule might be introduced into such a cell, including transformation with plasmid vectors, transfection with viral vectors, and

introduction of naked DNA by electroporation, lipofection, and particle gun acceleration.

[068] Vaccine: A vaccine is a pharmaceutical composition that elicits a prophylactic or therapeutic immune response in a subject. In some cases, the immune response is a protective immune response. Typically, a vaccine elicits an antigen-specific immune response to an antigen of a pathogen. In the context of this disclosure, the vaccines elicit an immune response against HIV. The vaccines described herein include nucleic acid constructs, for example, plasmids or viral vectors, encoding HIV antigens.

[069] Vector: A nucleic acid molecule as introduced into a host cell, thereby producing a transformed host cell. A vector may include nucleic acid sequences that permit it to replicate in a host cell, such as an origin of replication. A vector may also include one or more selectable marker gene and other genetic elements known in the art. The term vector includes plasmids, linear nucleic acid molecules, and viral vectors, such as adenovirus vectors and adenoviruses. The term adenovirus vector is utilized herein to refer to nucleic acids including one or more components of an adenovirus that generate viral particles in host cells. Such particles may be capable of one or more rounds of infection and replication, or can be replication deficient, e.g., due to a mutation. An adenovirus includes nucleic acids that encode at least a portion of the assembled virus. Thus, in many circumstances, the terms can be used interchangeably.

Nucleic Acid Constructs encoding HIV antigens

[070] The present disclosure concerns nucleic acid constructs including polynucleotide sequences that encode antigenic polypeptides of human immunodeficiency virus -1 ("HIV-1" or simply, "HIV"). The term polynucleotide or nucleic acid sequence refers to a polymeric form of nucleotide at least 10 bases in length. The nucleotides can be ribonucleotides, deoxyribonucleotides, or modified forms of either nucleotide. The term includes single- and double-stranded forms of DNA. In the context of this disclosure, the nucleic acid constructs are

"recombinant" nucleic acids. A recombinant nucleic acid is a nucleic acid that has a sequence that is not naturally occurring or has a sequence that is made by an artificial combination of two otherwise separated segments of sequence, for example, a heterologous sequence that is not immediately contiguous with both of the coding sequences with which it is immediately contiguous (one on the 5' end and one on the 3' end) in the naturally occurring genome of the organism from which it is derived. This artificial combination is often accomplished by chemical synthesis or, more commonly, by the artificial manipulation of isolated segments of nucleic acids, e.g., by genetic engineering techniques.

[071] In some cases, the nucleic acids are "isolated" nucleic acids. An "isolated" nucleic acid (and similarly, an isolated protein) has been substantially separated or purified away from other biological components in the cell of the organism in which the nucleic acid naturally occurs, for example, other chromosomal and extra-chromosomal DNA and RNA, proteins and organelles. Nucleic acids and proteins that have been "isolated" include nucleic acids and proteins purified by standard purification methods. The term also embraces nucleic acids and proteins prepared by recombinant expression in a host cell as well as chemically synthesized nucleic acids.

[072] An "HIV antigenic polypeptide" or "HIV antigen" can include any proteinaceous HIV molecule or portion thereof that is capable of provoking an immune response in an immunocompetent mammal. An "HIV molecule" is a molecule that is a part of a human immunodeficiency virus, is encoded by a nucleic acid sequence of a human immunodeficiency virus, or is derived from or synthetically based upon any such molecule. Administration of a nucleic acid that encodes an HIV antigen that provokes an immune response preferably leads to protective immunity against HIV. In this regard, an "immune response" to HIV is an immune response to any one or more HIV antigens.

[073] Examples of suitable HIV antigens include as all or part of the HIV Gag, Pol, Nef or Env proteins. In the virus, Gag proteins are components of the viral capsid. The Pol polyprotein provides reverse transcriptase (RT); integrase (IN) and

protease(PR) functions, which reverse transcribe the viral RNA into double stranded DNA, integrated into the chromosome of a host cell, and cleave the *gag-pol* derived proteins into functional polypeptides, respectively. The Nef polypeptide is a negative regulatory factor involved in determining pathogenicity of the virus following infection. Env proteins are envelope proteins involved in viral attachment and fusion to target cells. One of skill in the art will recognize that functional attributes of the polypeptides can be altered (for example, deleted) without altering antigenic properties of the polypeptides. Immunogenic variants or fragments of each of Gag, Pol, Nef or Env are also HIV antigenic polypeptides that can included in the immunogenic compositions disclosed herein. Immunogenic variants include those, for example, having at least 90%, 95%, or 98% sequence identity to SEQ ID NOs:20-25, or immunogenic fragments thereof. The nucleic acid vaccines disclosed herein can include SEQ ID NOs:1-19 or sequences that encode HIV antigens, such as those represented by SEQ ID NOS:20-25, or HIV antigens that have at least 90%, 95% or 98% sequence identity to SEQ ID NOs:20-25.

[074] Suitable Env proteins are known in the art and include, for example, gp160, gp120, gp41, and gp140. Any clade of HIV is appropriate for antigen selection, including HIV clades A, B, C, and the like. Thus, it will be appreciated that any one, or a combination, of the following HIV antigens can be used in the inventive method: HIV clade A gp140, Gag, Pol, Nef and/or Env; HIV clade B gp140, Gag, Pol, Nef and/or Env proteins; and HIV clade C gp140, Gag, Pol, Nef and/or Env proteins. While the compositions and methods are described in detail with respect to Gag, Pol, Nef and/or Env proteins, any HIV protein or portion thereof capable of inducing an immune response in a mammal can be used in connection with the inventive method. HIV Gag, Pol, Nef and/or Env proteins from HIV clades A, B, C, as well as nucleic acid sequences encoding such proteins and methods for the manipulation and insertion of such nucleic acid sequences into vectors, are known (see, for example, HIV Sequence Compendium, Division of AIDS, National Institute of Allergy and Infectious Diseases, 2003, HIV Sequence Database (on the world wide web at hiv-web.lanl.gov/content/hiv-db/mainpage.html), Sambrook et al., *Molecular Cloning, a Laboratory Manual*, 2d edition, Cold Spring Harbor Press,

Cold Spring Harbor, N.Y., 1989, and Ausubel et al., *Current Protocols in Molecular Biology*, Greene Publishing Associates and John Wiley & Sons, New York, N.Y., 1994).

[075] Gag, Pol, Nef and Env polypeptide sequences are known in the art, and numerous amino acid sequences are available from publicly accessible databases, such as GENBANK®. For example, a Gag polypeptide corresponding to the amino acid sequence of the strain HXB2 is represented by the sequence of GENBANK® accession number K03455. Pol and Nef polypeptides corresponding to the amino acid sequence of the strain NL4-3 is represented by the sequence of GENBANK® accession number M19921. Exemplary Env polypeptides, for example, corresponding to clades A, B and C are represented by the sequences of GENBANK® accession numbers U08794, K03455 and AF286227, respectively. Particular exemplary sequences encoded by the nucleic acid constructs disclosed herein are represented by SEQ ID NOs:20-25, corresponding to Gag, Pol, Nef, clade A Env, clade B Env, and clade C Env, respectively. Certain of these exemplary polypeptides have been modified functionally (as indicated in further detail in the Examples) but nonetheless retain important antigenic characteristics of the naturally occurring proteins.

[076] An entire, intact HIV protein is not required to produce an immune response. Indeed, most antigenic epitopes of HIV proteins are relatively small in size. Thus, fragments (for example, epitopes or other antigenic fragments) of an HIV protein, such as any of the HIV proteins described herein, can be used as an HIV antigen. Antigenic fragments and epitopes of the HIV Gag, Pol, Nef and/or Env proteins, as well as nucleic acid sequences encoding such antigenic fragments and epitopes, are known (see, for example, HIV Immunology and HIV/SIV Vaccine Databases, Vol. 1, Division of AIDS, National Institute of Allergy and Infectious Diseases, 2003).

[077] A nucleic acid construct is said to "encode" an antigen when a polynucleotide sequence incorporated into the construct includes one or more open reading frames that upon recognition and activity by cellular transcriptional and

translational processes gives rise to a sequence of amino acids constituting the antigen.

[078] HIV antigens are "different" if they comprise a different antigenic amino acid sequence. When referring to a plurality of different HIV antigens, the two or more different HIV antigens can be any HIV antigens, such as two or more (or three, or four, or five, or six, or more) of the HIV antigens described herein. Different HIV antigenic polypeptides can be two or more antigenic polypeptides from different HIV proteins, that is proteins encoded by different genes in the HIV genome (for example, an HIV Gag polypeptide is different from an HIV Pol polypeptide, which is different from an HIV Nef polypeptide, which again is different from an HIV Env polypeptide). Thus, Gag, Pol, Nef and Env are different HIV proteins or antigenic polypeptides. Alternatively, different HIV antigenic polypeptides are different if they are encoded by a homologous genomic segment (or gene) from different strains or clades of HIV. Thus, a clade A Env polypeptide is different from a clade B Env polypeptide, which is different from a clade C Env polypeptide, and the like. In the context of immunogenic (for example, vaccine) compositions described herein, the two or more different HIV antigens include HIV antigens from two or more different HIV clades or strains, such as from three or more different HIV clades (such as clades A, B and C) or from two or more variant HIV strains of the same clade. Exposing the immune system of a mammal to a "cocktail" of different HIV antigens can elicit a broader and more effective immune response than exposing the immune system to only a single HIV antigen.

[079] Thus, a plurality of separate nucleic acid constructs each including a polynucleotide sequence encoding a single HIV antigenic polypeptide, wherein the plurality of nucleic acid constructs encode a plurality of antigenic polypeptides or a plurality of HIV clades or strains, can include a plurality of encoded polypeptides of the same clade or strain (for example all clade B) or encoded polypeptides of different clades or strains (for example some of clade A and others of clade B).

[080] In some particularly disclosed embodiments the composition includes a plurality of different nucleic acid constructs. The nucleic acid constructs include a

polynucleotide sequence encoding a single (no more than once) HIV antigen operably linked to a transcription control sequence, and the single HIV antigen is different for the different nucleic acid constructs. In particular examples, the different single HIV antigens of the different nucleic acid constructs, are different encoded polypeptides of the same clade or strain, but may further include different encoded polypeptides, expressed from different constructs, of clades or strains that differ from the encoded polypeptides that share the same clade or strain. For example, the different nucleic acid constructs that encode HIV antigens of the same clade or strain can be three separate constructs that respectively encode Gag, Pol, and Nef as the only HIV antigen expressed from each of the constructs, and each of Gag, Pol, and Nef are of the same clade or strain (for example, all clade B). In addition, in some embodiments the composition can further include separate nucleic acid constructs that encode Env antigens of different clades or strains. For example, at least three separate constructs independently encode clade A Env, clade B Env and clade C Env as their only encoded HIV antigen.

[081] For example, a nucleic acid construct can include a polynucleotide sequence that encodes a single HIV antigenic polypeptide. In specific examples provided herein, the nucleic acid construct encodes a single Gag polypeptide, a single Pol polypeptide, a single Nef polypeptide or a single Env polypeptide. For example, the nucleic acid construct can include a polynucleotide sequence that encodes a single Gag polypeptide, such as a clade B Gag polypeptide (e.g., the amino acid sequence of SEQ ID NO:20); a polynucleotide sequence that encodes a single Pol polypeptide, such as a clade B Pol polypeptide (e.g., SEQ ID NO:21); a polynucleotide sequence that encodes a single Nef polypeptide, such as a clade B Nef polypeptide (e.g., SEQ ID NO:22), or a polynucleotide sequence that encodes a single Env polypeptide, such as a clade A, a clade B or a clade C Env polypeptide (for examples, SEQ ID NO:23, SEQ ID NO:24 and SEQ ID NO:25). Exemplary nucleic acid constructs encoding these polypeptides are represented by SEQ ID NOs:1-6, respectively.

[082] Alternatively, a nucleic acid construct can include a polynucleotide sequence that encodes an HIV antigenic polypeptide that includes subsequences of multiple clades or strains, that is, a "chimeric" HIV polypeptide. A chimeric HIV antigenic

polypeptide can include subsequences of two or more clades or strains, such as three or more different clades or strains. For example, a chimeric HIV Env polypeptide can include one or more subsequence of a clade A Env polypeptide in combination with one or more subsequence of a clade B Env polypeptide and/or one or more subsequence of a clade C Env polypeptide, or in combination with one or more subsequences of a different clade A strain (or strains) of HIV with a different amino acid sequence. Similarly, subsequences of clade B and C Env polypeptides can be combined with subsequences of other clades and/or strains. Nucleic acid constructs including chimeric Env polypeptides are represented by SEQ ID NOs:7-15.

[083] Typically, the nucleic acid constructs encoding the HIV antigenic polypeptides are plasmids. However, other vectors (for example, viral vectors, phage, cosmids, etc.) can be utilized to replicate the nucleic acids. In the context of this disclosure, the nucleic acid constructs typically are expression vectors that contain a promoter sequence which facilitates the efficient transcription of the inserted genetic sequence of the host. The expression vector typically contains an origin of replication, a promoter, as well as specific nucleic acid sequences that allow phenotypic selection of the transformed cells. In exemplary nucleic acid constructs, the coding sequence is operably linked under the transcriptional control of a human cytomegalovirus (CMV) immediate early (IE) enhancer/promoter that has been modified to include a regulatory sequence from the R region of the long terminal repeat (LTR) of human T-cell leukemia virus type 1 (HTLV-1). This transcription regulatory sequence is designated "CMV/R" or "CMV/R promoter." The CMV/R transcription regulatory sequence (alternatively referred to as a "transcription control sequence") contains, in a 5′ to 3′ direction: the CMV IE enhancer/promoter; the HTLV-1 R region; and a 123 base pair (bp) fragment of the CMV IE 3′ intron. The CMV/R transcription regulatory region confers substantially increased expression and improved cellular immune responses to HIV antigens operably linked under its control. An exemplary CMV/R is represented by SEQ ID NO:26. However, transcription control sequences that retain the regulatory properties or have been modified to enhance expression, including transcription

regulatory regions that are at least about 90%, or 95% or 98% identical to SEQ ID NO:26, can also be used.

[084] More generally, polynucleotide sequences encoding HIV antigenic polypeptides can be operably linked to any promoter and/or enhancer that is capable of driving expression of the nucleic acid following introduction into a host cell. A promoter is an array of nucleic acid control sequences that directs transcription of a nucleic acid. A promoter includes necessary nucleic acid sequences (which can be) near the start site of transcription, such as in the case of a polymerase II type promoter (a TATA element). A promoter also can include distal enhancer or repressor elements which can be located as much as several thousand base pairs from the start site of transcription. Both constitutive and inducible promoters are included (see, for example, Bitter *et al.*, *Methods in Enzymology* 153:516-544, 1987). Specific, non-limiting examples of promoters include promoters derived from the genome of mammalian cells (e.g., metallothionein promoter) or from mammalian viruses (e.g., the cytomegalovirus immediate early gene promoter, the retrovirus long terminal repeat; the adenovirus late promoter; the vaccinia virus 7.5K promoter) may be used. Promoters produced by recombinant DNA or synthetic techniques may also be used. A first nucleic acid sequence is operably linked with a second nucleic acid sequence when the first nucleic acid sequence is placed in a functional relationship with the second nucleic acid sequence. For instance, a promoter is operably linked to a coding sequence if the promoter affects the transcription or expression of the coding sequence.

[085] To produce such nucleic acid constructs, polynucleotide sequences encoding HIV antigenic polypeptides are inserted into a suitable expression vector, such as a plasmid expression vector that use the CMV/R promoter and the bovine growth hormone polyadenylation sequence to regulate expression. The CMV/R promoter consists of a translational enhancer region of the CMV immediate early region 1 enhancer (CMV-IE) substituted with the 5'-untranslated HTLV-1 R-U5 region of the human T-cell leukemia virus type 1 (HTLV-1) long terminal repeat (LTR) to optimize gene expression. The HIV-1 polynucleotide sequences are typically modified to optimize expression in human cells. The plasmid expression vectors are

introduced into bacterial cells, such as, *E. coli*, which are grown in culture in kanamycin selection medium. In all cases, bacterial cell growth is dependent upon the cellular expression of the kanamycin resistance protein encoded by a portion of the plasmid DNA. Following growth of bacterial cells harboring the plasmid, the plasmid DNA is purified from cellular components. Procedures for producing polynucleotide sequences encoding HIV antigenic polypeptides and for manipulating them *in vitro* are well known to those of skill in the art, and can be found, e.g., in Sambrook and Ausubel, *supra*.

[086] In addition to the polynucleotide sequences encoding the polypeptides represented by SEQ ID NOs:20-25 disclosed herein, such as SEQ ID NOs:1-6 (as well as nucleic acids encoding chimeric Env polypeptides represented by SEQ ID NOs:7-15 and nucleic acids encoding adenoviral vectors represented by SEQ ID NOs:16-19) as disclosed herein, the nucleic acid constructs can include variant polynucleotide sequences that encode polypeptides that are substantially similar to SEQ ID NOs:20-25 (for example, are substantially similar to SEQ ID NOs:1-6 and/or SEQ ID NOs:16-19). Similarly, the nucleic acid constructs can include polynucleotides that encode chimeric polypeptides that are substantially similar to those encoded by SEQ ID NOs:7-15. The similarity between amino acid (and polynucleotide) sequences is expressed in terms of the similarity between the sequences, otherwise referred to as sequence identity. Sequence identity is frequently measured in terms of percentage identity (or similarity); the higher the percentage, the more similar are the primary structures of the two sequences. In general, the more similar the primary structures of two amino acid sequences, the more similar are the higher order structures resulting from folding and assembly. Variants of an HIV antigenic polypeptide (for example, of a particular clade) can have one or a small number of amino acid deletions, additions or substitutions but will nonetheless share a very high percentage of their amino acid (and generally their polynucleotide sequence). To the extent that variants of a subtype differ from each other, their overall antigenic characteristics are maintained. In contrast, HIV antigens of different clades share less sequence identity and/or differ from each other such that their antigenic characteristics are no longer identical. Thus, the

nucleic acid constructs can include polynucleotides that encode polypeptides that are at least about 90%, or 95%, or 98% identical to one of SEQ ID NOs:20-25 with respect to amino acid sequence, or that have at least about 90%, 95%, or 98% sequence identity to one or more of SEQ ID NOs;1-19 and/or that differ from one of these sequences by the substitution of degenerate codons.

[087] Methods of determining sequence identity are well known in the art. Various programs and alignment algorithms are described in: Smith and Waterman, *Adv. Appl. Math.* 2:482, 1981; Needleman and Wunsch, *J. Mol. Biol.* 48:443, 1970; Higgins and Sharp, *Gene* 73:237, 1988; Higgins and Sharp, *CABIOS* 5:151, 1989; Corpet *et al.*, *Nucleic Acids Research* 16:10881, 1988; and Pearson and Lipman, *Proc. Natl. Acad. Sci. USA* 85:2444, 1988. Altschul *et al.*, *Nature Genet.* 6:119, 1994, presents a detailed consideration of sequence alignment methods and homology calculations. The NCBI Basic Local Alignment Search Tool (BLAST) (Altschul *et al.*, *J. Mol. Biol.* 215:403, 1990) is available from several sources, including the National Center for Biotechnology Information (NCBI, Bethesda, MD) and on the internet, for use in connection with the sequence analysis programs blastp, blastn, blastx, tblastn and tblastx. A description of how to determine sequence identity using this program is available on the NCBI website on the internet.

[088] Another indicia of sequence similarity between two nucleic acids is the ability to hybridize. The more similar are the sequences of the two nucleic acids, the more stringent the conditions at which they will hybridize. The stringency of hybridization conditions are sequence-dependent and are different under different environmental parameters. Thus, hybridization conditions resulting in particular degrees of stringency will vary depending upon the nature of the hybridization method of choice and the composition and length of the hybridizing nucleic acid sequences. Generally, the temperature of hybridization and the ionic strength (especially the Na^+ and/or Mg^{++} concentration) of the hybridization buffer will determine the stringency of hybridization, though wash times also influence stringency. Generally, stringent conditions are selected to be about 5°C to 20°C lower than the thermal melting point (T_m) for the specific sequence at a defined ionic

strength and pH. The T_m is the temperature (under defined ionic strength and pH) at which 50% of the target sequence hybridizes to a perfectly matched probe. Conditions for nucleic acid hybridization and calculation of stringencies can be found, for example, in Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY, 2001; Tijssen, *Hybridization With Nucleic Acid Probes, Part I: Theory and Nucleic Acid Preparation*, Laboratory Techniques in Biochemistry and Molecular Biology, Elsevier Science Ltd., NY, NY, 1993.and Ausubel *et al. Short Protocols in Molecular Biology*, 4th ed., John Wiley & Sons, Inc., 1999.

[089] For purposes of the present disclosure, "stringent conditions" encompass conditions under which hybridization will only occur if there is less than 25% mismatch between the hybridization molecule and the target sequence. "Stringent conditions" may be broken down into particular levels of stringency for more precise definition. Thus, as used herein, "moderate stringency" conditions are those under which molecules with more than 25% sequence mismatch will not hybridize; conditions of "medium stringency" are those under which molecules with more than 15% mismatch will not hybridize, and conditions of "high stringency" are those under which sequences with more than 10% mismatch will not hybridize. Conditions of "very high stringency" are those under which sequences with more than 6% mismatch will not hybridize. In contrast nucleic acids that hybridize under "low stringency conditions include those with much less sequence identity, or with sequence identity over only short subsequences of the nucleic acid. For example, a nucleic acid construct can include a polynucleotide sequence that hybridizes under high stringency or very high stringency, or even higher stringency conditions to a polynucleotide sequence that encodes any one of SEQ ID NOs:20-25. Similarly, the nucleic acid constructs can hybridize under such conditions to any one of SEQ ID NOs:1-19.

[090] Thus, in addition to polynucleotides encoding the particular amino acid sequences represented by SEQ ID NOs:20-25, for example those polynucleotides represented by the codon optimized constructs of SEQ ID NO:s1-19, the nucleic acid constructs used in the vaccine compositions can include polynucleotide

sequences having a high percentage of sequence identity, for example, that hybridize under high stringency, or very high stringency (or even higher stringency) to one of these sequences. A codon composition at one or more positions that is found in a naturally occurring or mutant strain of HIV are also encompassed within the nucleic acid constructs disclosed herein. One of skill in the art can easily identify numerous HIV polynucleotide sequences, and determine which nucleotides can be varied without substantially altering the amino acid content of the encoded polypeptide. In addition, polynucleotide sequences that encode variants with a small number of amino acid additions, deletions or substitution are also encompassed within the nucleic acid constructs described herein. Typically, any amino acid additions, deletions and/or substitutions are located in positions that do not alter the antigenic epitopes and that do not interfere with folding, or other translational or post-translational processing. Most commonly, any amino acid substitutions are conservative amino acid substitutions. For example, a variant polynucleotide sequence can encode an HIV antigenic polypeptide with one or two or three or four or five, or more amino acid additions, deletions or substitutions.

[091] Conservative variants of particular amino acids are well known in the art, and can be selected, for example from groupings set forth in Table 1.

Table 1: Conservative amino acid substitutions

Original Residue	Conservative Substitutions
Ala	Ser
Arg	Lys
Asn	Gln, His
Asp	Glu
Cys	Ser
Gln	Asn
Glu	Asp
His	Asn; Gln
Ile	Leu, Val
Leu	Ile; Val
Lys	Arg; Gln; Glu
Met	Leu; Ile
Phe	Met; Leu; Tyr
Ser	Thr
Thr	Ser
Trp	Tyr
Tyr	Trp; Phe
Val	Ile; Leu

IMMUNOGENIC COMPOSITIONS

[092] Used in combination, the nucleic acid constructs, such as those exemplified by SEQ ID NOs:1-6, can be used to provide immunogenic compositions that elicit a broad spectrum immune response against HIV. This specific combination of nucleic acid constructs is referred to herein as VRC-HIVDNA016-00-VP, and includes the plasmidsVRC-4401, VRC-4409, VRC-4404, VRC-5736, VRC 5737, and VRC-5738, corresponding respectively to SEQ ID NOs:1-6).

[093] The composition including two or more nucleic acid construct encoding different HIV antigens is typically provided by a composition including multiple nucleic acid constructs, each of which encodes a single HIV antigen. Collectively, the two or more nucleic acid constructs encode antigens from more than one clade or strain, for example, from two or more clades or strains, or from three or more clades or strains. In some cases, the composition includes polynucleotide sequences that encode a chimeric HIV antigen, with subsequences of more than one clade or strain.

[094] For clinical purposes, all nucleic acid constructs, such as plasmids and host *E. coli* strains used in the production of the vaccine are characterized in accordance with the relevant sections of the "Points to Consider in the Production and Testing of New Drugs and Biologicals Produced by Recombinant DNA Technology" (1985), the "Supplement: Nucleic Acid Characterization and Genetic Stability" (1992), and "Points to Consider in Human Somatic Cell Therapy and Gene Therapy" (1991, 1998), "Points to Consider on Plasmid DNA Vaccines for Preventive Infectious Disease Indications" (1996). In addition for clinical testing and use, all compositions are produced in compliance with current Good Manufacturing Practices (cGMP).

[095] Thus, in one embodiment, the immunogenic composition is VRC-HIVDNA016-00-VP, a six-component multiclade plasmid DNA vaccine, expressing Gag, Pol and Nef proteins from clade B HIV-1 and Env glycoproteins from clades A, B and C. This composition is suitable for the prophylactic treatment of HIV, that is, as a preventive HIV-1 vaccine. The vaccine has been designed to elicit immune responses against several proteins from a variety of HIV-1 strains. This vaccine differs from previous multiclade vaccine compositions in two significant ways. First, previous compositions have relied on a single plasmid encoding a Gag-Pol-Nef fusion protein. In the particular examples described herein, these three proteins are separated into three different plasmids, encoding Gag (VRC 4401), Pol (VRC 4409), and Nef (VRC 4404) individually. Additionally, there is a 68 amino acid addition in the *gag* gene as compared to the previous fusion protein composition. Second, the promoter is modified to include the 5'-untranslated HTLV-1 R-U5 region of the human T-cell leukemia virus type 1 (HTLV-1) long terminal repeat (LTR) rather than a portion of the translational enhancer region of the CMV immediate early region 1 enhancer used in previous constructs. Vaccination, for example, of non-human primates, with plasmids containing CMV/R transcription regulatory region elicited higher and more consistent HIV-1 specific cellular immune responses than vaccination with plasmids constructed with the unmodified CVM IE promoter/enhancer sequence.

[096] VRC-HIVDNA016-00-VPis designed to elicit immune responses against several proteins from a variety of HIV-1 strains. This vaccine product has evolved from the initial HIV-1 DNA plasmid product (VRC-4302; BB-IND 9782) that encoded for an HIV-1 clade B Gag-Pol fusion protein. Preclinical studies demonstrated expression of immunogenic protein in small animals, and an ongoing Phase I clinical trial has revealed no safety concerns at the doses tested to date. The VRC-HIVDNA009-00-VP vaccine (BB-IND 10681) expanded upon the product concept to include proteins from multiple subtypes (clades) of HIV-1 and increased the number of vaccine components to include a highly immunogenic regulatory protein (Nef), as well as modified Envelope glycoproteins that have been able to generate immune responses in rhesus macaques.

[097] The four plasmid product, VRC-HIVDNA009-00-VP, was chosen to advance to clinical testing based upon preclinical immunogenicity studies conducted in rhesus macaques and mice, as well as preclinical safety studies of a vaccine product (VRC-HIVDNA006-00-VP) consisting of the same four plasmids and two additional Gag-Pol-Nef expressing plasmids. Based on biological safety testing of these plasmid products, and the high degree of homology between the candidate vaccines VRC-HIVDNA009-00-VP (BB-IND 10681) and VRC-HIVDNA016-00-VP, it was determined that the six plasmid vaccine was safe for human clinical trials.

THERAPEUTIC METHODS

[098] The nucleic acid constructs encoding HIV antigenic polypeptides described herein are used, for example, in combination, as pharmaceutical compositions (medicaments) for use in therapeutic, for example, prophylactic regimens (e.g., vaccines) and administered to subjects (e.g., human subjects) to elicit an immune response against one or more clade or strain of HIV. For example, the compositions described herein can be administered to a human (or non-human) subject prior to infection with HIV to inhibit infection by or replication of the virus. Thus, the pharmaceutical compositions described above can be administered to a subject to elicit a protective immune response against HIV. To elicit an immune response, a

therapeutically effective (e.g., immunologically effective) amount of the nucleic acid constructs are administered to a subject, such as a human (or non-human) subject.

[099] A "therapeutically effective amount" is a quantity of a chemical composition (such as a nucleic acid construct or vector) used to achieve a desired effect in a subject being treated. For instance, this can be the amount necessary to express an adequate amount of antigen to elicit an antibody or T cell response, or to inhibit or prevent infection by or replication of the virus, or to prevent, lessen or ameliorate symptoms caused by infection with the virus. When administered to a subject, a dosage will generally be used that will achieve target tissue or systemic concentrations that are empirically determined to achieve an *in vitro* effect. Such dosages can be determined without undue experimentation by those of ordinary skill in the art. Exemplary dosages are described in detail in the Examples.

[0100] A pharmaceutical composition including an HIV encoding nucleic acid construct can be administered by any means known to one of skill in the art (see Banga, A., "Parenteral Controlled Delivery of Therapeutic Peptides and Proteins," in *Therapeutic Peptides and Proteins*, Technomic Publishing Co., Inc., Lancaster, PA, 1995; *DNA Vaccines: Methods and Protocols* (Methods in Molecular Medicine) by Douglas B. Lowrie and Robert G. Whalen (Eds.), Humana Press, 2000) such as by intramuscular, subcutaneous, or intravenous injection, but even oral, nasal, or anal administration is contemplated. In one embodiment, administration is by subcutaneous or intramuscular injection. Actual methods for preparing administrable compositions will be known or apparent to those skilled in the art and are described in more detail in such publications as *Remingtons Phamaceutical Sciences*, 19th Ed., Mack Publishing Company, Easton, Pennsylvania, 1995.

[0101] Suitable formulations for the nucleic acid constructs, for example, the primer or booster compositions disclosed herein, include aqueous and non-aqueous solutions, isotonic sterile solutions, which can contain anti-oxidants, buffers, and bacteriostats, and aqueous and non-aqueous sterile suspensions that can include suspending agents, solubilizers, thickening agents, stabilizers, and preservatives. The formulations can be presented in unit-dose or multi-dose sealed containers, such

as ampules and vials, and can be stored in a freeze-dried (lyophilized) condition requiring only the addition of the sterile liquid carrier, for example, water, immediately prior to use. Extemporaneous solutions and suspensions can be prepared from sterile powders, granules, and tablets. Preferably, the carrier is a buffered saline solution. More preferably, the composition for use in the inventive method is formulated to protect the nucleic acid constructs from damage prior to administration. For example, the composition can be formulated to reduce loss of the adenoviral vectors on devices used to prepare, store, or administer the expression vector, such as glassware, syringes, or needles. The compositions can be formulated to decrease the light sensitivity and/or temperature sensitivity of the components. To this end, the composition preferably comprises a pharmaceutically acceptable liquid carrier, such as, for example, those described above, and a stabilizing agent selected from the group consisting of polysorbate 80, L-arginine, polyvinylpyrrolidone, trehalose, and combinations thereof. Use of such an adenoviral vector composition will extend the shelf life of the vector, facilitate administration, and increase the efficiency of the inventive method. Formulations for adenoviral vector-containing compositions are further described in, for example, U.S. Patent 6,225,289, 6,514,943, U.S. Patent Application Publication No. 2003/0153065 A1, and International Patent Application Publication WO 00/34444. An adenoviral vector composition also can be formulated to enhance transduction efficiency. In addition, one of ordinary skill in the art will appreciate that the composition can comprise other therapeutic or biologically-active agents. For example, factors that control inflammation, such as ibuprofen or steroids, can be part of the adenoviral vector composition to reduce swelling and inflammation associated with *in vivo* administration of the adenoviral vectors. As discussed herein, immune system stimulators can be administered to enhance any immune response to the antigens. Antibiotics, i.e., microbicides and fungicides, can be present to treat existing infection and/or reduce the risk of future infection, such as infection associated with gene transfer procedures.

[0102] The compositions can be administered for therapeutic treatments. In therapeutic applications, a therapeutically effective amount of the composition is

administered to a subject prior to or following exposure to or infection by HIV. When administered prior to exposure, the therapeutic application can be referred to as a prophylactic administration (e.g., a vaccine). Single or multiple administrations of the compositions are administered depending on the dosage and frequency as required and tolerated by the subject. In one embodiment, the dosage is administered once as a bolus, but in another embodiment can be applied periodically until a therapeutic result, such as a protective immune response, is achieved. Generally, the dose is sufficient to treat or ameliorate symptoms or signs of disease without producing unacceptable toxicity to the subject. Systemic or local administration can be utilized.

[0103] Controlled release parenteral formulations can be made as implants, oily injections, or as particulate systems. Particulate systems include microspheres, microparticles, microcapsules, nanocapsules, nanospheres, and nanoparticles. Particles, microspheres, and microcapsules smaller than about 1 μm are generally referred to as nanoparticles, nanospheres, and nanocapsules, respectively. Capillaries have a diameter of approximately 5 μm so that only nanoparticles are administered intravenously. Microparticles are typically around 100 μm in diameter and are administered subcutaneously or intramuscularly (*see*, Kreuter, *Colloidal Drug Delivery Systems*, J. Kreuter, ed., Marcel Dekker, Inc., New York, NY, pp. 219-342, 1994; Tice & Tabibi, *Treatise on Controlled Drug Delivery*, A. Kydonieus, ed., Marcel Dekker, Inc. New York, NY, pp. 315-339, 1992).

[0104] In certain embodiments, the pharmaceutical composition includes an adjuvant. An adjuvant can be a suspension of minerals, such as alum, aluminum hydroxide, aluminum phosphate, on which antigen is adsorbed; or water-in-oil emulsion in which antigen solution is emulsified in oil (MF-59, Freund's incomplete adjuvant), sometimes with the inclusion of killed mycobacteria (Freund's complete adjuvant) to further enhance antigenicity (inhibits degradation of antigen and/or causes influx of macrophages). In the context of nucleic acid vaccines, naturally occurring or synthetic immunostimulatory compositions that bind to and stimulate receptors involved in innate immunity can be administered along with nucleic acid

constructs encoding the HIV antigenic polypeptides. For example, agents that stimulate certain Toll-like receptors (such as TLR7, TLR8 and TLR9) can be administered in combination with the nucleic acid constructs encoding HIV antigenic polypeptides. In some embodiments, the nucleic acid construct is administered in combination with immunostimulatory CpG oligonucleotides.

[0105] Nucleic acid constructs encoding HIV antigenic polypeptides can be introduced *in vivo* as naked DNA plasmids. DNA vectors can be introduced into the desired host cells by methods known in the art, including but not limited to transfection, electroporation (e.g., transcutaneous electroporation), microinjection, transduction, cell fusion, DEAE dextran, calcium phosphate precipitation, use of a gene gun, or use of a DNA vector transporter (*See* e.g., Wu et al. *J. Biol. Chem.*, 267:963-967, 1992; Wu and Wu *J. Biol. Chem.*, 263:14621-14624, 1988; and Williams et al. *Proc. Natl. Acad. Sci. USA* 88:2726-2730, 1991). As described in detail in the Examples, a needleless delivery device, such as a BIOJECTOR® needleless injection device can be utilized to introduce the therapeutic nucleic acid constructs *in vivo*. Receptor-mediated DNA delivery approaches can also be used (Curiel et al. *Hum. Gene Ther.*, 3:147-154, 1992; and Wu and Wu, J. *Biol. Chem.*, 262:4429-4432, 1987). Methods for formulating and administering naked DNA to mammalian muscle tissue are disclosed in U.S. Pat. Nos. 5,580,859 and 5,589,466, both of which are herein incorporated by reference. Other molecules are also useful for facilitating transfection of a nucleic acid *in vivo*, such as a cationic oligopeptide (e.g., WO95/21931), peptides derived from DNA binding proteins (e.g., WO96/25508), or a cationic polymer (e.g., WO95/21931).

[0106] Alternatively, electroporation can be utilized conveniently to introduce nucleic acid constructs encoding HIV antigens into cells. Electroporation is well known by those of ordinary skill in the art (see, for example: Lohr et al. *Cancer Res.* 61:3281-3284, 2001; Nakano et al. *Hum Gene Ther.* 12:1289-1297, 2001; Kim et al. *Gene Ther.* 10:1216-1224, 2003; Dean et al. *Gene Ther.* 10:1608-1615, 2003; and Young et al. *Gene Ther* 10:1465-1470, 2003). For example, in electroporation, a high concentration of vector DNA is added to a suspension of host cell (such as isolated autologous peripheral blood or bone marrow cells) and the mixture shocked

with an electrical field. Transcutaneous electroporation can be utilized in animals and humans to introduce heterologous nucleic acids into cells of solid tissues (such as muscle) *in vivo*. Typically, the nucleic acid constructs are introduced into tissues in vivo by introducing a solution containing the DNA into a target tissue, for example, using a needle or trochar in conjunction with electrodes for delivering one or more electrical pulses. For example, a series of electrical pulses can be utilized to optimize transfection, for example, between 3 and ten pulses of 100V and 50 msec. In some cases, multiple sessions or administrations are performed.

[0107] Another well known method that can be used to introduce nucleic acid constructs encoding HIV antigens into host cells is particle bombardment (also know as biolistic transformation). Biolistic transformation is commonly accomplished in one of several ways. One common method involves propelling inert or biologically active particles at cells. This technique is disclosed in, e.g., U.S. Pat. Nos. 4,945,050, 5,036,006; and 5,100,792, all to Sanford et al., which are hereby incorporated by reference. Generally, this procedure involves propelling inert or biologically active particles at the cells under conditions effective to penetrate the outer surface of the cell and to be incorporated within the interior thereof. When inert particles are utilized, the plasmid can be introduced into the cell by coating the particles with the plasmid containing the exogenous DNA. Alternatively, the target cell can be surrounded by the plasmid so that the plasmid is carried into the cell by the wake of the particle.

[0108] Alternatively, the vector can be introduced in vivo by lipofection. For the past decade, there has been increasing use of liposomes for encapsulation and transfection of nucleic acids in vitro. Synthetic cationic lipids designed to limit the difficulties and dangers encountered with liposome mediated transfection can be used to prepare liposomes for in vivo transfection of a gene encoding a marker (Felgner et. al. *Proc. Natl. Acad. Sci. USA* 84:7413-7417, 1987; Mackey, et al. *Proc. Natl. Acad. Sci. USA* 85:8027-8031, 1988; Ulmer et al. *Science* 259:1745-1748, 1993). The use of cationic lipids can promote encapsulation of negatively charged nucleic acids, and also promote fusion with negatively charged cell membranes (Felgner and Ringold *Science* 337:387-388, 1989). Particularly useful lipid

compounds and compositions for transfer of nucleic acids are described in WO95/18863 and WO96/17823, and in U.S. Pat. No. 5,459,127, herein incorporated by reference.

[0109] In other embodiments, the nucleic acid constructs are viral vectors. Methods for constructing and using viral vectors are known in the art (*See* e.g., Miller and Rosman, *BioTech.*, 7:980-990, 1992). Preferably, the viral vectors are replication defective, that is, they are unable to replicate autonomously in the target cell. In general, the genome of the replication defective viral vectors that are used within the scope of the present disclosure lack at least one region that is necessary for the replication of the virus in the infected cell. These regions can either be eliminated (in whole or in part), or be rendered non-functional by any technique known to a person skilled in the art. These techniques include the total removal, substitution (by other sequences, in particular by the inserted nucleic acid), partial deletion or addition of one or more bases to an essential (for replication) region. Such techniques can be performed in vitro (for example, on the isolated DNA).

[0110] In some cases, the replication defective virus retains the sequences of its genome that are necessary for encapsidating the viral particles. DNA viral vectors commonly include attenuated or defective DNA viruses, including, but not limited to, herpes simplex virus (HSV), papillomavirus, Epstein Barr virus (EBV), adenovirus, adeno-associated virus (AAV), Moloney leukemia virus (MLV) and human immunodeficiency virus (HIV) and the like. Defective viruses, that entirely or almost entirely lack viral genes, are preferred, as defective virus is not infective after introduction into a cell. Use of defective viral vectors allows for administration to cells in a specific, localized area, without concern that the vector can infect other cells. Thus, a specific tissue can be specifically targeted. Examples of particular vectors include, but are not limited to, a defective herpes virus 1 (HSV1) vector (Kaplitt et al. *Mol. Cell. Neurosci.*, 2:320-330, 1991), defective herpes virus vector lacking a glycoprotein L gene (*See* for example, Patent Publication RD 371005 A), or other defective herpes virus vectors (*See* e.g., WO 94/21807; and WO 92/05263); an attenuated adenovirus vector, such as the vector described by Stratford-Perricaudet et al. (*J. Clin. Invest.*, 90:626-630 1992; La Salle et al., *Science* 259:988-

990, 1993); and a defective adeno-associated virus vector (Samulski et al., *J. Virol.*, 61:3096-3101, 1987; Samulski et al., *J. Virol.*, 63:3822-3828, 1989; and Lebkowski et al., *Mol. Cell. Biol.*, 8:3988-3996, 1988).

[0111] In one embodiment, the vector is an adenovirus vector. Adenoviruses are eukaryotic DNA viruses that can be modified to efficiently deliver a nucleic acid of the disclosure to a variety of cell types. Various serotypes of adenovirus exist. Of these serotypes, preference is given, within the scope of the present disclosure, to type 2 or type 5 human adenoviruses (Ad 2 or Ad 5), or adenoviruses of animal origin (*See* e.g., WO94/26914). Those adenoviruses of animal origin that can be used within the scope of the present disclosure include adenoviruses of canine, bovine, murine (e.g., Mav1, Beard et al. *Virol.*, 75-81, 1990), ovine, porcine, avian, and simian (e.g., SAV) origin. In some embodiments, the adenovirus of animal origin is a canine adenovirus, such as a CAV2 adenovirus (e.g. Manhattan or A26/61 strain (ATCC VR-800)).

[0112] The replication defective adenoviral vectors described herein include the ITRs, an encapsidation sequence and the polynucleotide sequence of interest. In some embodiments, at least the E1 region of the adenoviral vector is non-functional. The deletion in the E1 region preferably extends from nucleotides 455 to 3329 in the sequence of the Ad5 adenovirus (*Pvu*II-*Bgl*II fragment) or 382 to 3446 (*Hinf*II-*Sau*3A fragment). Other regions can also be modified, in particular the E3 region (e.g., WO95/02697), the E2 region (e.g., WO94/28938), the E4 region (e.g., WO94/28152, WO94/12649 and WO95/02697), or in any of the late genes L1-L5.

[0113] In other embodiments, the adenoviral vector has a deletion in the E1 region (Ad 1.0). Examples of E1-deleted adenoviruses are disclosed in EP 185,573, the contents of which are incorporated herein by reference. In another embodiment, the adenoviral vector has a deletion in the E1 and E4 regions (Ad 3.0). Examples of E1/E4-deleted adenoviruses are disclosed in WO95/02697 and WO96/22378.

[0114] The replication defective recombinant adenoviruses according to this disclosure can be prepared by any technique known to the person skilled in the art

(*See* e.g., Levrero et al. *Gene* 101:195, 1991; EP 185 573; and Graham *EMBO J.*, 3:2917, 1984). In particular, they can be prepared by homologous recombination between an adenovirus and a plasmid, which includes, *inter alia*, the DNA sequence of interest. The homologous recombination is accomplished following co-transfection of the adenovirus and plasmid into an appropriate cell line. The cell line that is employed should preferably (i) be transformable by the elements to be used, and (ii) contain the sequences that are able to complement the part of the genome of the replication defective adenovirus, preferably in integrated form in order to avoid the risks of recombination. Examples of cell lines that can be used are the human embryonic kidney cell line 293 (Graham et al. *J. Gen. Virol.* 36:59, 1977), which contains the left-hand portion of the genome of an Ad5 adenovirus (12%) integrated into its genome, and cell lines that are able to complement the E1 and E4 functions, as described in applications WO94/26914 and WO95/02697. Recombinant adenoviruses are recovered and purified using standard molecular biological techniques that are well known to one of ordinary skill in the art. Nucleic acids encoding HIV antigens can also be introduced using other viral vectors, such as retroviral vectors, for example, lentivirus vectors or adenovirus-associated viral (AAV) vectors.

[0115] As described in detail in the Examples, in one embodiment, a pharmaceutical composition including nucleic acid constructs encoding HIV antigens that correspond to antigenic polypeptides of multiple clades or strains of HIV are introduced into a subject prior to exposure to HIV to elicit a protective immune response. Typically, the nucleic acid constructs are plasmids. For example, several plasmids including polynucleotide sequences that encode different HIV antigens can be included in a pharmaceutical composition. For example, a set of plasmids that encodes antigenic polypeptides of different HIV clades or strains can be included in the composition to elicit immunity that protects against infection by HIV of multiple clades or strains. In an exemplary embodiment, the composition includes six plasmids. Each of the plasmids includes a polynucleotide sequence encoding a different HIV antigen operably linked to a transcription regulatory sequence that promotes expression of the antigenic polypeptide *in vivo*. For example, the

composition can include different plasmids that encode a Gag polypeptide, a Pol polypeptide, a Nef polypeptide, and optionally, Env polypeptides of different clades or strains (for example, a clade A Env polypeptide, a clade B Env polypeptide and/or a clade C polypeptide. In one specific embodiment, the vaccine composition includes the six plasmids (VRC 4409, VRC 4401, VRC-4404, VRC 5736, VRC 5737 and VRC 5738 represented by SEQ ID NOs:1-6, respectively. This particular embodiment is designated VRC-HIVDNA016-00-VP, and is described in further detail in the Examples.

[0116] Typically, the multi-plasmid composition includes the six plasmids in substantially equal ratio (e.g., approximately 1:1:1:1:1:1). The pharmaceutical composition can be administered to a subject in a single or multiple doses. The dose range can be varied according to the physical, metabolic and immunological characteristics of the subject, however, a dose of at least about 1 mg and no more than about 12 mg is typically administered. For example, a single dose can be at least about 2 mg, or at least about 3 mg, or at least about 4 mg of combined DNA. Typically, a single dose does not exceed about 6 mg, or about 8 mg or about 10 mg of combined DNA. As described in the Examples, a dose of about 4 mg combined plasmid weight is typically effective to elicit a protective immune response in an immunocompetent adult.

[0117] A single dose, or multiple doses separated by a time interval can be administered to elicit an immune response against HIV. For example, two doses, or three doses, or four doses, or five doses, or six doses or more can be administered to a subject over a period of several weeks, several months or even several years, to optimize the immune response.

[0118] In some cases the pharmaceutical composition including the nucleic acid constructs, for example the multi-plasmid vaccine VRC-HIVDNA016-00-VP is included in combination modality regimens using it as a DNA vaccine prime followed by an adenoviral vector boost. Prime-boost regimens have shown promise in non-human primate models of HIV infection. Such regimens have the potential for raising high levels of immune responses. For example, a "primer" composition

including one or more nucleic acid constructs that encode at least one HIV antigen that is the same as an HIV antigen encoded by an adenoviral vector of an adenoviral vector composition can be administered to a subject. For example, the primer composition can be administered at least about one week before the administration of the "booster" composition including one or more adenoviral vectors.. The one or more nucleic acid sequences of the primer composition (such as VRC-HIVDNA016-00-VP) can be administered as part of a gene transfer vector or as naked DNA. Any gene transfer vector can be employed in the primer composition, including, but not limited to, a plasmid, a retrovirus, an adeno-associated virus, a vaccine virus, a herpesvirus, or an adenovirus. In an exemplary embodiment, the transfer vector is a plasmid.

[0119] Thus, the multi-plasmid composition described above can be used to prime an immune response against HIV, in combination with administration of a composition including one or more adenovirus vectors encoding HIV antigens. For example, the adenoviral vector composition can include (i) a single adenoviral vector that encodes two or more HIV antigens, for example, as a polyprotein or fusion protein, such as a fusion protein encoding a Gag-Pol-Nef polypepetide. Alternatively, the adenoviral vector composition can include (ii) multiple adenoviral vectors each of which encodes a single HIV antigen, such as, two or more, such as three, or four, or more, adenovirus vectors that each encode one HIV antigen, such as an Env polypeptide. Consistent with configuration (i), it is within the scope of the invention to use an adenoviral vector comprising a nucleic acid sequence that encodes more than two different HIV antigens (e.g., three or more, four or more, or even five or more different HIV antigens) or encodes multiple copies of the same antigen, provided that it encodes at least two or more different HIV antigens. Likewise, consistent with configuration (ii), it is within the scope of the invention to use an adenoviral vector comprising several nucleic acid sequences (e.g., three or more, four or more, or even five or more different nucleic acid sequences) each encoding different HIV antigens or multiple copies of the same antigen, provided that the adenoviral vector encodes at least two different HIV antigens. Whether by configuration (i) or (ii), the adenoviral vector composition preferably comprises one

or more adenoviral vectors encoding three or more, or even four or more, different HIV antigens (e.g., wherein each vector comprises a nucleic acid sequence that encodes three or more, or four or more different HIV antigens, or wherein each vector comprises three or more, or four or more nucleic acid sequences, and each nucleic acid sequence encodes a different HIV antigen). In certain embodiments, the two or more, three or more, or four or more different HIV antigens are from two or more, three or more, or four or more different HIV clades. There is no upper limit to the number of adenoviral vectors used or the number of different HIV antigens encoded thereby.

[0120] Of course, a combination of the above configurations of adenoviral vectors can be used in a single composition. For example, the adenoviral vector composition used in accordance with the invention can comprise a first adenoviral vector encoding a single HIV antigen and a second adenoviral vector encoding two or more HIV antigens that are different from the HIV antigen encoded by the first adenoviral vector. Other similar combinations and permutations of the adenoviral vector configurations disclosed herein can be readily determined by one of skill in the art.

[0121] In certain embodiments, the booster composition includes multiple adenoviral vectors. For example, the booster can include multiple adenoviral vectors each of which encodes an HIV Env polypeptide, such as Env polypeptide of different clades or strains. In addition, the booster composition can include an adenoviral vector that encodes Gag, Pol and/or Nef polypeptides. In one specific embodiment, designated VRC-HIVDNA014-00VP, the booster composition includes four adenoviral vectors, three of which encode Env polypeptides of different clades (that is, clade A, clade B and clade C), and an adenoviral vector that encodes Gag and Pol antigens (of clade B). Of course, numerous variants can easily be designed by one of skill in the art, incorporating fewer or more adenoviral vectors, and/or encoding antigens of the same or different HIV clades or strains.

[0122] While the HIV antigen encoded by the one or more nucleic acid sequences of the boost composition often is the same as an HIV antigen encoded by the nucleic

acid constructs of the primer composition, in some embodiments it may be appropriate to use a primer composition comprising one or more nucleic acid sequences encoding an HIV antigen that is different from the antigen(s) encoded by the adenoviral vector composition. For example, Gag and/or Pol and/or Nef antigens of a different clade or strain, or Env antigens of a different clade or strain.

[0123] The primer composition is administered to the mammal to prime the immune response to HIV. More than one dose of primer composition can be provided in any suitable timeframe (e.g., at least about 1 week, 2 weeks, 4 weeks, 8 weeks, 12 weeks, 16 weeks, or more prior to boosting). Preferably, the primer composition is administered to the mammal at least three months (e.g., three, six, nine, twelve, or more months) before administration of the booster composition. Most preferably, the primer composition is administered to the mammal at least about six months to about nine months before administration of the booster composition. More than one dose of booster composition can be provided in any suitable timeframe to maintain immunity.

[0124] Any route of administration can be used to deliver the adenoviral vector composition and/or the primer composition to the mammal. Indeed, although more than one route can be used to administer the adenoviral vector composition and/or the primer composition, a particular route can provide a more immediate and more effective reaction than another route. Most commonly, the adenoviral vector composition and/or the primer composition is administered via intramuscular injection. The adenoviral vector composition and/or the primer composition also can be applied or instilled into body cavities, absorbed through the skin (for example, via a transdermal patch), inhaled, ingested, topically applied to tissue, or administered parenterally via, for instance, intravenous, peritoneal, or intraarterial administration.

[0125] The adenoviral primer composition and/or the booster composition can be administered in or on a device that allows controlled or sustained release, such as a sponge, biocompatible meshwork, mechanical reservoir, or mechanical implant. Implants (*see*, e.g., U.S. Patent 5,443,505), devices (*see*, e.g., U.S. Patent

4,863,457), such as an implantable device, e.g., a mechanical reservoir or an implant or a device comprised of a polymeric composition, are particularly useful for administration of the composition. The adenoviral vector composition and/or the primer composition also can be administered in the form of sustained-release formulations (*see*, e.g., U.S. Patent 5,378,475) comprising, for example, gel foam, hyaluronic acid, gelatin, chondroitin sulfate, a polyphosphoester, such as bis-2-hydroxyethyl-terephthalate (BHET), and/or a polylactic-glycolic acid.

[0126] A booster composition can include a single dose of adenoviral vector comprising at least about $1x10^5$ particles (which also is referred to as particle units) of adenoviral vector. The dose preferably is at least about $1x10^6$ particles (for example, about $1x10^6$-$1x10^{12}$ particles), more preferably at least about $1x10^7$ particles, more preferably at least about $1x10^8$ particles (e.g., about $1x10^8$-$1x10^{11}$ particles or about $1x10^8$-$1x10^{12}$ particles), and most preferably at least about $1x10^9$ particles (e.g., about $1x10^9$-$1x10^{10}$ particles or about $1x10^9$-$1x10^{12}$ particles), or even at least about $1x10^{10}$ particles (e.g., about $1x10^{10}$-$1x10^{12}$ particles) of the adenoviral vector. Alternatively, the dose comprises no more than about $1x10^{14}$ particles, preferably no more than about $1x10^{13}$ particles, even more preferably no more than about $1x10^{12}$ particles, even more preferably no more than about $1x10^{11}$ particles, and most preferably no more than about $1x10^{10}$ particles (e.g., no more than about $1x10^9$ particles). In other words, the adenoviral vector composition can comprise a single dose of adenoviral vector comprising, for example, about $1x10^6$ particle units (pu), $2x10^6$ pu, $4x10^6$ pu, $1x10^7$ pu, $2x10^7$ pu, $4x10^7$ pu, $1x10^8$ pu, $2x10^8$ pu, $4x10^8$ pu, $1x10^9$ pu, $2x10^9$ pu, $4x10^9$ pu, $1x10^{10}$ pu, $2x10^{10}$ pu, $4x10^{10}$ pu, $1x10^{11}$ pu, $2x10^{11}$ pu, $4x10^{11}$ pu, $1x10^{12}$ pu, $2x10^{12}$ pu, or $4x10^{12}$ pu of adenoviral vector.

EXAMPLES

Example 1: Construction of Plasmids

[0127] The nucleic acid constructs were derived from parental 1012 DNA vaccine plasmid containing the human CMV immediate early (IE) enhancer, promoter, and intron. To construct the CMV/R regulatory element, a *Sac*II/*Hpa*I fragment of the 1012 plasmid containing the majority of the CMV IE intron was replaced with a 227

bp *Eco*RV/*Hpa*I fragment of the HTLV-1 R region (Seiki et al., *Proc. Natl. Acad. Sci. USA* 80: 3618-3622, 1983). The resulting CMV/R plasmid thus contains the human CMV IE enhancer/promoter, followed by the HTLV-1 R region and a 123 bp fragment of CMV IE 3' intron. The splice donor in the R region and the splice acceptor in the CMV IE 3' intron serve as the pair of splicing signals. RSV/R and mUB/R plasmids were similarly constructed by replacing the CMV enhancer/promoter region of the CMV/R plasmid with a 381 bp *Afl*III/*Hin*dIII fragment of the Rous sarcoma virus (RSV) enhancer/promoter or an 842 bp *Spe*I/*Eco*RV fragment of the mouse ubiquitin B(mUB) enhancer/promoter respectively. The mUB enhancer/promoter has been described previously (Yew et al., *Mol. Ther.* 4:75-82, 2001).

Construction of CMV/R Clade B Gag/h (VRC-4401)

[0128] To construct DNA plasmid VRC-4401, diagrammed in FIG. 1, the protein sequence of the gag polyprotein (Pr55, amino acids 1-432) from HXB2 (GENBANK® accession number K03455) was used to create a synthetic version of the gag gene using codons optimized for expression in human cells. The nucleotide sequence of the synthetic gag gene shows little homology to the HXB2 gene, but the protein encoded is the same. A SalI/BamHI fragment including the synthetic gene encoding Gag (B) was excised from plasmid VRC 3900, which contained the same insert in a pVR1012 backbone, and cloned into the SalI/BamHI sites of the CMV/R backbone described above. A summary of predicted VRC-4401 domains is provided in Table 2. The plasmid is 5886 nucleotide base pairs (bp) in length and has an approximate molecular weight of 3.9 MDa. The sequence of VRC-4401 is provided in SEQ ID NO:1.

Table 2: Description of plasmid VRC-4401

Fragment Name or Protein Domain	Fragment Size (bp)	Predicted Fragment
pUC18 plasmid-derived	247	1-247
CMV-IE Enhancer/Promoter	742	248-989
HTLV-1 R region	231	990-1220
CMV IE Splicing Acceptor	123	1221-1343
Synthetic Linker	31	1344-1374
HIV-1 Gag (Clade B)	1509	1375-2883
Synthetic Linker	23	2884-2906
Bovine Growth Hormone Poly A	548	2907-3454
pUC18 plasmid-derived	1311	3455-4765
Kanamycin Resistance Gene	816	4766-5581
pUC18 plasmid-derived	305	5582-5886

Construction of CMV/R Clade B Pol/h (VRC-4409)

[0129] To construct DNA plasmid VRC-4409 diagrammed in FIG. 2, the protein sequence of the Pol polyprotein (amino acids 3-1003) from NL4-3 (GENBANK® accession number M19921) was used to create a synthetic version of the pol gene using codons optimized for expression in human cells. To initiate translation at the beginning of Pol, a methionine codon was added to the 5'-end of the synthetic polymerase gene to create the Pol/h gene. Additionally, a Protease (PR) mutation was introduced at amino acid 553 (AGG->GGC or amino acids R->G), a Reverse Transcriptase (RT) mutation was introduced at amino acid 771 (GAC->CAC or amino acids D->H), and an Integrase (IN) mutation was introduced at amino acid 1209 (ACT->CAT or amino acids D->A). The gene expressing Pol was inserted into the CMV/R backbone described above. A summary of predicted VRC-4409 domains is provided in Table 3. The plasmid is 7344 nucleotide base pairs (bp) in length and has an approximate molecular weight of 4.8 MDa. The sequence of VRC-4409 is provided in SEQ ID NO:2.

Table 3: Description of Plasmid VRC-4409

Fragment Name or Protein Domain	Fragment Size (bp)	Predicted Fragment
pUC18 plasmid-derived	247	1-247
CMV-IE Enhancer/Promoter	742	248-989
HTLV-1 R region	231	990-1220
CMV IE Splicing Acceptor	123	1221-1343
Synthetic Linker	5	1344-1348
HIV-1 Pol (Clade B) (Pr-, RT-, IN-)	3009	1349-4357
Synthetic Linker	7	4358-4364
Bovine Growth Hormone Poly A	548	4365-4912
pUC18 plasmid-derived	1311	4913-6223
Kanamycin Resistance Gene	816	6224-7039
pUC18 plasmid-derived	305	7040-7344

Construction of CMV/R HIV-1 Nef/h (VRC-4404)

[0130] To construct DNA plasmid VRC-4404, diagrammed in FIG. 3, the protein sequence of the Nef protein from HIV-1 NY5/BRU (LAV-1) clone pNL4-3 (GENBANK® accession number M19921) was used to create a synthetic version of the Nef gene (Nef/h) using codons optimized for expression in human cells. The nucleotide sequence Nef/h shows little homology to the viral gene, but the protein encoded is the same. The Myristol site (GGC-Gly, amino acid 2-3) was deleted. The fragment encoding Nef was digested from the pVR1012 backbone in which it was originally inserted, with XbaI/BamHI, and then cloned into the XbaI/BamHI site of the CMV/R backbone described above. A summary of predicted VRC-4404 domains is provided in Table 4. The plasmid is 5039 nucleotide base pairs (bp) in length and has an approximate molecular weight of 3.3 MDa. The sequence of VRC-4404 is provided in SEQ ID NO:3.

Table 4: Description of plasmid VRC-4404

Fragment Name or Protein Domain	Fragment Size (bp)	Predicted Fragment
pUC18 plasmid-derived	247	1-247
CMV-IE Enhancer/Promoter	742	248-989
HTLV-1 R region	231	990-1220
CMV IE Splicing Acceptor	123	1221-1343
Synthetic Linker	48	1344-1391
HIV-1 Nef (Clade B) (Delta Myr)	615	1392-2006
Synthetic Linker	19	2007-2025
Bovine Growth Hormone Poly A	548	2026-2573
pUC18 plasmid-derived	1345	2574-3918
Kanamycin Resistance Gene	816	3919-4734
pUC18 plasmid-derived	305	4735-5039

CMV/R-HIV-1 Clade A Env/h (VRC-5736)

[0131] To construct DNA plasmid VRC-5736, diagrammed in FIG. 4, the protein sequence of the envelope polyprotein (gp160) from 92rw020 (R5-tropic, GENBANK® accession number U08794) was used to create a synthetic version of the gene (Clade-A gp145delCFI) using codons altered for expression in human cells. Plasmids expressing the HIV-1 genes were made synthetically with sequences designed to disrupt viral RNA structures that limit protein expression by using codons typically found in human cells. The nucleotide sequence R5gp145delCFI shows little homology to the 92rw020 gene, but the protein encoded is the same. The truncated envelope polyprotein contains the entire SU protein and the TM domain, but lacks the fusion domain and cytoplasmic domain. Heptad (H) 1, Heptad 2 and their Interspace (IS) are involved in oligomerization. The Fusion and Cleavage (F/CL) domains, from amino acids 486-519, have been deleted. The Interspace (IS) between Heptad (H) 1 and 2, from amino acids 576-604, has been deleted. The XbaI (18nt up-stream from ATG) to BamH1 (1912 nt down-stream from ATG) fragment, which contains a polylinker at the 5' end, a Kozak sequence and ATG, was cloned into the XbaI to BamH1 sites of the CMV/R backbone described above. EnvA summary of predicted VRC-5736 domains is provided in Table 5. The plasmid is 6305 nucleotide base pairs (bp) in length and has an

approximate molecular weight of 4.2 MDa. The sequence of VRC-5736 is provided in SEQ ID NO:4.

Table 5: Description of plasmid VRC-5736

Fragment Name or Protein Domain	Fragment Size (bp)	Predicted Fragment
pUC18 plasmid-derived	247	1-247
CMV-IE Enhancer/Promoter	742	248-989
HTLV-1 R region	231	990-1220
CMV IE Splicing Acceptor	123	1221-1343
Synthetic Linker	48	1344-1391
HIV-1 Env (Clade A), gp145 (delCFI)/h	1881	1392-3272
Synthetic Linker	19	3273-3291
Bovine Growth Hormone Poly A	548	3292-3839
pUC18 plasmid-derived	1345	3840-5184
Kanamycin Resistance Gene	816	5185-6000
pUC18 plasmid-derived	305	6001-6305

Construction of CMV/R Clade B Env/h (VRC-5737)

[0132] To construct DNA plasmid VRC-5737 diagrammed in FIG. 5, the protein sequence of the envelope polyprotein (gp160) from HXB2 (X4-tropic, GENBANK® accession number K03455) was used to create a synthetic version of the gene (X4gp160/h) using codons optimized for expression in human cells. The nucleotide sequence X4gp160/h shows little homology to the HXB2 gene, but the protein encoded is the same with the following amino acid substitutions: F53L, N94D, K192S, I215N, A224T, A346D, and P470L. To produce an R5-tropic version of the envelope protein (R5gp160/h), the region encoding HIV-1 envelope polyprotein amino acids 275 to 361 from X4gp160/h (VRC3300) were replaced with the corresponding region from the BaL strain of HIV-1 (GENBANK® accession number M68893, again using human preferred codons). The full-length R5-tropic version of the envelope protein gene from pR5gp160/h (VRC3000) was terminated after the codon for amino acid 704. The truncated envelope polyprotein (gp145) contains the entire SU protein and a portion of the TM protein including the fusion domain, the transmembrane domain, and regions important for oligomer formation. Heptad(H) 1, Heptad 2 and their Interspace(IS) are involved in oligomerization. The Fusion and Cleavage (F/CL) domains, from amino acids 503-536, have been

deleted. The Interspace (IS) between Heptad (H) 1 and 2, from amino acids 593-620, has been deleted. The expression vector backbone is CMV/R, described above. A summary of predicted VRC-5737 domains is provided in Table 6. The plasmid is 6338 nucleotide base pairs (bp) in length and has an approximate molecular weight of 4.2 MDa. The sequence of VRC-5737 is provided in SEQ ID NO:5.

Table 6: Description of plasmid VRC-5737

Fragment Name or Protein Domain	Fragment Size (bp)	Predicted Fragment
pUC18 plasmid-derived	247	1-247
CMV-IE Enhancer/Promoter	742	248-989
HTLV-1 R region	231	990-1220
CMV IE Splicing Acceptor	123	1221-1343
Synthetic Linker	40	1344-1383
HIV-1 Env (Clade B), gp145 (delCFI)/h	1929	1384-3312
Synthetic Linker	12	3313-3324
Bovine Growth Hormone Poly A	548	3325-3872
pUC18 plasmid-derived	1345	3873-5217
Kanamycin Resistance Gene	816	5218-6033
pUC18 plasmid-derived	305	6034-6338

Construction of CMV/R HIV-1 Clade C Env/h (VRC-5738)

[0133] To construct DNA plasmid VRC-5738, diagrammed in FIG. 6, the protein sequence of the envelope polyprotein (gp145delCFI) from 97ZA012 (R5-tropic, GENBANK® accession number AF286227) was used to create a synthetic version of the gene (Clade-C gp145delCFI) using codons optimized for expression in human cells. The nucleotide sequence R5gp145delCFI shows little homology to the gene 97ZA012, but the protein encoded is the same. The truncated envelope polyprotein contains the entire SU protein and the TM domain, but lacks the fusion domain and cytoplasmic domain. Heptad(H) 1, Heptad 2 and their Interspace (IS) are involved in oligomerization. The Fusion and Cleavage (F/CL) domains, from amino acids 487-520, have been deleted. The Interspace (IS) between Heptad (H) 1 and 2, from amino acids 577-605, has been deleted. The XbaI (18nt up-stream from ATG) to BamH1 (1914 nt down-stream from ATG) fragment, which contains polylinker at the 5' end, Kozak sequence and ATG, was cloned into the XbaI to BamH1 sites of the CMV/R backbone. A summary of predicted VRC-5738 domains is provided in

Table 7. The plasmid is 6298 nucleotide base pairs (bp) in length and has an approximate molecular weight of 4.2 MDa. The sequence of VRC-5738 is provided in SEQ ID NO:6.

Table 7: Description of plasmid VRC-5738

Fragment Name or Protein Domain	Fragment Size (bp)	Predicted Fragment
pUC18 plasmid-derived	247	1-247
CMV-IE Enhancer/Promoter	742	248-989
HTLV-1 R region	231	990-1220
CMV IE Splicing Acceptor	123	1221-1343
Synthetic Linker	48	1344-1391
HIV-1 Env (Clade C), gp145 (delCFI)/h	1881	1392-3272
Synthetic Linker	12	3273-3284
Bovine Growth Hormone Poly A	548	3285-3832
pUC18 plasmid-derived	1345	3833-5177
Kanamycin Resistance Gene	816	5178-5993
pUC18 plasmid-derived	305	5994-6298

Example 2: Increased expression of HIV antigenic polypeptides by CMV/R transcription regulatory sequence.

[0134] To assess antigen expression from plasmids containing the CMV/R transcriptional regulatory elements, 3T3 cells were transfected with the above described expression vectors and gp145ΔCFI expression was measured by Western blots. Murine fibroblast 3T3 cells were transfected with 0.5 μg parental 1012 (CMV), CMV/R, RSV, RSV/R, mUB, and mUB/R DNA vaccines expressing HIV-1 Env gp145 ΔCFI (9) in 6-well plates using calcium phosphate. 24 h after transfection, cells were harvested and lysed in 50 mM HEPES, 150 mM NaCl, 1% NP-40 with protease inhibitors. 10 μg total protein was electrophoresed by SDS-PAGE, and gp145 expression was assessed by Western blot analysis. A 1:5000 dilution of human HIV-IgG was utilized as the primary antibody, and a 1:5000 dilution of HRP-conjugated goat anti-human IgG was utilized as the secondary antibody. The blots were developed with the ECL Western blot developing system (Amersham Biosciences, Piscataway, NJ).

[0135] The expression of gp145ΔCFI from the CMV/R plasmid was 5- to 10-fold higher than expression from the parental 1012 plasmid (FIG. 8). Thus, addition of the HTLV-1 R element substantially increased antigen expression driven by the CMV promoter. Baseline expression from the mUB plasmid was higher than from the 1012 plasmid but was not further enhanced by addition of the R element (FIG. 8), demonstrating that the effects of adding the R element were promoter-dependent. An increase in expression was observed in the RSV/R compared to RSV plasmid (FIG. 8). Expression from RSV plasmids is routinely lower than from the 1012 plasmid.

Example 3: Immunogenicity of CMV/R multiclade HIV vaccine

[0136] Non-clinical immunogenicity studies were conducted with plasmid constructs comprising the DNA plasmid vaccine VRC-HIVDNA016-00-VP as well as with DNA plasmid prime/adenoviral vector boost regimens using the recombinant adenoviral vector vaccine VRC-HIVADV014-00-VP in mice and non-human primates. Cellular immune responses were tested in these non-clinical immunogenicity studies by the interferon gamma (IFN-γ) ELISPOT assay which quantitatively measures the production of IFN-γ by peripheral blood mononuclear cells (PBMC) from immunized animals. The cells are exposed in vitro to HIV-1 antigens (a series of short, overlapping peptides that span the length of the protein expressed in the vaccine). The IFN-γ produced by antigen sensitized T-lymphocytes are bound to antibody coating an assay plate and may be counted colorimetrically as spot forming cells (SFC) by using an alkaline phosphatase conjugated read-out system. The results are expressed as SFCs per million PBMC.

[0137] DNA plasmid prime regimens are performed using plasmids expressing HIV-1 genes, identical in composition to clinical grade vaccine VRC-HIVDNA009-00-VP (4 plasmid vaccine, PCT Publication No. WO/05034992) or VRC-HIVDNA016-00-VP. The recombinant adenoviral vector vaccines used in preclinical immunology studies consisted of GMP grade VRC-HIVADV014-00-VP (Lot# 026-03017, PCT Application No. PCT/US2005/12291, filed April 12, 2005), composed of four adenoviral vectors that encode clade B gag/pol and clade A, B and

C Env, supplied by GenVec, Inc. Gaithersburg, MD). Table 8 provides a summary of the plasmids.

[0138] A tabulated summary of the immunology studies performed in mice and in non-human primates are summarized in Table 9.

Table 8: Summary of preclinical and clinical studies of VRC DNA vaccines

	Plasmid	Gag	Pol	Nef	Env (A)	Env (B)	Env (C)	Safety Testing	Clinical Trial
VRC-4302 (1-plasmid)	p1012w/ CMV promoter	Gag-Pol (B) Nef not included			Not included	Not included	Not included	+	+
VRC-HIVDNA006-00-VP (6-plasmids)	p1012w/ CMV promoter	Gag-Pol-Nef (A) (4413) Gag-Pol-Nef (B) (4306) Gag-Pol-Nef (C) (4311)			5305	2805	5309	+	N/A
VRC-HIVDNA009-00-VP (4-plasmids)	p1012w/ CMV promoter	Gag-Pol-Nef (B) (4306)			5305	2805	5309	+	+
VRC-EBODNA012-00-VP (3-plasmids)	p1012w/ CMV/R promoter	Ebola GP's and NP						+	+
VRC-HIVDNA016-00-VP (6-plasmids)	p1012w/ CMV/R promoter	4401	4409	4404	5736	5737	5738	*	In progress

Table 9: Summary of Vaccine Immunogenicity Studies in Mice and Non-Human Primates

Test System	Mouse	Cynomolgus macaques
Study Design	Immunogenicity	Immunogenicity
Route	i.m.[1]	i.m.[2]
Dose	DNA:50μg	DNA:8mg rAd:1x10[11] PU
Treatments per Animal	1 DNA	3 DNA 1 rAd
Treatment Period	0 day	38 Wks
Study Duration	21 days	58 Wks
Conclusions	Vaccination with *gag-pol-nef* (CMV/R) elicits higher HIV-1-specific cellular responses in mice than plasmids constructed with the 1012 backbone.	Cynomolgus macaques receiving DNA prime/rAd boost immunization with the 6-plasmid DNA vaccine that expresses HIV-1 Gag, Pol, Nef and clade A, B and C Env (VRC-HIVDNA016-00-VP), and boosted with rAd expressing HIV-1 Gag/Pol and 3 Env, elicited cellular immune responses to all viral antigens.
References	Item (8) Section 2.3.1	Item (8) Section 2.3.2 Study VRC-02-035

PU = Particle Unit

[1] DNA plasmid administered intramuscularly (i.m.) by needle and syringe

[2] DNA Plasmid administered i.m. by Biojector; recombinant adenoviral vector vaccine (rAd) VRC-HIVADV014-00-VP

(Lot # 026-03024) delivered i.m. by needle and syringe.

Vaccination with the CMV/R plasmid encoding the gag-pol-nef fusion protein elicits higher HIV-1-specific cellular responses in mice than the unmodified 1012 plasmid encoding the same fusion protein.

[0139] To explore the possibility that enhanced antigen expression results in improved immunogenicity of these novel DNA vaccines *in vivo*, Balb/c mice (N=5/group) were immunized with 50 μg of the parental 1012 DNA vaccine or the CMV/R, RSV/R, mUB, or mUB/R DNA vaccines expressing HIV-1 Env gp145 ΔCFI. Mice were immunized three times at weeks 0, 2, and 6. On day 10 following

the final immunization, splenocytes were assessed for Env-specific cellular immune responses by IFN-γ and TNF-α intracellular cytokine staining (ICS) assays. The CMV/R DNA vaccine elicited approximately 2-fold higher $CD4^+$ ($p=0.15$) and $CD8^+$ ($p=0.043$) T lymphocyte responses as compared with the parental 1012 DNA vaccine expressing the same antigen (FIG. 9). In contrast, the RSV/R, mUB, and mUB/R DNA vaccines did not elicit enhanced $CD8^+$ immune responses, suggesting that the HTLV-1 R element selectively improved immunogenicity in the context of the CMV promoter.

[0140] Immunogenicity of the parental 1012 DNA vaccines and the CMV/R DNA vaccines expressing other antigens were then compared. Mice (N=8/group) were immunized with sham plasmids or with these DNA vaccines expressing the HIV-1 Gag-Pol-Nef fusion protein. Mice were immunized twice at weeks 0 and 6, and cellular immune responses were assessed by IFN-γ ELISPOT assays using splenocytes harvested 3 weeks after the initial or boost immunization. Groups of BALB/c female mice (8 mice per group) were immunized with the following regimens of plasmids diluted in normal saline:

clade B *g-p-n* (1012): VRC-4306 (50μg/animal); this plasmid expresses Gag-Pol-Nef as a fusion protein, and is contained in the four-plasmid vaccine VRC-HIVDNA009-00-VP (BB-IND 10681);

clade B *g-p-n* (CMV/R): VRC-4400 (50μg/animal); this plasmid expresses Gag-Pol-Nef as a fusion protein.

[0141] Mice were injected with a single intramuscular (i.m.) immunization of 50 μl total DNA in the quadriceps muscles using on day 0. On day 21 following immunization, mice were sacrificed for immunologic assays.

[0142] ICS assays. $CD4^+$ and $CD8^+$ T lymphocyte responses were evaluated by intracellular cytokine staining (ICS) for interferon-gamma (IFN-γ) and tumor necrosis factor-alpha (TNF-α). Briefly, splenocytes from immunized mice were harvested and incubated with pools of 15 amino acid peptides overlapping by 11

amino acids (2.5 μg/ml each) covering the entire HIV-1 Env protein, followed by treatment with 10 μg/ml brefeldin A (Sigma, St. Louis, MO). Cells were then fixed, permeabilized, and stained using rat anti-mouse CD3, CD4, CD8, IFN-γ and TNF-α monoclonal antibodies (BD Pharmingen, San Diego, CA). The IFN-γ and TNF-α positive cells in the $CD4^+$ and $CD8^+$ cell populations were analyzed with the program FlowJo (Tree Star, Ashland, OR).

[0143] Splenocytes were removed aseptically and homogenized to create a single-cell suspension. IFN-γ ELISPOT assays were then performed using splenocytes from vaccinated mice to assess the magnitude of vaccine-elicited cellular immune responses. Ninety-six-well multiscreen plates (Millipore, Bedford, MA) coated overnight with 100 μl/well of 10 μg/ml rat anti-mouse IFN-γ (Pharmingen, San Diego, CA) in PBS were washed with endotoxin-free Dulbecco's PBS (Life Technologies, Gaithersburg, MD) containing 0.25% Tween-20 and blocked with PBS containing 5% FBS for 2 h at 37° C. The plates were washed three times with Dulbecco's PBS containing 0.25% Tween-20, rinsed with RPMI 1640 containing 10% FBS, and incubated in triplicate with $5x10^5$ splenocytes per well in a 100 μl reaction volume containing pooled peptides. Responses were measured using the HIV-1 Gag, Pol, and Nef peptide pools (VRC, Bethesda, MD). Following an 18h incubation, the plates were washed nine times with Dulbecco's PBS containing 0.25% Tween-20 and once with distilled water. The plates were then incubated for 2 h with 75 μl/well of 5 μg/ml biotinylated rat anti-mouse IFN-γ (Pharmingen, San Diego, CA), washed six times with Coulter Wash (Coulter Corporation, Miami, FL), and incubated for 2 h with a 1:500 dilution of streptavidin-AP (Southern Biotechnology Associates, Birmingham, AL). Following five washes with Coulter Wash and one with PBS, the plates were developed with NBT/BCIP chromogen (Pierce, Rockford, IL), stopped by washing with tap water, air dried, and read using an ELISPOT reader (Hitech Instruments, Edgemont, PA).

[0144] Immunologic data are presented as means with standard errors. Statistical analyses were performed with GraphPad Prism version 4.01 (GraphPad Software, Inc., 2004). Comparisons of mean cellular immune responses between groups of

animals were performed by two-tailed nonparametric Mann-Whitney tests. In all cases, p-values of less than 0.05 were considered significant.

[0145] Consistent with the prior experiment, we observed approximately 2-fold higher Gag- (p=0.038) and Pol-specific (p=0.020) responses elicited by the CMV/R DNA vaccine compared to the parental 1012 DNA vaccine following the initial immunization (FIG. 10A). Following the boost immunization, responses elicited by the CMV/R DNA vaccine remained approximately 2-fold higher than responses elicited by the parental DNA vaccine using both unfractionated splenocytes (FIG. 10B) and CD8-depleted splenocytes (FIG. 10C).

Immunogenicity of DNA Prime/Recombinant Adenoviral Vector Boost Immunization of Cynomolgus Macaques

[0146] Immunogenicity of the parental 1012 DNA vaccines was compared with CMV/R DNA vaccines expressing multiple HIV-1 antigens in cynomolgus monkeys. Two groups of adult cynomolgus monkeys (N=6/group) were immunized with 4-plasmid mixtures of 1012 or CMV/R DNA vaccines expressing HIV-1 Env gp145 ΔCFI from clades A, B, and C and the Gag-Pol-Nef fusion protein from clade B in a 1:1:1:3 ratio. This multiclade, multivalent DNA vaccine has been previously described and is currently being evaluated in clinical trials (VRC-HIVDNA009-00-VP; PCT Publication No. WO/05034992). A third group of monkeys was included to investigate whether separating the Gag-Pol-Nef fusion protein into separate genes encoded on separate plasmids would further increase immune responses to these antigens (VRC-HIVDNA016-00-VP). This third group of monkeys received a 6-plasmid mixture of CMV/R DNA vaccines encoding HIV-1 Env gp145 from clades A, B, and C and separate Gag, Pol, and Nef proteins from clade B in a 1:1:1:1:1:1 ratio. All monkeys received three immunizations of 8 mg total DNA vaccine at weeks 0, 4, and 8.

[0147] Plasmid DNA vectors (Althea Technologies, Inc., San Diego CA) expressing HIV-1 Gag, Pol, Nef proteins or Gag-Pol-Nef fusion protein and Clade A, B and C Env were used for the DNA prime immunization. The plasmids expressed the same

proteins as those contained in 4–plasmid vaccine VRC-HIVDNA009-00-VP and 6–plasmid vaccine VRC-HIVDNA016-00-VP.

[0148] The 4-plasmid combination was formulated using 1012 plasmids VRC 4306 (clade B Gag-Pol-Nef), VRC 5305 (clade A Env), VRC 2805 (clade B Env), and VRC 5309 (clade C Env). To achieve the required volumes for the three scheduled injections in the animal study, three lots of formulated material were prepared. The three lots were combined in a 50 mL conical tube. Following inversion of the tube several times to mix, 15.6-15.7 mL of the mixture was aliquotted into each of three 50 mL conical tubes. Tubes were labeled with study number, lot number, plasmid numbers, tube number, and date of preparation. Tubes were stored at –20°C until distributed.

[0149] The 6–plasmid combination was formulated using CMV/R plasmids VRC 4401 (clade B Gag), VRC 4409 (clade B Pol), VRC 4404 (clade B Nef), VRC 5736 (clade A Env), VRC 5737 (clade B Env) and VRC 5738 (clade C Env). To achieve the required volumes for the three scheduled injections of the animal study, three lots of formulated material were prepared. The three lots were combined in a sterile container. Following inversion of the container several times to mix, 16.8 mL of the mixture was aliquotted into each of three 50 mL conical tubes. Tubes were labeled with study number, lot number, plasmid numbers, tube number and date of preparation and stored at –20°C until distributed.

[0150] VRC-HIVADV014-00-VP (Lot #026-03024) was used as the rAd boost.

[0151] Outbred adult Cynomolgus macaques (6 monkeys per group) were vaccinated with DNA vaccine prime, delivered i.m. at weeks 0, 4, and 8 by Biojector. In each case, plasmid vaccine was delivered as two 0.5 ml injections in the quadriceps muscles using a No. 3 Biojector syringe (BIOJECT). A rAd vaccine boost was delivered i.m. by needle and syringe at week 38 (Group 1) and week 24 (Group 2). The following vaccination regimens were administered:

Group 1: 1012 plasmid DNA prime (4–plasmid combination): 8 mg total dose delivered as a combination of clade B Gag-Pol-Nef

fusion protein (4 mg), clade A Env (1.3 mg), clade B Env (1.3 mg) and clade C Env (1.3 mg). This is a non–GMP version of the VRC-HIVDNA009-00-VP clinical product (BB-IND 10681). rAd vaccine boost: VRC-HIVADV014-00-VP (10^{11} PU total dose; GMP lot # 026-03024).

Group 2: CMV/R plasmid DNA (6–plasmid combination): 8 mg total dose delivered as a combination of clade B Gag (1.3 mg), clade B Pol (1.3 mg), clade B Nef (1.3 mg), clade A Env (1.3 mg), clade B Env (1.3 mg) and clade C Env (1.3 mg). This is a non-GMP version of the VRC-HIVDNA016-00-VP clinical product (the subject of this IND submission). rAd vaccine boost: VRC-HIVADV014-00-VP (GMP lot # 026-03024).

Group 3: CMV/R plasmid DNA (4 plasmid combination): 8 mg total dose delivered as a combination of clade B Gag-Pol-Nef fusion protein (4 mg), clade A Env (1.3 mg), clade B Env (1.3 mg) and clade C Env (1.3 mg). rAd vaccine boost: VRC-HIVADV014-00-VP (GMP lot # 026-03024).

Group 4: 1012 plasmid DNA (6 plasmid combination): 8 mg total dose delivered as a combination of clade B Gag (1.3 mg), clade B Pol (1.3 mg), clade B Nef (1.3 mg), clade A Env (1.3 mg), clade B Env (1.3 mg) and clade C Env (1.3 mg). rAd vaccine boost: VRC-HIVADV014-00-VP (GMP lot # 026-03024).

[0152] Monkeys were bled at various intervals through week 42 post-immunization.

[0153] ELISPOT assays were utilized to monitor the emergence of vaccine-elicited T cell immune responses to multiple viral antigens. Separate assays were performed for each animal using pools of 15 amino acid peptides overlapping by 11 amino acids spanning the HIV-1 Gag, Pol, Nef, clade A Env, clade B Env and clade C Env

proteins matching the sequences of the vaccine immunogens. 96-well multiscreen plates were coated overnight with 100 µl/well of 5µg/ml anti-human IFN-γ (B27; BD Pharmingen) in endotoxin-free Dulbecco's PBS (D-PBS). The plates were then washed three times with D-PBS containing 0.25% Tween-20 (D-PBS/Tween), blocked for 2 h with D-PBS containing 5% FBS at 37 °C, washed three times with D-PBS/Tween, rinsed with RPMI 1640 containing 10% FBS to remove the Tween-20, and incubated with peptide pools and 2 x 10^5 PBMC in triplicate in 100 µl reaction volumes. Following an 18h incubation at 37 °C, the plates were washed nine times with D-PBS/Tween and once with distilled water. The plates were then incubated with 2 µg/ml biotinylated rabbit anti-human IFN-γ (Biosource) for 2 h at room temperature, washed six times with Coulter Wash (Beckman-Coulter), and incubated for 2.5 h with a 1:500 dilution of streptavidin-AP (Southern Biotechnology). Following five washes with Coulter Wash and one with PBS, the plates were developed with NBT/BCIP chromogen (Pierce), stopped by washing with tap water, air dried, and read using an ELISPOT reader (Hitech Instruments). Spot-forming cells (SFC) per 10^6 PBMC were calculated. Media backgrounds were consistently <15 spot-forming cells per 10^6 PBMC.

[0154] Cellular immune responses against Env clade A, Env clade B, Env clade C, and Gag, Pol, and Nef from clade B were compared in monkeys that received the 4-plasmid mixtures under the control of CMV (1012) (Group 1) or CMV/R regulatory elements (Group 3). Monkeys immunized with the parental 1012 DNA vaccines developed low and sporadic IFN-γ ELISPOT responses to Env two weeks following the second immunization at week 6, and no clear responses above background were detected to Gag, Pol, and Nef (FIG. 11A). In contrast, monkeys immunized with the analogous CMV/R DNA vaccines exhibited significantly higher responses to all antigens (FIG. 11B). Compared to the parental 1012 DNA vaccines, the CMV/R DNA vaccines elicited >10-fold higher ELISPOT responses to Gag (p=0.0022), Pol (p=0.0043), and Nef (p=0.041) and 7- to 9-fold higher responses to Env clade A (p=0.026), B (p=0.0087), and C (p=0.030) at this time point. These results demonstrate that the CMV/R DNA vaccines were markedly more immunogenic than the parental 1012 DNA vaccines for multiple HIV-1 antigens in nonhuman primates.

[0155] Separating the Gag-Pol-Nef fusion protein into individual genes encoded on different plasmids further improved these responses. In particular, monkeys that received the 6-plasmid mixture of CMV/R DNA vaccines (Group 2) developed 4-fold higher responses to Gag ($p=0.0022$), a trend towards 2-fold higher responses to Pol ($p=0.19$), and 4-fold higher responses to Nef ($p=0.049$) (FIG. 11C), as compared to animals that received the 4-plasmid mixture of CMV/R DNA vaccines that included the Gag-Pol-Nef fusion protein (FIG. 11B). Env-specific responses between these two groups of monkeys that received the 4-plasmid and 6-plasmid mixtures of CMV/R DNA vaccines were comparable ($p=0.48$).

[0156] The evolution of mean IFN-γ ELISPOT responses in these groups of monkeys was evaluated at weeks 0, 2, 6, 10, and 12. Following the third DNA immunization at week 8, responses increased in all groups of monkeys (FIG. 12). At week 10, the parental 1012 DNA vaccines elicited Env- and Pol-specific responses in the majority of animals, although Gag- and Nef-specific responses remained low (FIG. 12A). In contrast, the CMV/R DNA vaccines elicited potent and broad responses to all antigens (FIG. 12B-C). At week 10, the 4-plasmid CMV/R DNA vaccines (FIG. 12B) elicited >10-fold higher ELISPOT responses to Gag ($p=0.0022$) and Nef ($p=0.0022$), 4-fold higher ELISPOT responses to Pol ($p=0.043$), and trends toward 1.5- to 4-fold higher responses to Env clade A, B, and C (FIG. 12B), as compared with the 4-plasmid parental 1012 DNA vaccines (FIG. 12A). Gag-, Pol- and Nef-specific responses remained highest in the animals that received the 6-plasmid CMV/R DNA vaccines with these genes encoded on separate plasmids (FIG. 12C). All responses boosted well with rAd. These studies confirm that the CMV/R DNA vaccines elicited substantially higher magnitude and broader cellular immune responses to multiple antigens as compared with the parental 1012 DNA vaccines. Thus, including the HTLV-1 R element and separating the Gag, Pol, and Nef genes significantly enhanced the immunogenicity of HIV-1 DNA vaccines in nonhuman primates.

[0157] In both mice and cynomolgus monkeys, CMV/R DNA vaccines expressing HIV-1 antigens elicited higher cellular immune responses than the parental 1012 DNA vaccines expressing the same antigens. However, the magnitude of the

observed effects differed substantially between the two species. While the CMV/R DNA vaccines elicited only 2-fold higher responses in mice (FIG. 10), the CMV/R DNA vaccines elicited >10-fold higher cellular immune responses to Gag, Pol, and Nef and 7- to 9-fold higher responses to Env after two immunizations in cynomolgus monkeys (FIGS. 11,12). This difference reflects the lower baseline immunogenicity of the parental 1012 DNA vaccines in nonhuman primates and indicates that the beneficial effects of the R element is more apparent in limiting situations. Consistent with this observation, the R element had the greatest effect at enhancing the weakest responses elicited by the parental 1012 DNA vaccine against Gag and Nef. However, Env- and Pol-specific cellular immune were also significantly higher when induced by CMV/R DNA vaccines as compared with the parental 1012 DNA vaccines.

[0158] The 6-plasmid mixture of CMV/R DNA vaccines that included Gag, Pol, and Nef on separate plasmids elicited significantly higher cellular immune responses to these antigens as compared to the 4-plasmid mixture of CMV/R DNA vaccines that included the Gag-Pol-Nef fusion protein. These effects are particularly notable since the separate Gag, Pol, and Nef plasmids were each utilized at one-third the dose of the plasmid encoding the Gag-Pol-Nef fusion protein. Without being bound by theory, this increased immunogenicity may reflect enhanced translation or mRNA stability of the shorter genes as compared with the fusion gene, which might potentially affect antigen processing and presentation.

[0159] Accumulating data has confirmed the importance of cellular immune responses in controlling HIV-1 replication in humans and SIV replication in rhesus monkeys. Moreover, vaccines aimed at eliciting virus-specific cellular immune responses have afforded partial control of SHIV and SIV challenges in rhesus monkeys. Thus, the markedly increased magnitude and breadth of HIV-1-specific cellular immune responses afforded by the CMV/R DNA vaccines in nonhuman primates in the present study is believed to be beneficial in the development of second-generation DNA vaccines for both HIV-1 and other pathogens. In particular, incorporating the HTLV-1 R element and utilizing separate genes in place of fusion

genes represent simple and practical strategies to improve DNA vaccines, making these vaccines suitable for clinical applications.

Example 4: Preparation of Material for Clinical Use

[0160] The process for manufacturing, filling, and packaging the VRC-HIVDNA016-00-VP drug product involves *E. coli* fermentation, purification, and formulation as a sterile liquid injectable dosage form for intramuscular injection. This naked DNA product involves no lipid, viral, or cellular vector components.

[0161] The vaccine, VRC-HIVDNA016-00-VP, is composed of a combination of six closed circular plasmid DNA macromolecules (VRC-4401, 4409, 4404, 5736, 5737 and 5738). For preparation of plasmids for clinical use, a master cell band (MCB) was prepared for each source plasmid (VRC-4401, 4409, 4404, 5736, 5737 and 5738). Identity and composition of plasmid DNA samples from each of these MCBs was confirmed by sequence analysis. Restriction enzyme analysis and microbial analysis (including mold and yeast) were also performed to confirm identity and sterility.

[0162] Bulk plasmid preparations are prepared from bacterial cell cultures containing a kanamycin selection medium. In all cases, bacterial cell growth is dependent upon the cellular expression of the kanamycin resistance protein encoded by a portion of the plasmid DNA. Following growth of bacterial cells harboring the plasmid, the plasmid DNA is purified from cellular components.

[0163] Clinical trial vaccines are prepared under cGMP conditions. The vaccines meet lot release specifications prior to administration. The DNA vaccine is manufactured at a 4.0 mg dose in phosphate buffered saline (PBS). Vials are aseptically filled to a volume of 1.2 mL at a ratio of 1:1:1:1:1:1 of the six plasmids. The 4.0 mg plasmid DNA vaccine vials is shipped, unblinded, to the study pharmacist on dry ice, and is stored at or below -20°C until use. Placebo control vials of 2.4 mL PBS, pH 7.2 ± 0.2, are obtained from Bell-More Labs, Incorporated (Hampstead, MD).

[0164] Expression testing of the individual plasmids and the final formulated drug product are conducted prior to release of the vaccine product. Qualitative expression of the plasmid proteins is verified by comparing the reactive protein bands on the Western blot with the standards run under the same conditions. Once the plasmids are combined, expression is verified using the same assay procedures. Expression is determined by detecting proteins expressed by transfected 293 human embryonic kidney (HEK) cells. For transfection, 10^5 to 10^6 cells are transfected with 1-5 μg of plasmid DNA using the calcium phosphate method. Cells are incubated for 14-20 hours to allow for DNA uptake. Following a medium change, cells are grown for an additional 24-48 hours before harvesting. Transfection efficiency is monitored using a known similar vector in the same backbone. After cell lysis, 10 μg of an appropriate amount of total cellular protein is loaded onto an SDS-PAGE gel to separate the crude lysate proteins.

[0165] Following electrophoresis for approximately 1.5 hours, the proteins are transferred to a nitrocellulose membrane (0.45 μm) for Western blot analysis. The membrane is blocked with skim milk to prevent non-specific binding interaction prior to incubation with the primary antibody for 60 minutes. Following washing, the membrane is incubated for 45 minutes with HRP conjugated second antibody. Visualization of the protein bands is achieved by incubating the membrane with chemiluminescent substrates and exposing to X-ray film for 2 minutes or an appropriate time. Expression of protein produced by transfected cells is determined by observing the intensity of expressed protein on the Western blot. The assay is being further developed to allow for semi-quantitative analysis of protein expression by the vaccine plasmids.

Example 5: Clinical safety in humans.

[0166] For clinical use, VRC-HIVDNA016-00-VP is composed of 6 closed, circular DNA plasmids that are each 16.67% (by weight) of the vaccine. Each of the 6 plasmids in this vaccine expresses a single gene product. Plasmids VRC 4401, VRC 4409 and VRC 4404 are designed to express clade B HIV-1 Gag, Pol and Nef, respectively. VRC 5736, VRC 5737, and VRC 5738 are designed to express HIV-1

Env glycoprotein from clade A, clade B, and clade C, respectively. Vaccine vials are supplied at 4 mg/mL. Each DNA administration is 1 mL of the vaccine composition delivered intramuscularly (in deltoid muscle) using the Biojector 2000® Needle-Free Injection Management System™.

[0167] Evaluation of the safety of this vaccine includes laboratory studies, medical history, physical assessment by clinicians, and subject self-assessment recorded on a diary card. Potential adverse reactions are further evaluated prior to continuing the immunization schedule. Day 0 is defined as the day of enrollment and first injection. Day 0 evaluations prior to the first injection are the baseline for subsequent safety assessments. The schedule of vaccination is Day 0, Day 28 ± 7, Day 56 ± 7 (with at least 21 days between injection days). All study injections are given by an intramuscular administration of VRC-HIVDNA016-00-VP at a 4 mg dose using a Biojector 2000® needle-free injection system. Study injections are administered into deltoid muscle.

[0168] Following study injections, subjects are observed for a minimum of 30 minutes. Vital signs (temperature, blood pressure, pulse and respiratory rate) are taken at 30-45 minutes post-immunization. The injection site is inspected for evidence of local reaction. Subjects will be given a "Diary Card" on which to record temperature and symptoms daily for 5 days. Follow-up on subject well-being will be performed by telephone on the first or second day following each injection. A clinic visit will occur if indicated by the telephone interview. On each injection day (prior to injection) and at 14±3 days after each injection, study subjects are evaluated by clinical exam and laboratory tests. Long-term follow-up visits are at Week 12±7 days, Week 24 ±14 days and Week 32 ±14 days. At intervals throughout the study subjects have blood drawn for immunologic assays. Any cells, serum or plasma not used will be stored for future virological and immunological assays. Subjects are also interviewed at the final clinical visit (Week 32) regarding social harms, including problems with employment, travel, immigration, access to insurance, medical or dental care, and negative reactions from family, friends, and co-workers.

[0169] Assessment of product safety includes clinical observation and monitoring of hematological and chemical parameters. The following parameters will be assessed: local reactogenicity signs and symptoms; systemic reactogenicity signs and symptoms; laboratory measures of safety; and adverse and serious adverse experiences.

[0170] The principal immunogenicity endpoints are measured at Week 0 (baseline) and Weeks 6, 8, 10 and 12 (for cellular immune responses) and consist of HIV-1-specific T cell responses, as measured by intracellular cytokine staining (ICS) assays. ICS at other study timepoints, as well as HIV-1-specific humoral immune responses as measured by HIV-specific antibody assays will be completed as exploratory evaluations.

[0171] Administration of the vaccine composition is performed using a BIOJECTOR 2000® NEEDLE-FREE INJECTION MANAGEMENT SYSTEM® as directed by the company. Neither the material being injected nor the deltoid injection site skin preparation require deviation from standard procedures. In brief, the injection site is disinfected and the area allowed to dry completely. The skin around the injection site is held firmly while the syringe is placed against the injection site at a 90° angle. The actuator is pressed and the material is released into the muscle. Continue to hold firmly for 3 seconds. After the injection, the site is covered with a sterile covering and pressure applied with 3 fingers for 1 minute. BIOJECTOR 2000® utilizes sterile, single-use syringes for variable dose, up to 1.0 mL, medication administration. The study agent is delivered under pressure by a compressed CO_2 gas cartridge that is stored inside the BIOJECTOR®. When the BIOJECTOR®'s actuator is depressed, CO_2 is released, causing the plunger to push the study agent out of the sterile syringe through the skin and into the underlying tissue. The study agent is expelled through a micro-orifice at high velocity in a fraction of a second to pierce the skin. The CO_2 does not come in contact with the injectate and the syringe design prevents any back splatter or contamination of the device by tissue from the subject.

[0172] Fifteen subjects received three 1 mL doses at 4 mg/mL on a 0, 1, 2 month schedule. Vaccinations were administered intramuscularly using the BIOJECTOR 2000®. Fourteen of the 15 subjects received 3 intramuscular injections of a 4 mg dose of vaccine administered by BIOJECTOR 2000®; one subject was lost to follow-up after two vaccinations. No subjects reported fever following vaccination. Reactogenicity was none to mild except that two subjects reported moderate injection site pain and one subject reported moderate nausea and malaise. The only adverse event requiring expedited reporting to the IND sponsor was a grade 3 generalized urticaria. The subject had reported starting an antihistamine about 2 weeks after first vaccination but reported at that time that the reason was latex allergy. While being screened for the rollover booster study, VRC 010, it was learned that the subject had experienced generalized urticaria around the time of the second vaccination when the supply of antihistamine ran out. The subject has chronic urticaria that are well controlled by antihistamine. Evaluation is ongoing. The etiology is unknown but at this time the chronic urticaria is assessed as possibly related to study vaccine. To date, there have been two moderate (grade 2) adverse events possibly attributed to vaccine. These were intermittent dizziness of 2 days duration beginning 13 days after the second vaccination in one subject (this subject received the third vaccination without recurrence of symptoms) and asymptomatic hypoglycemia in another subject, first noted at the follow-up visit that was 14 days after the third vaccination. The last safety evaluation of the subject lost to follow-up was by telephone one day after the second vaccination; at that time the subject reported no side effects from the vaccination.

[0173] An unexpected local injection site reaction for this DNA vaccine has been observed. Mild cutaneous lesions (0.5-1.0 cm diameter) at the vaccination site occurred after 4 of 44 (9%) vaccinations administered; these occurred in 3 of 15 (20%) subjects. Subjects were routinely asked to call if they experience any unusual problem after study vaccinations. The vaccination site cutaneous lesions did not alarm subjects enough to prompt them to contact the VRC Clinic prior to their next regularly-scheduled visit. In retrospect, three subjects reported that they experienced skin lesions that started as a small papule or vesicle within 3 days after vaccination.

After a few days the papule or vesicle unroofed and a scab formed. There was surrounding mild erythema and mild induration. After the scab came off, the skin healed without treatment. None of the cutaneous lesions were associated with pustular exudates, fever, rash or urticaria. They did not appear to be either a local infection or an allergic reaction.

[0174] The first three cutaneous lesions were discovered at the first post-vaccination clinic visit (days 14 ± 3 Day); at that time they were largely resolved. The fourth cutaneous lesion was examined in the clinic while still in an active stage and it was biopsied at post-vaccination day 6. This biopsy demonstrated a microscopic subcutaneous and dermal perivascular lymphocytic infiltrate. The infiltrate was composed almost exclusively of CD3 positive cells, including both $CD4^+$ and $CD8^+$. There were rare eosinophils present and rare giant cells noted. The process appeared to be primarily a subcutaneous and dermal response to vaccination with cutaneous manifestations.

[0175] Whether these reactions correlate with the strength of the vaccine-induced immune response is also not yet known. Eight of the 14 subjects who remained in follow-up have had a vaccine-induced positive HIV ELISA by a commercial test at one or more timepoints; this includes all three subjects who had a cutaneous lesion. Preliminary immunogenicity data with the 6-plasmid DNA indicate that the Env-specific T cell responses are similar to those seen in the 4-plasmid DNA, and the Gag- and Nef-specific responses are also present.

[0176] Cellular responses in subjects were measured by intracellular cytokine staining (ICS) and flow cytometry to detect IFN-γ or IL-2 in both CD4+ and CD8+ T lymphocytes after stimulation with peptide pools representing the viral antigens (FIG. 13). Data for each individual subject is shown in columns. Responses to each peptide pools are shown in rows. Each box represents the entire time course from prevaccination to 12 weeks (4 weeks after the last immunization). The scale for each box is 0-0.2% of the total CD4+ or CD8+ population tested. CD4+ responses are shown in red and CD8+ responses shown in green. Nearly all subject have detectable responses to Env peptides. In contrast to the 4-plasmid product, the

majority of subjects have detectable responses to Gag and there are also Nef responders.

Example 6: Immunogenicity of Chimeric Env Proteins

[0177] To demonstrate the role of different genetic sequences in the induction of neutralizing antibodies, nucleic acid constructs expressing chimeric antigenic polypeptides having different regions of the viral envelope from two different clades were produced. Nucleic acid constructs encoding different portions of the clade C Env polypeptide and clade B Env polypeptide were analyzed and compared to the clade C Env polypeptide. The transposition of the proximal 25% of clade C onto the clade B background showed an increase in the potency and breadth of neutralization against a variety of clade B isolates and improved the neutralization of clade C isolates. Replacement of the distal region of clade B Env with the clade C Env resulted in improved neutralization against clade B isolates, demonstrating that the region containing V_3 in clade B isolates contributes to its ability to inhibit a variety of diverse viral isolates. These nucleic acid constructs are represented by SEQ ID NOs:7-15. Thus, certain embodiments of the disclosed compositions can include constructs encoding chimeric Env polypeptides combining multiple clades.

[0178] To demonstrate the roles of V regions in alternative clades, mutations were made both in the V_1V_2 as well as the V_3 regions of clades A, B and C. To demonstrate the role of V_1V_2 in clade A, a clade A prototype was compared to that containing deletions of the V_1 and V_2 regions. Removal of V_1V_2 and/or V_3 enhanced the ability of the clade A Env polypeptide to elicit an immune response that neutralized a variety of clade B isolates, demonstrating that deletion of these regions increases the ability of the antigenic polypeptide to elicit broadly neutralizing antibodies (for example, by increasing accessibility to specific epitopes that elicit cross-reactive antibodies). Accordingly, in certain embodiments disclosed herein, the nucleic acid constructs include deletions of a V_1, V_2 and/or V_3 region.

[0179] To demonstrate the role of V_1V_2 in clade B against a heterologous V_3 from clade C, the V_3 from a South African clade C isolate was inserted in place of the V_3

from a clade B and compared to a stem-shortened version that has been shown to enhance neutralization using clade B V_3 loops. The ability of these plasmid DNA vectors in combination with a recombinant adenovirus boost to elicit neutralizing antibodies was evaluated against the indicated strains. Immunization with both V_3 substitutions allowed neutralization of viral isolates from clades A, B and C, although the magnitude of the response was greater with the stem-shortened 1AB V_3. In addition, the peptide inhibition revealed that the neutralizing antibodies elicited in this response were of greater breadth and intereacted with V_3 regions from diverse clades, A, B and C. Thus, the clade C V_3 loop appeared to elicit broadly reactive V_3 neutralizing antibodies.

[0180] Deletion of the V_1 and V_2 regions of these envelopes improves their ability to elicit neutralizing antibody responses. These responses are directed largely against the V_3 regions in diverse clades. The use of alternative V regions derived from different clades demonstrates that these V regions also display differences in their ability to elicit strain-specific responses. For example, the inclusion of V_3 regions from clade C allowed neutralization of a variety of clade B isolates and greater breadth of neutralization by V_3 peptides from diverse strains. Thus, the elimination of both the V_1 and V_2 regions as well as the presentation of more broadly reactive V_3s can enhance the breadth of neutralization mediated by an Env antigenic polypetpide.

[0181] In addition to the V_3-mediated neutralization, other variable regions contribute to virus neutralization when V_3 is not exposed. Among these, a highly exposed region in V_1 was identified. Although this region is highly likely to show strain-specific variation, there are also conserved subregions within the V_1 that contribute to increased breadth of the immune response to this variable loop.

[0182] The ability to define improved immunogens using genetic information based on viral diversity can improve the ability to design effective HIV vaccines. The results described above demonstrate that genotypic sequence variation can result in neutralization sensitivities that are independent of clade. This finding has important

implications for the design of improved HIV immunogens based on genetic sequence.

[0183] In view of the many possible embodiments to which the principles of the disclosed invention may be applied, it should be recognized that the illustrated embodiments are only preferred examples of the invention and should not be taken as limiting the scope of the invention. Rather, the scope of the invention is defined by the following claims. We therefore claim as our invention all that comes within the scope and spirit of these claims.

[0184] Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is solely for the purpose of providing a context for the present invention. It is not to be taken as an admission that any or all of these matters form part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed before the priority date of each claim of this application.

[0185] Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of inducing an immune response against HIV in a human subject, wherein said method comprises:

(i) administering a first composition to a human subject, wherein the first composition comprises as separate plasmids:

(a) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C;

(d) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Gag protein from clade B;

(e) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Pol protein from clade B; and

(f) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Nef protein from clade B; and

and wherein the plasmids are in combination with:

(g) a pharmaceutically acceptable carrier or excipient, and

(ii) administering a second composition to the human subject after administration of the first composition to the human subject, wherein the second composition comprises as separate adenoviral vectors:

(a) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C; and

(d) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Gag-Pol fusion protein from clade B;

and wherein the adenoviral vectors are in combination with:

(e) a pharmaceutically acceptable carrier or excipient,

to thereby induce an immune response against HIV in the human subject.

2. A method of treating or preventing HIV infection is a human subject, wherein said method comprises:

(i) administering a first composition to a human subject, wherein the first composition comprises as separate plasmids:

(a) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C;

(d) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Gag protein from clade B;

(e) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Pol protein from clade B; and

(f) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Nef protein from clade B;

and wherein the plasmids are in combination with:

(g) a pharmaceutically acceptable carrier or excipient, and

(ii) administering a second composition to the human subject after administration of the first composition to the human subject, wherein the second composition comprises as separate adenoviral vectors:

(a) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C; and

(d) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Gag-Pol fusion protein from clade B; and

wherein the adenoviral vectors are in combination with:

(e) a pharmaceutically acceptable carrier or excipient,

to thereby induce an immune response against HIV in the human subject.

3. The method of claim 1 or claim 2, wherein each of the Env proteins from clade A, B and C encoded by a plasmid of the first composition is a gp145 protein which lacks (a) the fusion and cleavage domains and (b) the interspace between heptad (H) 1 and 2.

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4. The method according to any one of claims 1 to 3, wherein each of the Env proteins from clade A, B and C encoded by an adenoviral vector of the second composition is HIV gp140 or gp140dv12.

5. The method according to any one of claims 1 to 4, wherein one or more of the nucleic acids that comprise a sequence encoding the HIV Env, Gag, Pol, Nef, and/or Gag-Nef-Pol protein comprise codons optimized for expression in a human subject.

6. The method according to any one of claims 1 to 5, wherein the first composition is administered to the human subject at least one week prior to administration of the second composition to the human subject.

7. The method according to any one of claims 1 to 6, wherein the first composition is administered to the human subject three months prior to administration of the second composition to the human subject.

8. The method according to any one of claims 1 to 6, wherein the first composition is administered to the human subject nine months prior to administration of the second composition to the human.

9. The method according to any one of claims 1 to 8, wherein the first composition is administered to the human subject two or more times prior to administration of the second composition to the human subject.

10. The method according to any one of claims 1 to 9, wherein the immune response is protective against multiple clades or strains of HIV.

11. The method according to any one of claims 1 to 10, wherein the first composition and the second composition are administered to the human subject intramuscularly or via a needleless delivery device.

12. The method according to any one of claims 1 to 11, wherein one or more of the adenoviral vectors of the second composition is replication-deficient.

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13. Use of a multidose composition comprising a first dosage unit and a second dosage unit to inducing an immune response against HIV in a human subject or to treat or prevent HIV infection in a subject, wherein:

(i) said first dosage unit comprises as separate plasmids:

(a) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C;

(d) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Gag protein from clade B;

(e) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Pol protein from clade B; and

(f) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Nef protein from clade B; and

(ii) said second dosage unit comprises as separate adenoviral vectors:

(a) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C; and

(d) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Gag-Pol fusion protein from clade B;

and wherein the adenoviral vectors are in combination with:

(e) a pharmaceutically acceptable carrier or excipient; and

wherein the second dosage unit is formulated for administration to the human subject after administration of the first dosage unit to the human subject.

14. Use of a multidose composition comprising a first dosage unit and a second dosage unit in the preparation of a medicament to induce an immune response against HIV in a human subject or to treat or prevent HIV infection in a subject, wherein:

(i) said first dosage unit comprises as separate plasmids:

(a) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C;

(d) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Gag protein from clade B;

(e) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Pol protein from clade B;

(f) a plasmid comprising a nucleic acid that comprises a sequence encoding an HIV Nef protein from clade B; and

(ii) said second dosage unit comprises as separate adenoviral vectors:

(a) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade A;

(b) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade B;

(c) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Env protein from clade C;

(d) an adenoviral vector comprising a nucleic acid that comprises a sequence encoding an HIV Gag-Pol fusion protein from clade B; and

and wherein the adenoviral vectors are in combination with:

(e) a pharmaceutically acceptable carrier or excipient; and

wherein the second dosage unit is formulated for administration to the human subject after administration of the first dosage unit to the human subject.

15. The use of claim 13 or claim 14, wherein each of the Env proteins from clade A, B and C encoded by a plasmid of the first dosage unit is a gp145 protein which lacks (a) the fusion and cleavage domains and (b) the interspace between heptad (H) 1 and 2.

16. The use according to any one of claims 13 to 15, wherein each of the Env proteins from clade A, B and C encoded by an adenoviral vector of the second dosage unit is HIV gp140 or gp140dv12.

17. The use according to any one of claims 13 to 16, wherein one or more of the nucleic acids that comprise a sequence encoding the HIV Env, Gag, Pol, Nef, and/or Gag-Nef-Pol protein comprise codons optimized for expression in a human subject.

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18. The use according to any one of claims 13 to 17, wherein one or more of the adenoviral vectors of the second dosage unit is replication-deficient.

19. The method according to any one of claims 1 to 12 or the use according to any one of claims 13 to 18, wherein the human subject is immunocompetent and/or been previously exposed to HIV.

20. The method according to any one of claims 1 to 12 or claim 19 or the use according to claims 13 to 19 substantially as hereinbefore described with reference to the accompanying Examples and/or Drawings and/or Sequence Listing.

DATED this TENTH day of AUGUST, 2011

The Government of the United States of America, as represented by the Secretary, Department of Health and Human Services
-and-
Genvec, Inc.
By patent attorneys for the applicants:
F.B. Rice

Editorial Note;

The Gene Sequence pages attached to the Drawings have been separated and are now in the Document Type of Gene Sequence on the application.

Pat Robertson 02.09.2011

FIG. 1

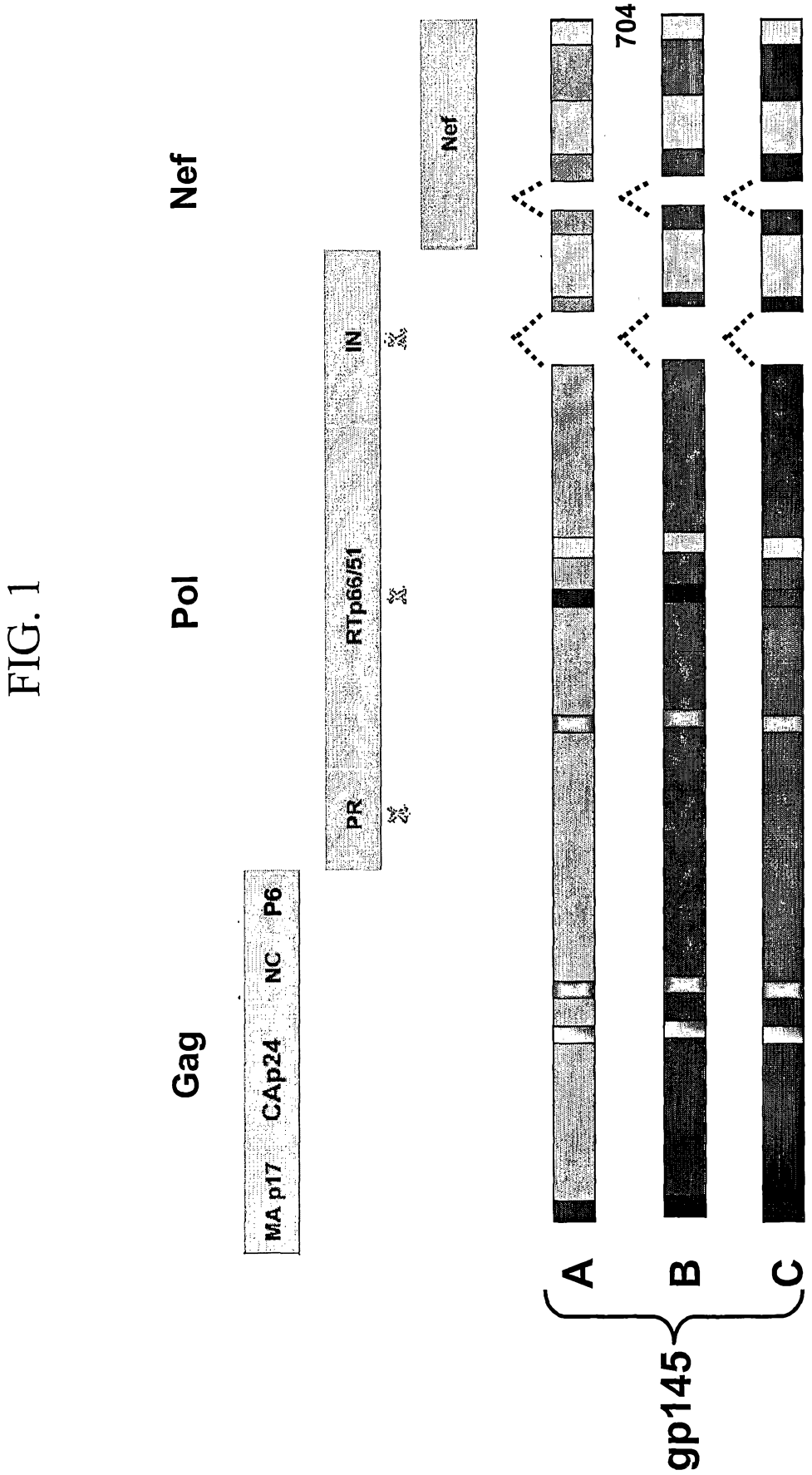


FIG. 2

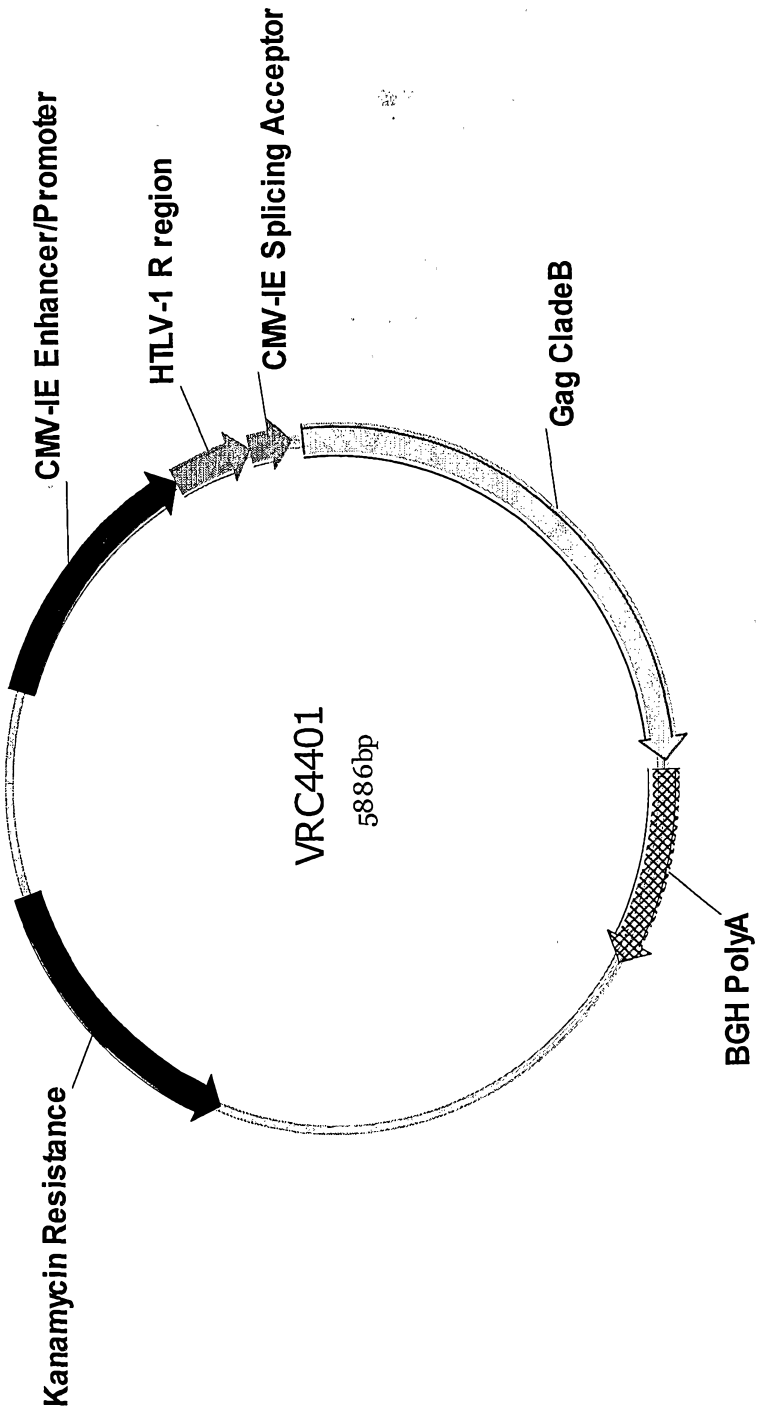

CMV-IE Enhancer/Promoter
HTLV-1 R region
CMV-IE Splicing Acceptor
Gag CladeB
VRC4401
5886bp
BGH PolyA
Kanamycin Resistance

FIG. 3

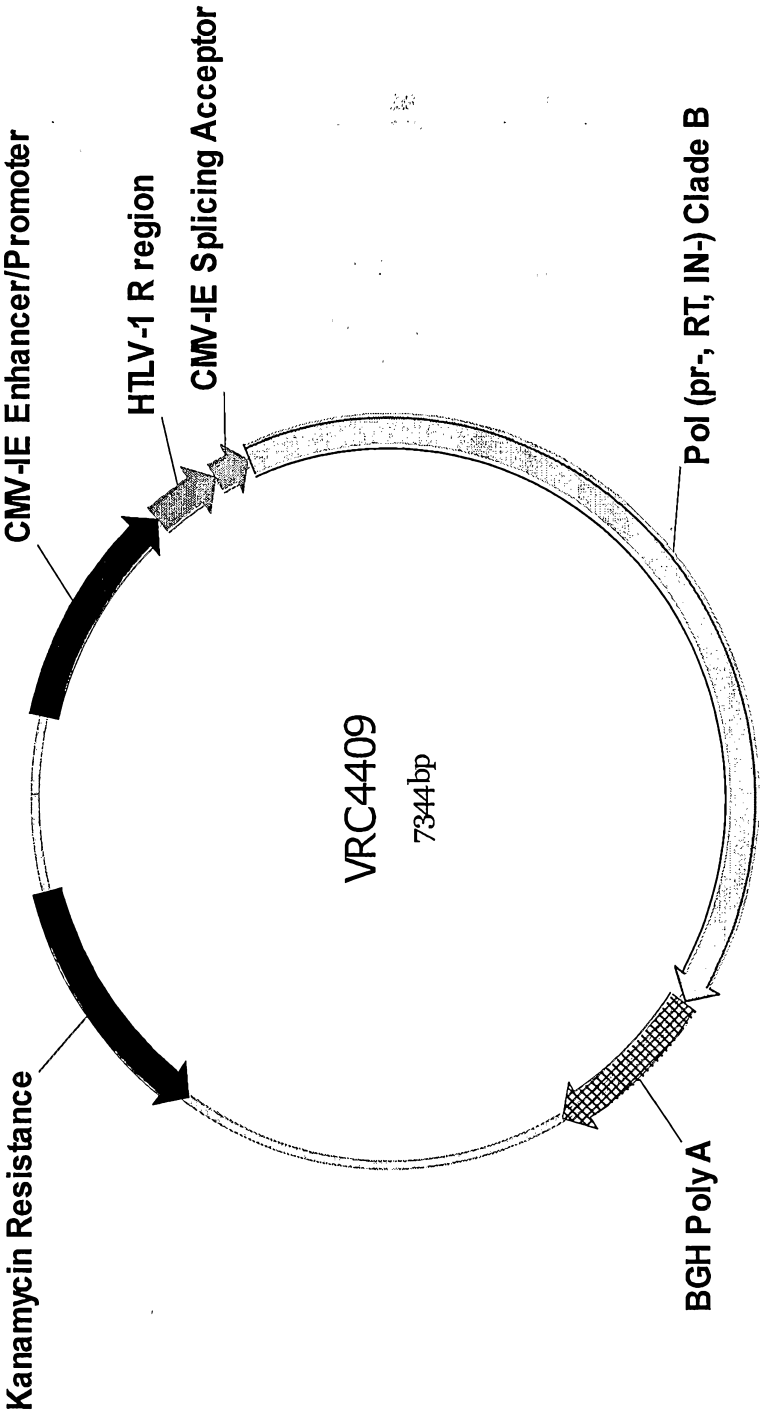
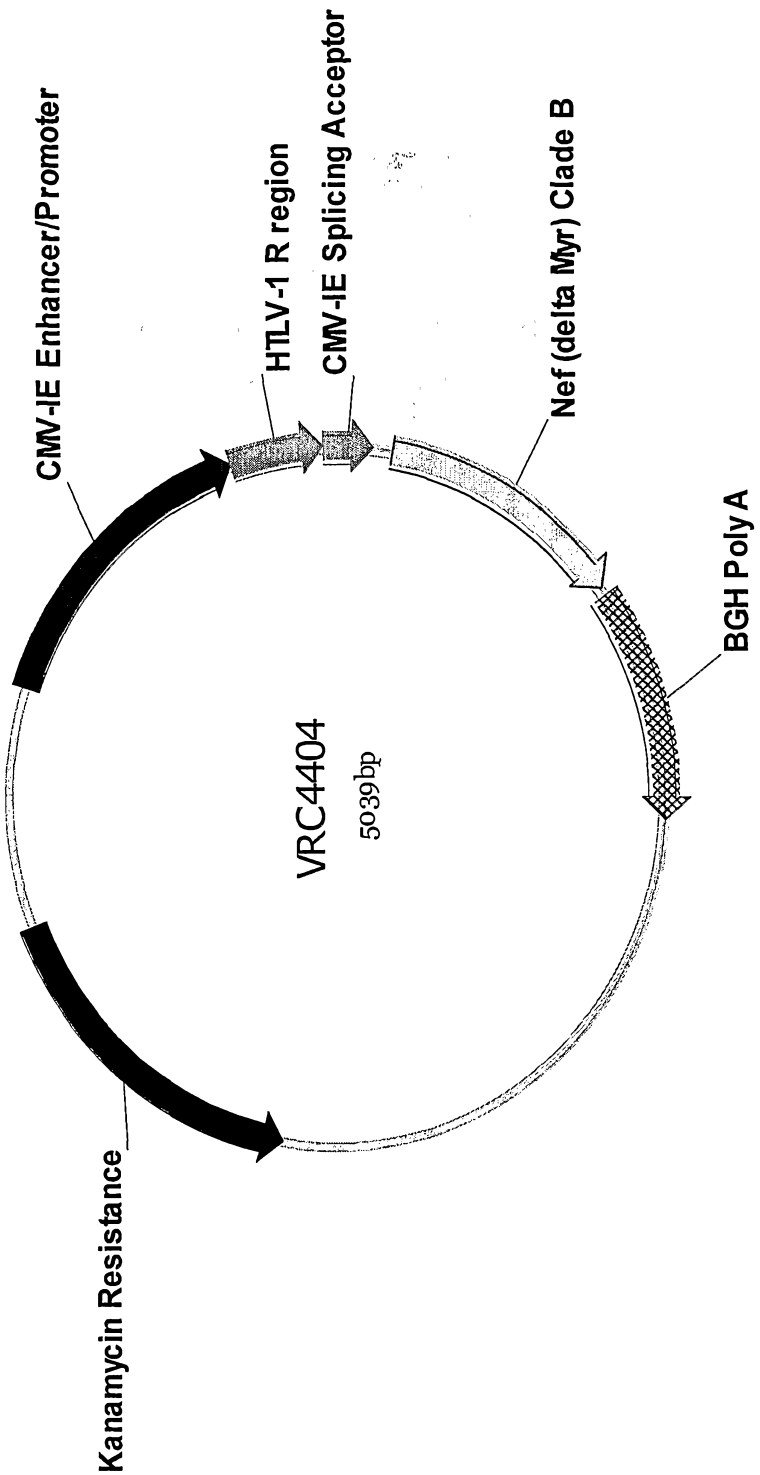

CMV-IE Enhancer/Promoter
HTLV-1 R region
CMV-IE Splicing Acceptor
Pol (pr-, RT, IN-) Clade B
VRC4409
7344bp
Kanamycin Resistance
BGH Poly A

FIG. 4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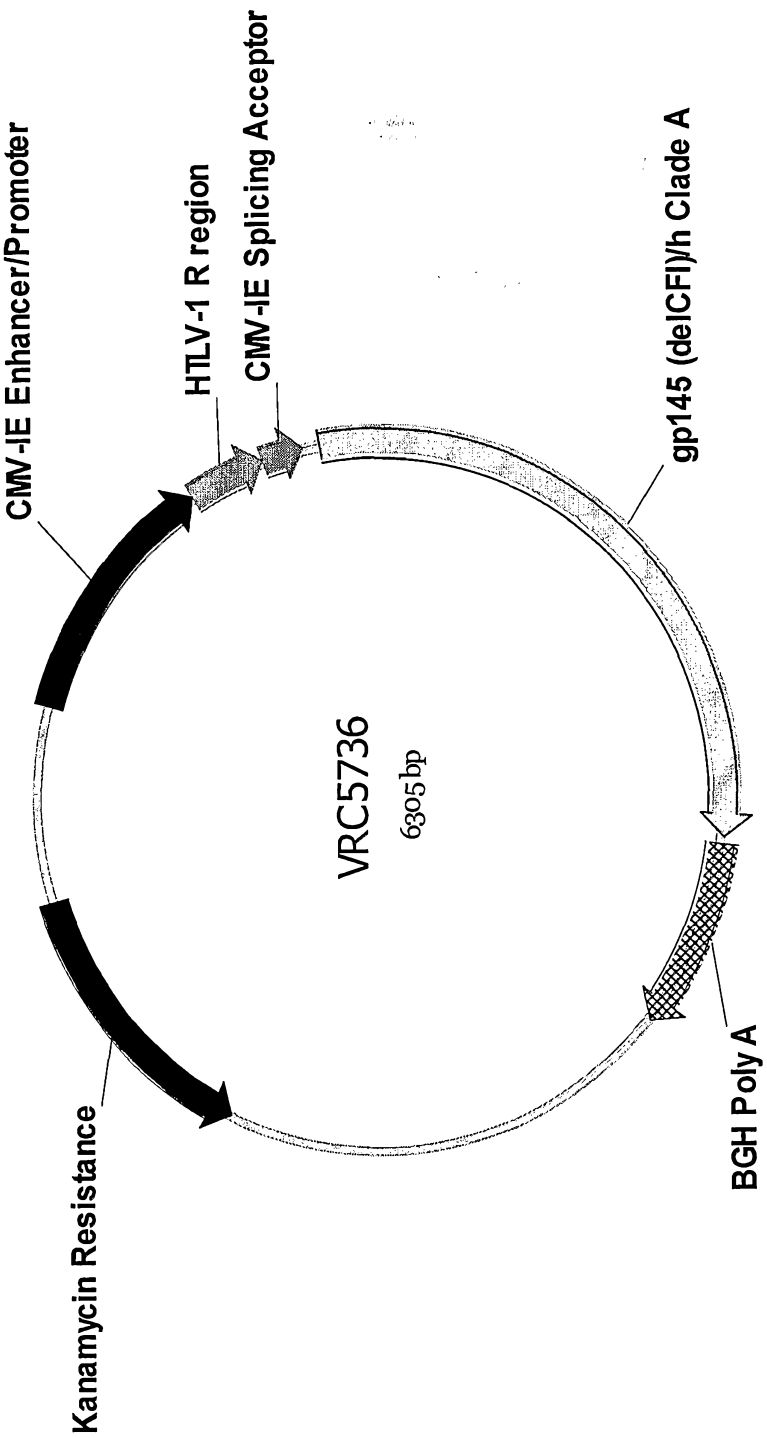
HTLV-1 R region
CMV-IE Splicing Acceptor
Nef (delta Myr) Clade B
BGH Poly A
VRC4404
5039bp
Kanamycin Resistance

FIG. 5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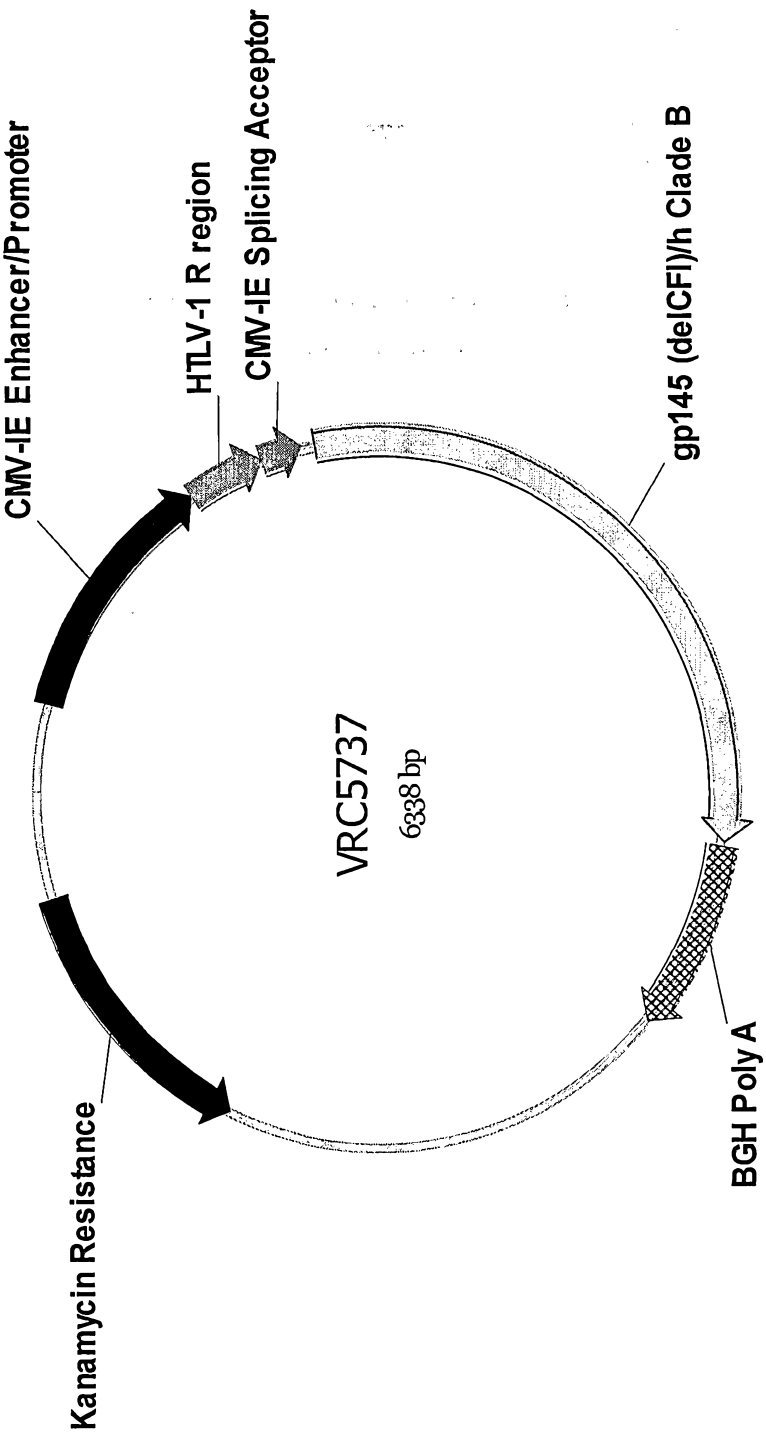
CMV-IE Splicing Acceptor
gp145 (delCFI)/h Clade A
VRC5736
6305 bp
Kanamycin Resistance
BGH Poly A

FIG. 6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gp145 (delCFI)/h Clade B
VRC5737
6338 bp
Kanamycin Resistance
BGH Poly A

FIG. 7

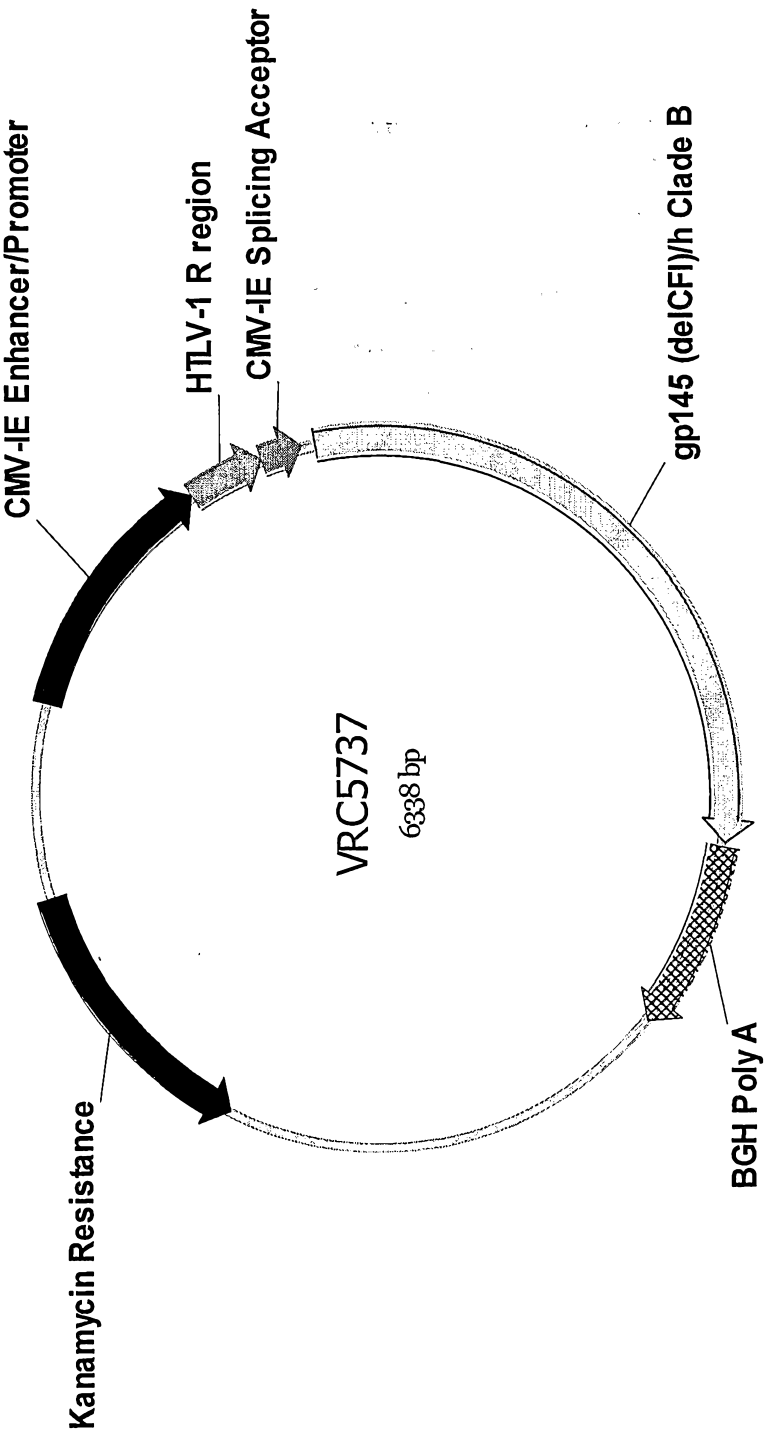

CMV-IE Enhancer/Promoter
HTLV-1 R region
CMV-IE Splicing Acceptor
gp145 (delCFI)/h Clade B
VRC5737
6338 bp
Kanamycin Resistance
BGH Poly A

FIG. 8

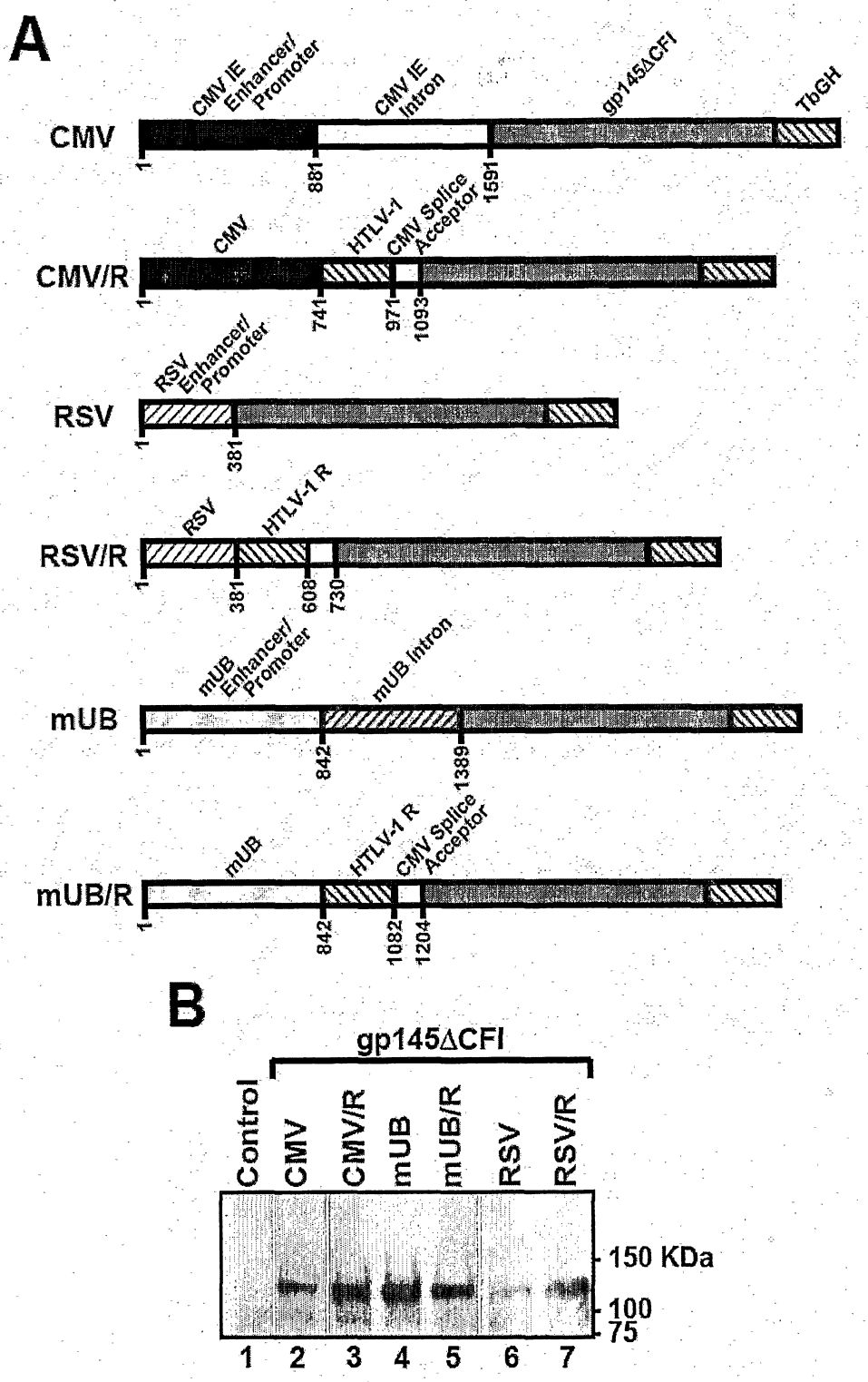

A
CMV
CMV IE Enhancer/ Promoter
CMV IE Intron
gp145ΔCFI
TpGH
1
881
1591
CMV/R
CMV
HTLV-1
CMV Splice Acceptor
1
741
971
1093
RSV
RSV Enhancer/ Promoter
1
381
RSV/R
RSV
HTLV-1 R
1
381
608
730
mUB
mUB Enhancer/ Promoter
mUB Intron
1
842
1389
mUB/R
mUB
HTLV-1 R
CMV Splice Acceptor
1
842
1082
1204
B
gp145ΔCFI
Control
CMV
CMV/R
mUB
mUB/R
RSV
RSV/R
150 KDa
100
75
1 2 3 4 5 6 7

FIG. 9

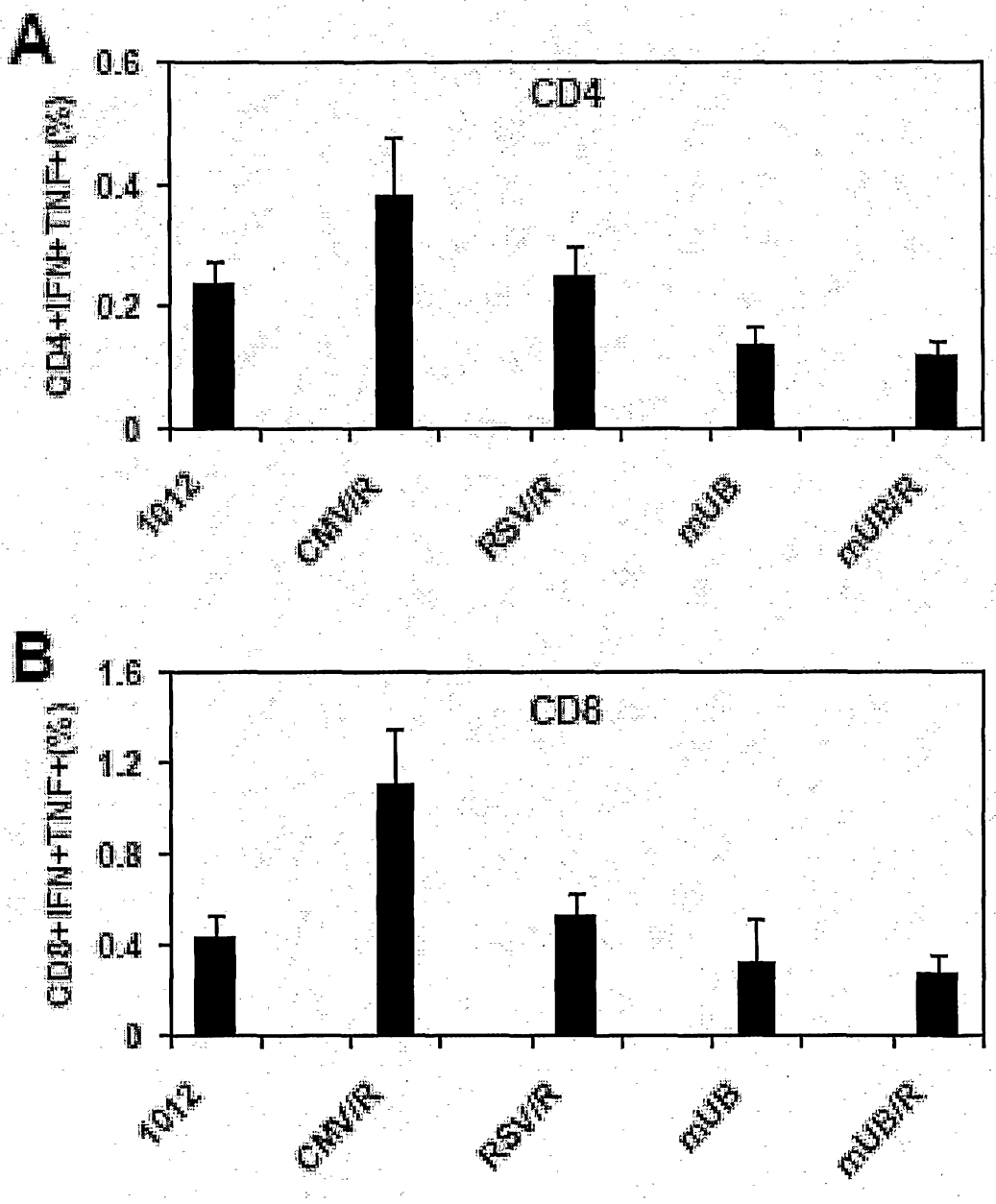

A
CD4
CD4+IFN+TNF+(%)
0.6
0.4
0.2
0
1012
CMVIR
RSVIR
mUB
mUBIR
B
CD8
CD8+IFN+TNF+(%)
1.6
1.2
0.8
0.4
0
1012
CMVIR
RSVIR
mUB
mUBIR

FIG. 10

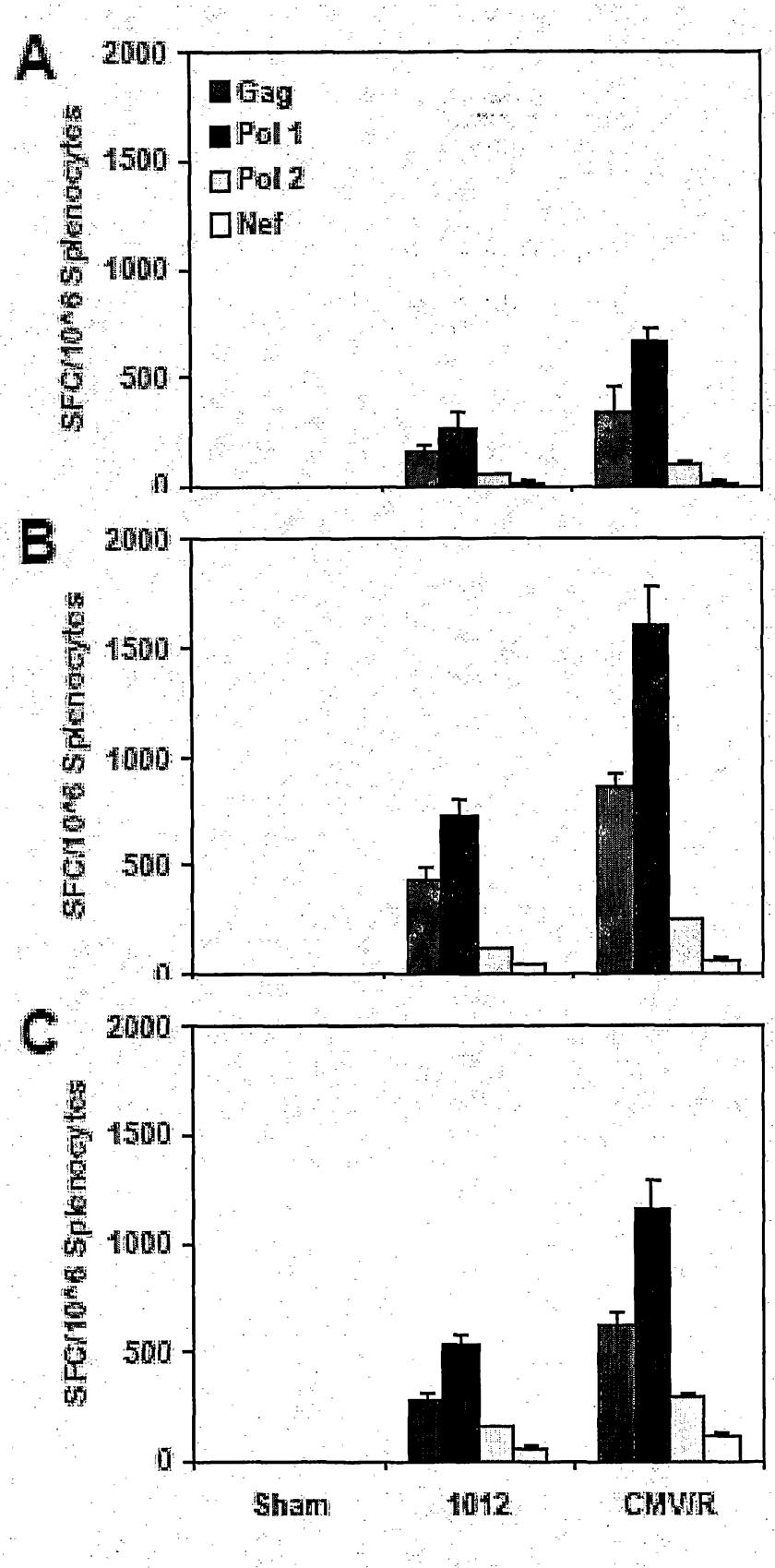

A
B
C
2000
1500
1000
500
0
Gag
Pol 1
Pol 2
Nef
SFC/10^6 Splenocytes
Sham
1012
CMVIR

FIG. 11

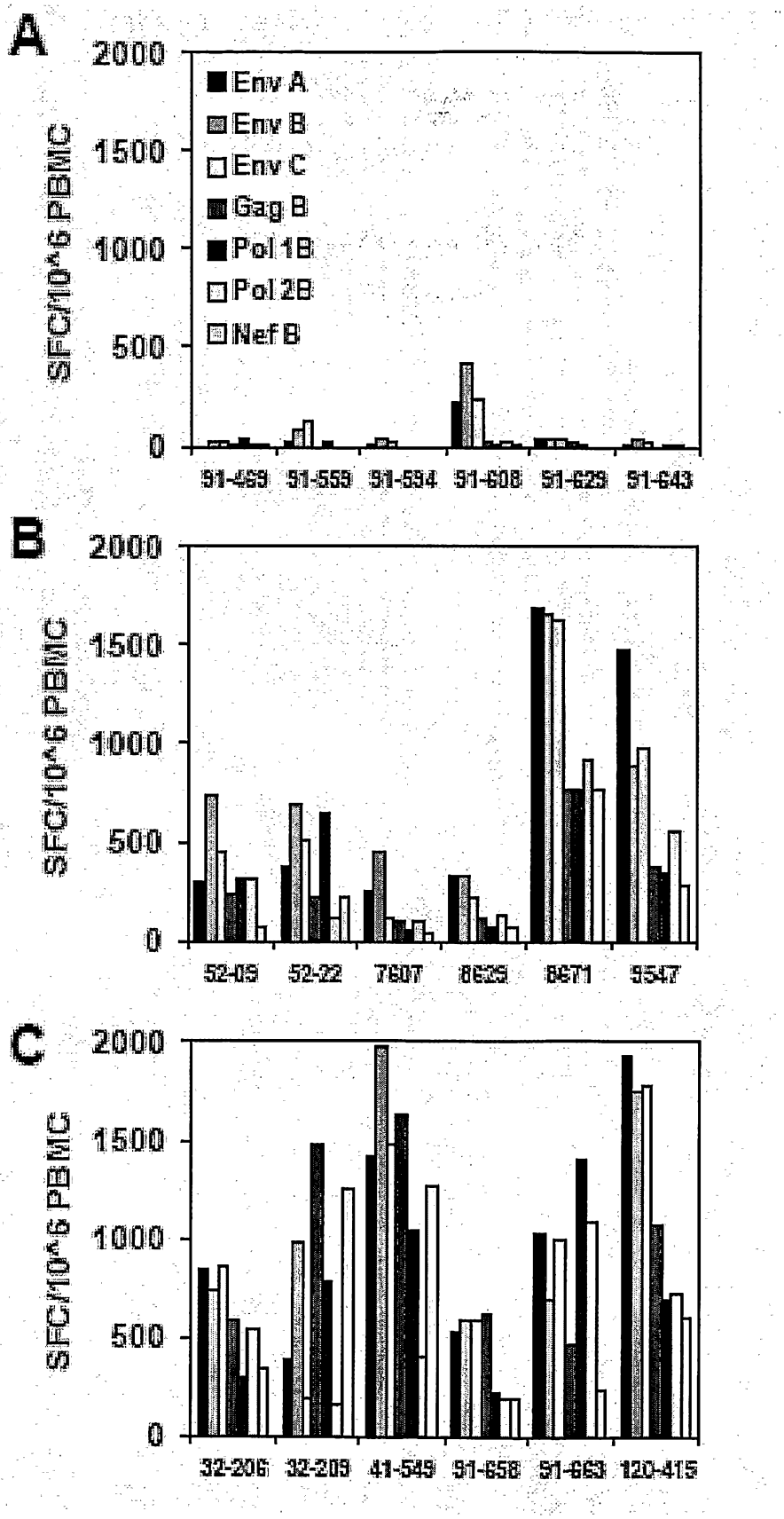

A
2000
1500
1000
500
0
SFC/10^6 PBMC
Env A
Env B
Env C
Gag B
Pol 1B
Pol 2B
Nef B
91-469
91-559
91-594
91-608
91-629
91-643
B
2000
1500
1000
500
0
SFC/10^6 PBMC
52-09
52-22
7607
8629
8671
9547
C
2000
1500
1000
500
0
SFC/10^6 PBMC
32-206
32-209
41-549
91-658
91-663
120-415

FIG. 12

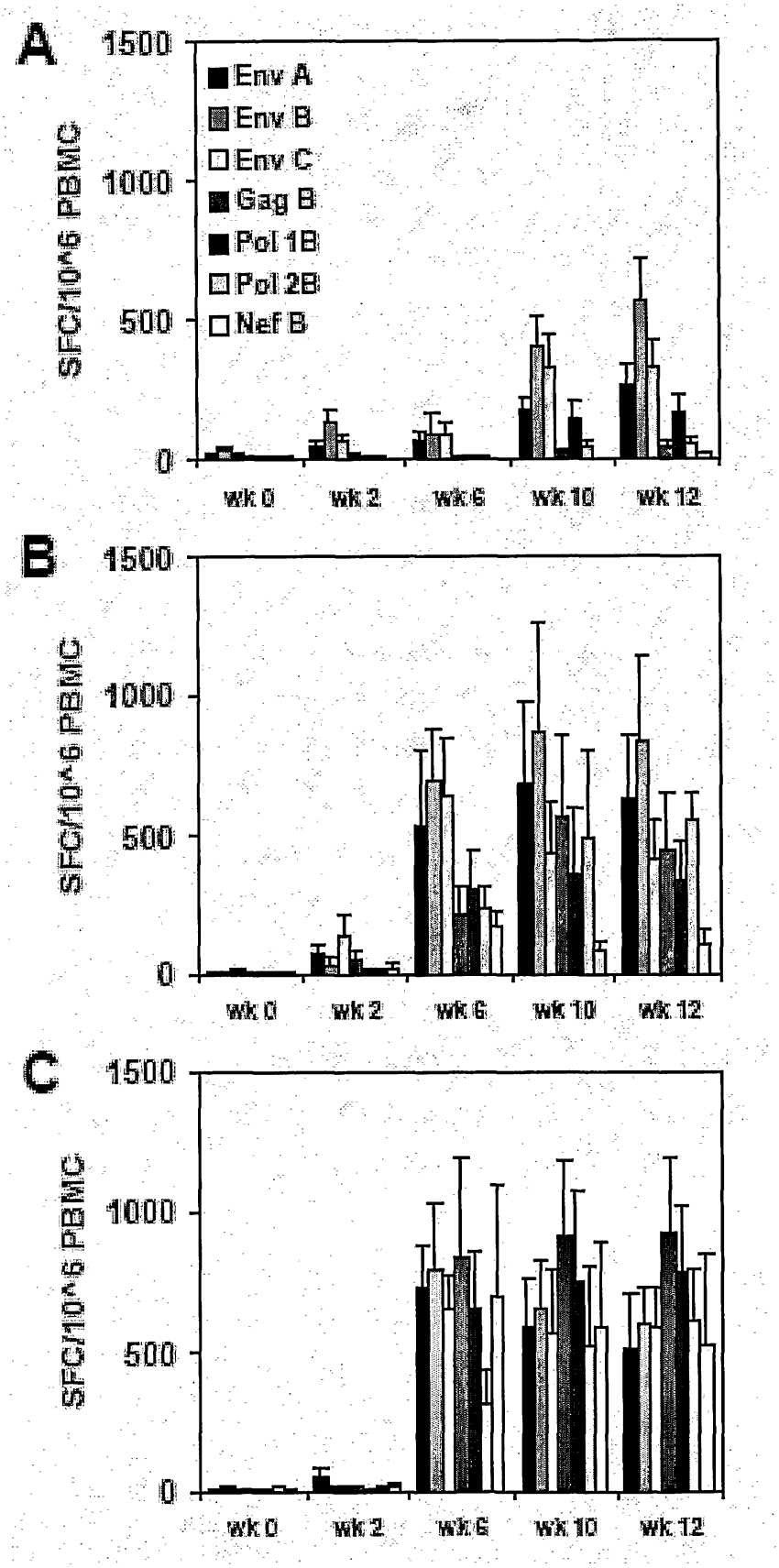
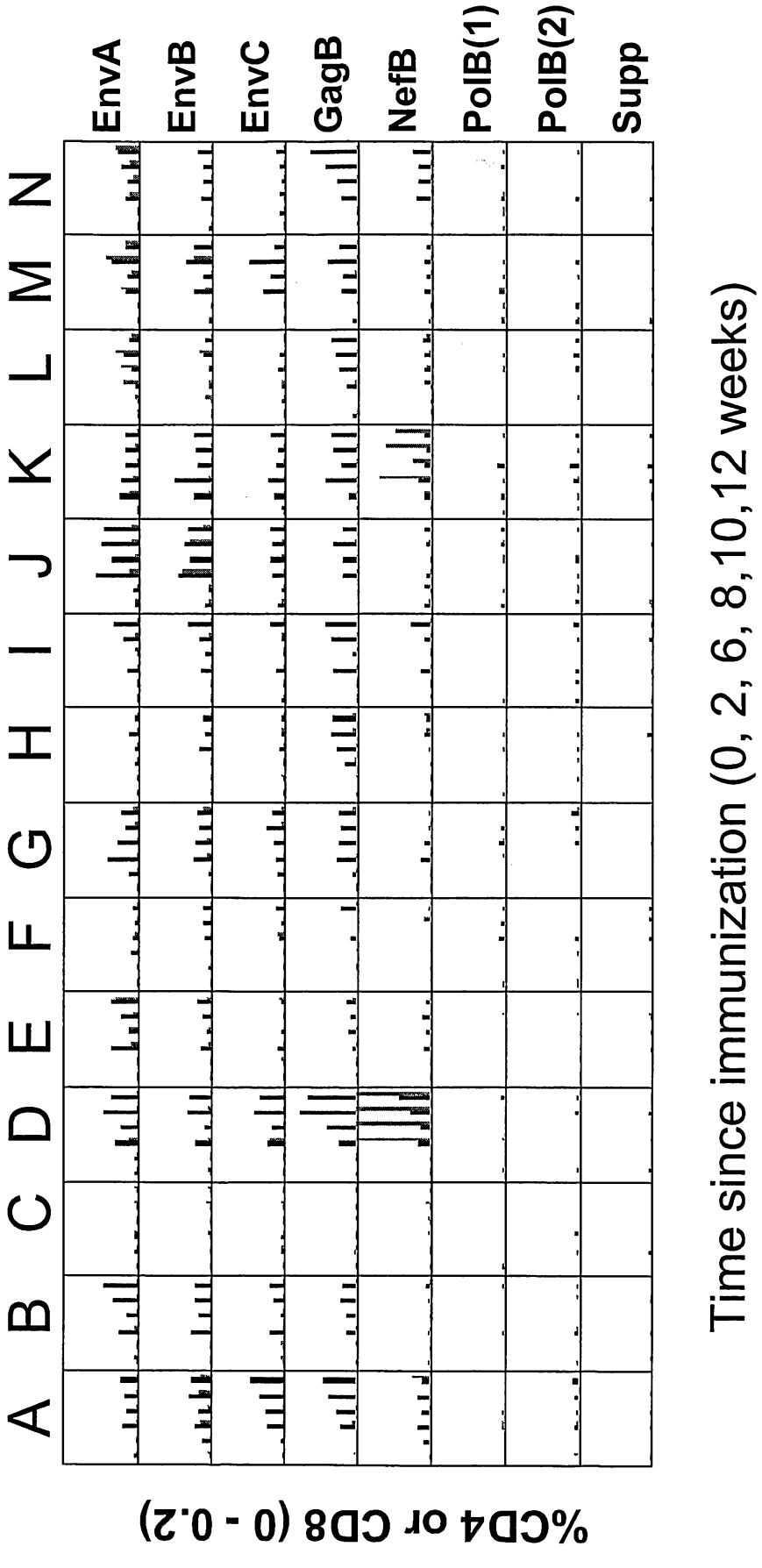

A
B
C
1500
1000
500
0
SFC/10^6 PBMC
Env A
Env B
Env C
Gag B
Pol 1B
Pol 2B
Nef B
wk 0
wk 2
wk 6
wk 10
wk 12

FIG. 13


EnvA
EnvB
EnvC
GagB
NefB
PolB(1)
PolB(2)
Supp
A B C D E F G H I J K L M N
%CD4 or CD8 (0 - 0.2)
Time since immunization (0, 2, 6, 8,10,12 weeks)

SEQUENCE LISTING

<110> The Government of the United States of America as represented by the Secretary of the Department of Health and Human Services
GenVec, Inc.
Nabel, Gary
Huang, Yue
Xu, Ling
Chakrabarti, Bimal
Wu, Lan
Yang, Zhi-yong
Gall, Jason G.D.
King, C. Richter

<120> VACCINE CONSTRUCTS AND COMBINATIONS OF VACCINES DESIGNED TO IMPROVE THE BREADTH OF THE IMMUNE RESPONSE TO DIVERSE STRAINS AND CLADES OF HIV

<130> 4239-71329-02

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<151> 2004-09-15

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Lys Lys Ala Gln Gln Ala Ala Ala Asp Thr Gly His Ser Asn Gln Val
115 120 125

Ser Gln Asn Tyr Pro Ile Val Gln Asn Ile Gln Gly Gln Met Val His
130 135 140

Gln Ala Ile Ser Pro Arg Thr Leu Asn Ala Trp Val Lys Val Val Glu
145 150 155 160

Glu Lys Ala Phe Ser Pro Glu Val Ile Pro Met Phe Ser Ala Leu Ser
165 170 175

Glu Gly Ala Thr Pro Gln Asp Leu Asn Thr Met Leu Asn Thr Val Gly
180 185 190

Gly His Gln Ala Ala Met Gln Met Leu Lys Glu Thr Ile Asn Glu Glu
195 200 205

Ala Ala Glu Trp Asp Arg Val His Pro Val His Ala Gly Pro Ile Ala
210 215 220

```
Pro Gly Gln Met Arg Glu Pro Arg Gly Ser Asp Ile Ala Gly Thr Thr
225                 230                 235                 240

Ser Thr Leu Gln Glu Gln Ile Gly Trp Met Thr Asn Asn Pro Pro Ile
                245                 250                 255

Pro Val Gly Glu Ile Tyr Lys Arg Trp Ile Ile Leu Gly Leu Asn Lys
            260                 265                 270

Ile Val Arg Met Tyr Ser Pro Thr Ser Ile Leu Asp Ile Arg Gln Gly
        275                 280                 285

Pro Lys Glu Pro Phe Arg Asp Tyr Val Asp Arg Phe Tyr Lys Thr Leu
    290                 295                 300

Arg Ala Glu Gln Ala Ser Gln Glu Val Lys Asn Trp Met Thr Glu Thr
305                 310                 315                 320

Leu Leu Val Gln Asn Ala Asn Pro Asp Cys Lys Thr Ile Leu Lys Ala
                325                 330                 335

Leu Gly Pro Ala Ala Thr Leu Glu Glu Met Met Thr Ala Cys Gln Gly
            340                 345                 350

Val Gly Gly Pro Gly His Lys Ala Arg Val Leu Ala Glu Ala Met Ser
        355                 360                 365

Gln Val Thr Asn Ser Ala Thr Ile Met Met Gln Arg Gly Asn Phe Arg
    370                 375                 380

Asn Gln Arg Lys Ile Val Lys Cys Phe Asn Cys Gly Lys Glu Gly His
385                 390                 395                 400

Thr Ala Arg Asn Cys Arg Ala Pro Arg Lys Lys Gly Cys Trp Lys Cys
                405                 410                 415

Gly Lys Glu Gly His Gln Met Lys Asp Cys Thr Glu Arg Gln Ala Asn
            420                 425                 430

Phe Leu Gly Lys Ile Trp Pro Ser His Lys Gly Arg Pro Gly Asn Phe
        435                 440                 445

Leu Gln Ser Arg Pro Glu Pro Thr Ala Pro Pro Glu Glu Ser Phe Arg
    450                 455                 460

Phe Gly Glu Glu Thr Thr Thr Pro Ser Gln Lys Gln Glu Pro Ile Asp
465                 470                 475                 480

Lys Glu Leu Tyr Pro Leu Ala Ser Leu Arg Ser Leu Phe Gly Ser Asp
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485 490 495

Pro Ser Ser Gln
500

<210> 21
<211> 1002
<212> PRT
<213> HIV

<400> 21

Met Arg Glu Asp Leu Ala Phe Pro Gln Gly Lys Ala Arg Glu Phe Ser
1 5 10 15

Ser Glu Gln Thr Arg Ala Asn Ser Pro Thr Arg Arg Glu Leu Gln Val
20 25 30

Trp Gly Arg Asp Asn Asn Ser Leu Ser Glu Ala Gly Ala Asp Arg Gln
35 40 45

Gly Thr Val Ser Phe Ser Phe Pro Gln Ile Thr Leu Trp Gln Arg Pro
50 55 60

Leu Val Thr Ile Lys Ile Gly Gly Gln Leu Lys Glu Ala Leu Leu Asp
65 70 75 80

Thr Gly Ala Asp Asp Thr Val Leu Glu Glu Met Asn Leu Pro Gly Arg
85 90 95

Trp Lys Pro Lys Met Ile Gly Gly Ile Gly Gly Phe Ile Lys Val Gly
100 105 110

Gln Tyr Asp Gln Ile Leu Ile Glu Ile Cys Gly His Lys Ala Ile Gly
115 120 125

Thr Val Leu Val Gly Pro Thr Pro Val Asn Ile Ile Gly Arg Asn Leu
130 135 140

Leu Thr Gln Ile Gly Cys Thr Leu Asn Phe Pro Ile Ser Pro Ile Glu
145 150 155 160

Thr Val Pro Val Lys Leu Lys Pro Gly Met Asp Gly Pro Lys Val Lys
165 170 175

Gln Trp Pro Leu Thr Glu Glu Lys Ile Lys Ala Leu Val Glu Ile Cys
180 185 190

Thr Glu Met Glu Lys Glu Gly Lys Ile Ser Lys Ile Gly Pro Glu Asn
195 200 205

```
Pro Tyr Asn Thr Pro Val Phe Ala Ile Lys Lys Lys Asp Ser Thr Lys
    210                 215                 220

Trp Arg Lys Leu Val Asp Phe Arg Glu Leu Asn Lys Arg Thr Gln Asp
225                 230                 235                 240

Phe Trp Glu Val Gln Leu Gly Ile Pro His Pro Ala Gly Leu Lys Gln
                245                 250                 255

Lys Lys Ser Val Thr Val Leu Asp Val Gly Asp Ala Tyr Phe Ser Val
            260                 265                 270

Pro Leu Asp Lys Asp Phe Arg Lys Tyr Thr Ala Phe Thr Ile Pro Ser
        275                 280                 285

Ile Asn Asn Glu Thr Pro Gly Ile Arg Tyr Gln Tyr Asn Val Leu Pro
    290                 295                 300

Gln Gly Trp Lys Gly Ser Pro Ala Ile Phe Gln Cys Ser Met Thr Lys
305                 310                 315                 320

Ile Leu Glu Pro Phe Arg Lys Gln Asn Pro Asp Ile Val Ile Tyr Gln
                325                 330                 335

Tyr Met Asp His Leu Tyr Val Gly Ser Asp Leu Glu Ile Gly Gln His
            340                 345                 350

Arg Thr Lys Ile Glu Glu Leu Arg Gln His Leu Leu Arg Trp Gly Phe
        355                 360                 365

Thr Thr Pro Asp Lys Lys His Gln Lys Glu Pro Pro Phe Leu Trp Met
    370                 375                 380

Gly Tyr Glu Leu His Pro Asp Lys Trp Thr Val Gln Pro Ile Val Leu
385                 390                 395                 400

Pro Glu Lys Asp Ser Trp Thr Val Asn Asp Ile Gln Lys Leu Val Gly
                405                 410                 415

Lys Leu Asn Trp Ala Ser Gln Ile Tyr Ala Gly Ile Lys Val Arg Gln
            420                 425                 430

Leu Cys Lys Leu Leu Arg Gly Thr Lys Ala Leu Thr Glu Val Val Pro
        435                 440                 445

Leu Thr Glu Glu Ala Glu Leu Glu Leu Ala Glu Asn Arg Glu Ile Leu
    450                 455                 460
```

```
Lys Glu Pro Val His Gly Val Tyr Tyr Asp Pro Ser Lys Asp Leu Ile
465                 470                 475                 480

Ala Glu Ile Gln Lys Gln Gly Gln Gly Gln Trp Thr Tyr Gln Ile Tyr
                485                 490                 495

Gln Glu Pro Phe Lys Asn Leu Lys Thr Gly Lys Tyr Ala Arg Met Lys
            500                 505                 510

Gly Ala His Thr Asn Asp Val Lys Gln Leu Thr Glu Ala Val Gln Lys
        515                 520                 525

Ile Ala Thr Glu Ser Ile Val Ile Trp Gly Lys Thr Pro Lys Phe Lys
    530                 535                 540

Leu Pro Ile Gln Lys Glu Thr Trp Glu Ala Trp Trp Thr Glu Tyr Trp
545                 550                 555                 560

Gln Ala Thr Trp Ile Pro Glu Trp Glu Phe Val Asn Thr Pro Pro Leu
                565                 570                 575

Val Lys Leu Trp Tyr Gln Leu Glu Lys Glu Pro Ile Ile Gly Ala Glu
            580                 585                 590

Thr Phe Tyr Val Asp Gly Ala Ala Asn Arg Glu Thr Lys Leu Gly Lys
        595                 600                 605

Ala Gly Tyr Val Thr Asp Arg Gly Arg Gln Lys Val Val Pro Leu Thr
    610                 615                 620

Asp Thr Thr Asn Gln Lys Thr Glu Leu Gln Ala Ile His Leu Ala Leu
625                 630                 635                 640

Gln Asp Ser Gly Leu Glu Val Asn Ile Val Thr Asp Ser Gln Tyr Ala
                645                 650                 655

Leu Gly Ile Ile Gln Ala Gln Pro Asp Lys Ser Glu Ser Glu Leu Val
            660                 665                 670

Ser Gln Ile Ile Glu Gln Leu Ile Lys Lys Glu Lys Val Tyr Leu Ala
        675                 680                 685

Trp Val Pro Ala His Lys Gly Ile Gly Gly Asn Glu Gln Val Asp Gly
    690                 695                 700

Leu Val Ser Ala Gly Ile Arg Lys Val Leu Phe Leu Asp Gly Ile Asp
705                 710                 715                 720

Lys Ala Gln Glu Glu His Glu Lys Tyr His Ser Asn Trp Arg Ala Met
```

725 730 735

Ala Ser Asp Phe Asn Leu Pro Pro Val Val Ala Lys Glu Ile Val Ala
740 745 750

Ser Cys Asp Lys Cys Gln Leu Lys Gly Glu Ala Met His Gly Gln Val
755 760 765

Asp Cys Ser Pro Gly Ile Trp Gln Leu Ala Cys Thr His Leu Glu Gly
770 775 780

Lys Val Ile Leu Val Ala Val His Val Ala Ser Gly Tyr Ile Glu Ala
785 790 795 800

Glu Val Ile Pro Ala Glu Thr Gly Gln Glu Thr Ala Tyr Phe Leu Leu
805 810 815

Lys Leu Ala Gly Arg Trp Pro Val Lys Thr Val His Thr Asp Asn Gly
820 825 830

Ser Asn Phe Thr Ser Thr Thr Val Lys Ala Ala Cys Trp Trp Ala Gly
835 840 845

Ile Lys Gln Glu Phe Gly Ile Pro Tyr Asn Pro Gln Ser Gln Gly Val
850 855 860

Ile Glu Ser Met Asn Lys Glu Leu Lys Lys Ile Ile Gly Gln Val Arg
865 870 875 880

Asp Gln Ala Glu His Leu Lys Thr Ala Val Gln Met Ala Val Phe Ile
885 890 895

His Asn Phe Lys Arg Lys Gly Gly Ile Gly Gly Tyr Ser Ala Gly Glu
900 905 910

Arg Ile Val Asp Ile Ile Ala Thr Asp Ile Gln Thr Lys Glu Leu Gln
915 920 925

Lys Gln Ile Thr Lys Ile Gln Asn Phe Arg Val Tyr Tyr Arg Asp Ser
930 935 940

Arg Asp Pro Val Trp Lys Gly Pro Ala Lys Leu Leu Trp Lys Gly Glu
945 950 955 960

Gly Ala Val Val Ile Gln Asp Asn Ser Asp Ile Lys Val Val Pro Arg
965 970 975

Arg Lys Ala Lys Ile Ile Arg Asp Tyr Gly Lys Gln Met Ala Gly Asp
980 985 990

```
Asp Cys Val Ala Ser Arg Gln Asp  Glu Asp
        995                 1000


<210>  22
<211>  204
<212>  PRT
<213>  HIV

<400>  22

Met Lys Trp Ser Lys Ser Ser Val Ile Gly Trp Pro Ala Val Arg Glu
1               5                   10                  15


Arg Met Arg Arg Ala Glu Pro Ala Ala Asp Gly Val Gly Ala Val Ser
            20                  25                  30


Arg Asp Leu Glu Lys His Gly Ala Ile Thr Ser Ser Asn Thr Ala Ala
        35                  40                  45


Asn Asn Ala Ala Cys Ala Trp Leu Glu Ala Gln Glu Glu Glu Glu Val
    50                  55                  60


Gly Phe Pro Val Thr Pro Gln Val Pro Leu Arg Pro Met Thr Tyr Lys
65                  70                  75                  80


Ala Ala Val Asp Leu Ser His Phe Leu Lys Glu Lys Gly Gly Leu Glu
                85                  90                  95


Gly Leu Ile His Ser Gln Arg Arg Gln Asp Ile Leu Asp Leu Trp Ile
            100                 105                 110


Tyr His Thr Gln Gly Tyr Phe Pro Asp Trp Gln Asn Tyr Thr Pro Gly
        115                 120                 125


Pro Gly Val Arg Tyr Pro Leu Thr Phe Gly Trp Cys Tyr Lys Leu Val
    130                 135                 140


Pro Val Glu Pro Asp Lys Val Glu Glu Ala Asn Lys Gly Glu Asn Thr
145                 150                 155                 160


Ser Leu Leu His Pro Val Ser Leu His Gly Met Asp Asp Pro Glu Arg
                165                 170                 175


Glu Val Leu Glu Trp Arg Phe Asp Ser Arg Leu Ala Phe His His Val
            180                 185                 190


Ala Arg Glu Leu His Pro Glu Tyr Phe Lys Asn Cys
        195                 200
```

<210> 23
<211> 626
<212> PRT
<213> HIV

<400> 23

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Met Arg Val Arg Gly Ile Gln Thr Ser Trp Gln Asn Leu Trp Arg Trp
1               5                  10                  15

Gly Thr Met Ile Leu Gly Met Leu Val Ile Tyr Ser Ala Ala Glu Asn
            20                  25                  30

Leu Trp Val Ala Val Tyr Tyr Gly Val Pro Val Trp Lys Asp Ala Glu
        35                  40                  45

Thr Thr Leu Phe Cys Ala Ser Asp Ala Lys Ala Tyr Asp Thr Glu Val
    50                  55                  60

His Asn Val Trp Glu Thr His Ala Cys Val Pro Thr Asp Pro Asn Pro
65                  70                  75                  80

Gln Glu Ile His Leu Glu Asn Val Thr Glu Asp Phe Asn Met Trp Arg
                85                  90                  95

Asn Asn Met Val Glu Gln Met His Thr Asp Ile Ile Ser Leu Trp Asp
            100                 105                 110

Gln Ser Leu Lys Pro Cys Val Lys Leu Thr Pro Leu Cys Val Thr Leu
        115                 120                 125

Asp Cys Asn Ala Thr Ala Ser Asn Val Thr Asn Glu Met Arg Asn Cys
    130                 135                 140

Ser Phe Asn Ile Thr Thr Glu Leu Lys Asp Lys Lys Gln Gln Val Tyr
145                 150                 155                 160

Ser Leu Phe Tyr Lys Leu Asp Val Val Gln Ile Asn Glu Lys Asn Glu
                165                 170                 175

Thr Asp Lys Tyr Arg Leu Ile Asn Cys Asn Thr Ser Ala Ile Thr Gln
            180                 185                 190

Ala Cys Pro Lys Val Ser Phe Glu Pro Ile Pro Ile His Tyr Cys Ala
        195                 200                 205

Pro Ala Gly Phe Ala Ile Leu Lys Cys Lys Asp Thr Glu Phe Asn Gly
    210                 215                 220

Thr Gly Pro Cys Lys Asn Val Ser Thr Val Gln Cys Thr His Gly Ile
225                 230                 235                 240
```

```
Arg Pro Val Ile Ser Thr Gln Leu Leu Leu Asn Gly Ser Leu Ala Glu
                245                 250                 255

Glu Gly Ile Gln Ile Arg Ser Glu Asn Ile Thr Asn Asn Ala Lys Thr
            260                 265                 270

Ile Ile Val Gln Leu Asp Lys Ala Val Lys Ile Asn Cys Thr Arg Pro
        275                 280                 285

Asn Asn Asn Thr Arg Lys Gly Val Arg Ile Gly Pro Gly Gln Ala Phe
    290                 295                 300

Tyr Ala Thr Gly Gly Ile Ile Gly Asp Ile Arg Gln Ala His Cys His
305                 310                 315                 320

Val Ser Arg Ala Lys Trp Asn Asp Thr Leu Arg Gly Val Ala Lys Lys
                325                 330                 335

Leu Arg Glu His Phe Lys Asn Lys Thr Ile Ile Phe Glu Lys Ser Ser
            340                 345                 350

Gly Gly Asp Ile Glu Ile Thr Thr His Ser Phe Ile Cys Gly Gly Glu
        355                 360                 365

Phe Phe Tyr Cys Asn Thr Ser Gly Leu Phe Asn Ser Thr Trp Glu Ser
    370                 375                 380

Asn Ser Thr Glu Ser Asn Asn Thr Thr Ser Asn Asp Thr Ile Thr Leu
385                 390                 395                 400

Thr Cys Arg Ile Lys Gln Ile Ile Asn Met Trp Gln Lys Val Gly Gln
                405                 410                 415

Ala Met Tyr Pro Pro Pro Ile Gln Gly Val Ile Arg Cys Glu Ser Asn
            420                 425                 430

Ile Thr Gly Leu Leu Leu Thr Arg Asp Gly Gly Asn Asn Ser Thr Asn
        435                 440                 445

Glu Ile Phe Arg Pro Gly Gly Gly Asn Met Arg Asp Asn Trp Arg Ser
    450                 455                 460

Glu Leu Tyr Lys Tyr Lys Val Val Lys Ile Glu Pro Leu Gly Val Ala
465                 470                 475                 480

Pro Ser Arg Ala Lys Leu Thr Ala Gln Ala Arg Gln Leu Leu Ser Gly
                485                 490                 495
```

Ile Val Gln Gln Gln Ser Asn Leu Leu Arg Ala Ile Glu Ala Gln Gln
500 505 510

His Met Leu Lys Leu Thr Val Trp Gly Ile Lys Gln Leu Gln Ala Arg
515 520 525

Val Leu Ala Val Glu Arg Tyr Leu Lys Asp Gln Gln Leu Glu Ile Trp
530 535 540

Asp Asn Met Thr Trp Leu Gln Trp Asp Lys Glu Ile Ser Asn Tyr Thr
545 550 555 560

Gln Ile Ile Tyr Asn Leu Ile Glu Glu Ser Gln Asn Gln Gln Glu Lys
565 570 575

Asn Glu Gln Asp Leu Leu Ala Leu Asp Lys Trp Ala Ser Leu Trp Asn
580 585 590

Trp Phe Asp Ile Ser Arg Trp Leu Trp Tyr Ile Lys Ile Phe Ile Met
595 600 605

Ile Val Gly Gly Leu Ile Gly Leu Arg Ile Val Phe Ala Val Leu Ser
610 615 620

Val Ile
625

<210> 24
<211> 642
<212> PRT
<213> HIV

<400> 24

Met Arg Val Lys Glu Lys Tyr Gln His Leu Trp Arg Trp Gly Trp Arg
1 5 10 15

Trp Gly Thr Met Leu Leu Gly Met Leu Met Ile Cys Ser Ala Thr Glu
20 25 30

Lys Leu Trp Val Thr Val Tyr Tyr Gly Val Pro Val Trp Lys Glu Ala
35 40 45

Thr Thr Thr Leu Leu Cys Ala Ser Asp Ala Lys Ala Tyr Asp Thr Glu
50 55 60

Val His Asn Val Trp Ala Thr His Ala Cys Val Pro Thr Asp Pro Asn
65 70 75 80

Pro Gln Glu Val Val Leu Val Asn Val Thr Glu Asn Phe Asp Met Trp

```
                85                  90                  95

Lys Asn Asp Met Val Glu Gln Met His Glu Asp Ile Ile Ser Leu Trp
            100                 105                 110

Asp Gln Ser Leu Lys Pro Cys Val Lys Leu Thr Pro Leu Cys Val Ser
        115                 120                 125

Leu Lys Cys Thr Asp Leu Lys Asn Asp Thr Asn Thr Asn Ser Ser Ser
    130                 135                 140

Gly Arg Met Ile Met Glu Lys Gly Glu Ile Lys Asn Cys Ser Phe Asn
145                 150                 155                 160

Ile Ser Thr Ser Ile Arg Gly Lys Val Gln Lys Glu Tyr Ala Phe Phe
                165                 170                 175

Tyr Lys Leu Asp Ile Ile Pro Ile Asp Asn Asp Thr Thr Ser Tyr Ser
            180                 185                 190

Leu Thr Ser Cys Asn Thr Ser Val Ile Thr Gln Ala Cys Pro Lys Val
        195                 200                 205

Ser Phe Glu Pro Ile Pro Asn His Tyr Cys Ala Pro Ala Gly Phe Ala
    210                 215                 220

Ile Leu Lys Cys Lys Asp Lys Lys Phe Asn Gly Lys Gly Pro Cys Thr
225                 230                 235                 240

Asn Val Ser Thr Val Gln Cys Thr His Gly Ile Arg Pro Val Val Ser
                245                 250                 255

Thr Gln Leu Leu Val Thr Gly Asn Leu Ala Glu Glu Glu Val Val Ile
            260                 265                 270

Arg Ser Ala Asn Phe Ala Asp Asn Ala Lys Val Ile Ile Val Gln Leu
        275                 280                 285

Asn Glu Ser Val Glu Ile Asn Cys Thr Arg Pro Asn Asn Asn Thr Arg
    290                 295                 300

Lys Ser Ile His Ile Gly Pro Gly Arg Ala Phe Tyr Thr Thr Gly Glu
305                 310                 315                 320

Ile Ile Gly Asp Ile Arg Gln Ala His Cys Asn Leu Ser Arg Ala Lys
                325                 330                 335

Trp Asn Asp Thr Leu Asn Lys Ile Val Ile Lys Leu Arg Glu Gln Phe
            340                 345                 350
```

```
Gly Asn Lys Thr Ile Val Phe Lys His Ser Ser Gly Gly Asp Pro Glu
        355                 360                 365

Ile Val Thr His Ser Phe Asn Cys Gly Gly Glu Phe Phe Tyr Cys Asn
    370                 375                 380

Ser Thr Gln Leu Phe Asn Ser Thr Trp Phe Asn Ser Thr Trp Ser Thr
385                 390                 395                 400

Glu Gly Ser Asn Asn Thr Glu Gly Ser Asp Thr Ile Thr Leu Pro Cys
                405                 410                 415

Arg Ile Lys Gln Ile Ile Asn Met Trp Gln Lys Val Gly Lys Ala Met
            420                 425                 430

Tyr Ala Pro Pro Ile Ser Gly Gln Ile Arg Cys Ser Ser Asn Ile Thr
        435                 440                 445

Gly Leu Leu Leu Thr Arg Asp Gly Gly Asn Ser Asn Asn Glu Ser Glu
    450                 455                 460

Ile Phe Arg Leu Gly Gly Gly Asp Met Arg Asp Asn Trp Arg Ser Glu
465                 470                 475                 480

Leu Tyr Lys Tyr Lys Val Val Lys Ile Glu Pro Leu Gly Val Ala Pro
                485                 490                 495

Thr Lys Ala Lys Leu Thr Val Gln Ala Arg Gln Leu Leu Ser Gly Ile
            500                 505                 510

Val Gln Gln Gln Asn Asn Leu Leu Arg Ala Ile Glu Ala Gln Gln His
        515                 520                 525

Leu Leu Gln Leu Thr Val Trp Gly Ile Lys Gln Leu Gln Ala Arg Thr
    530                 535                 540

Leu Ala Val Glu Arg Tyr Leu Lys Asp Gln Gln Leu Leu Glu Gln Ile
545                 550                 555                 560

Trp Asn His Thr Thr Trp Met Glu Trp Asp Arg Glu Ile Asn Asn Tyr
                565                 570                 575

Thr Ser Leu Ile His Ser Leu Ile Glu Glu Ser Gln Asn Gln His Glu
            580                 585                 590

Lys Asn Glu Gln Glu Leu Leu Glu Leu Asp Lys Trp Ala Ser Leu Trp
        595                 600                 605
```

Asn Trp Phe Asn Ile Thr Asn Trp Leu Trp Tyr Ile Lys Leu Phe Ile
610 615 620

Met Ile Val Gly Gly Leu Val Gly Leu Arg Ile Val Phe Ala Val Leu
625 630 635 640

Ser Ile

<210> 25
<211> 626
<212> PRT
<213> HIV

<400> 25

Met Arg Val Arg Gly Ile Pro Arg Asn Trp Pro Gln Trp Trp Met Trp
1 5 10 15

Gly Ile Leu Gly Phe Trp Met Ile Ile Ile Cys Arg Val Val Gly Asn
20 25 30

Met Trp Val Thr Val Tyr Tyr Gly Val Pro Val Trp Thr Asp Ala Lys
35 40 45

Thr Thr Leu Phe Cys Ala Ser Asp Thr Lys Ala Tyr Asp Arg Glu Val
50 55 60

His Asn Val Trp Ala Thr His Ala Cys Val Pro Thr Asp Pro Asn Pro
65 70 75 80

Gln Glu Ile Val Leu Glu Asn Val Thr Glu Asn Phe Asn Met Trp Lys
85 90 95

Asn Asp Met Val Asp Gln Met His Glu Asp Ile Ile Ser Leu Trp Asp
100 105 110

Gln Ser Leu Lys Pro Cys Val Lys Leu Thr Pro Leu Cys Val Thr Leu
115 120 125

His Cys Thr Asn Ala Thr Phe Lys Asn Asn Val Thr Asn Asp Met Asn
130 135 140

Lys Glu Ile Arg Asn Cys Ser Phe Asn Thr Thr Thr Glu Ile Arg Asp
145 150 155 160

Lys Lys Gln Gln Gly Tyr Ala Leu Phe Tyr Arg Pro Asp Ile Val Leu
165 170 175

Leu Lys Glu Asn Arg Asn Asn Ser Asn Asn Ser Glu Tyr Ile Leu Ile

```
            180                 185                 190

Asn Cys Asn Ala Ser Thr Ile Thr Gln Ala Cys Pro Lys Val Asn Phe
        195                 200                 205

Asp Pro Ile Pro Ile His Tyr Cys Ala Pro Ala Gly Tyr Ala Ile Leu
    210                 215                 220

Lys Cys Asn Asn Lys Thr Phe Ser Gly Lys Gly Pro Cys Asn Asn Val
225                 230                 235                 240

Ser Thr Val Gln Cys Thr His Gly Ile Lys Pro Val Val Ser Thr Gln
                245                 250                 255

Leu Leu Leu Asn Gly Ser Leu Ala Glu Lys Glu Ile Ile Ile Arg Ser
            260                 265                 270

Glu Asn Leu Thr Asp Asn Val Lys Thr Ile Ile Val His Leu Asn Lys
        275                 280                 285

Ser Val Glu Ile Val Cys Thr Arg Pro Asn Asn Asn Thr Arg Lys Ser
    290                 295                 300

Met Arg Ile Gly Pro Gly Gln Thr Phe Tyr Ala Thr Gly Asp Ile Ile
305                 310                 315                 320

Gly Asp Ile Arg Gln Ala Tyr Cys Asn Ile Ser Gly Ser Lys Trp Asn
                325                 330                 335

Glu Thr Leu Lys Arg Val Lys Glu Lys Leu Gln Glu Asn Tyr Asn Asn
            340                 345                 350

Asn Lys Thr Ile Lys Phe Ala Pro Ser Ser Gly Gly Asp Leu Glu Ile
        355                 360                 365

Thr Thr His Ser Phe Asn Cys Arg Gly Glu Phe Phe Tyr Cys Asn Thr
    370                 375                 380

Thr Arg Leu Phe Asn Asn Asn Ala Thr Glu Asp Glu Thr Ile Thr Leu
385                 390                 395                 400

Pro Cys Arg Ile Lys Gln Ile Ile Asn Met Trp Gln Gly Val Gly Arg
                405                 410                 415

Ala Met Tyr Ala Pro Pro Ile Ala Gly Asn Ile Thr Cys Lys Ser Asn
            420                 425                 430

Ile Thr Gly Leu Leu Leu Val Arg Asp Gly Gly Glu Asp Asn Lys Thr
        435                 440                 445
```

Glu Glu Ile Phe Arg Pro Gly Gly Gly Asn Met Lys Asp Asn Trp Arg
450 455 460

Ser Glu Leu Tyr Lys Tyr Lys Val Ile Glu Leu Lys Pro Leu Gly Ile
465 470 475 480

Ala Pro Thr Gly Ala Lys Leu Thr Val Gln Ala Arg Gln Leu Leu Ser
485 490 495

Ser Ile Val Gln Gln Gln Ser Asn Leu Leu Arg Ala Ile Glu Ala Gln
500 505 510

Gln His Met Leu Gln Leu Thr Val Trp Gly Ile Lys Gln Leu Gln Thr
515 520 525

Arg Val Leu Ala Ile Glu Arg Tyr Leu Lys Asp Gln Gln Leu Glu Ile
530 535 540

Trp Asn Asn Met Thr Trp Met Glu Trp Asp Arg Glu Ile Ser Asn Tyr
545 550 555 560

Thr Asp Thr Ile Tyr Arg Leu Leu Glu Asp Ser Gln Thr Gln Gln Glu
565 570 575

Lys Asn Glu Lys Asp Leu Leu Ala Leu Asp Ser Trp Lys Asn Leu Trp
580 585 590

Ser Trp Phe Asp Ile Ser Asn Trp Leu Trp Tyr Ile Lys Ile Phe Ile
595 600 605

Met Ile Val Gly Gly Leu Ile Gly Leu Arg Ile Ile Phe Ala Val Leu
610 615 620

Ser Ile
625

<210> 26
<211> 973
<212> DNA
<213> Artificial sequence

<220>
<223> CMV/R promoter

<400> 26
ccattgcata cgttgtatcc atatcataat atgtacattt atattggctc atgtccaaca 60

ttaccgccat gttgacattg attattgact agttattaat agtaatcaat tacggggtca 120

ttagttcata gcccatatat ggagttccgc gttacataac ttacggtaaa tggcccgcct 180

ggctgaccgc ccaacgaccc ccgcccattg acgtcaataa tgacgtatgt tcccatagta 240

acgccaatag ggactttcca ttgacgtcaa tgggtggagt atttacggta aactgcccac 300

ttggcagtac atcaagtgta tcatatgcca agtacgcccc ctattgacgt caatgacggt 360

aaatggcccg cctggcatta tgcccagtac atgaccttat gggactttcc tacttggcag 420

tacatctacg tattagtcat cgctattacc atggtgatgc ggttttggca gtacatcaat 480

gggcgtggat agcggtttga ctcacgggga tttccaagtc tccaccccat tgacgtcaat 540

gggagtttgt tttggcacca aaatcaacgg gactttccaa aatgtcgtaa caactccgcc 600

ccattgacgc aaatgggcgg taggcgtgta cggtgggagg tctatataag cagagctcgt 660

ttagtgaacc gtcagatcgc ctggagacgc catccacgct gttttgacct ccatagaaga 720

caccgggacc gatccagcct ccatcggctc gcatctctcc ttcacgcgcc cgccgcccta 780

cctgaggccg ccatccacgc cggttgagtc gcgttctgcc gcctcccgcc tgtggtgcct 840

cctgaactgc gtccgccgtc taggtaagtt taaagctcag gtcgagaccg ggcctttgtc 900

cggcgctccc ttggagccta cctagactca gccggctctc cacgctttgc ctgaccctgc 960

ttgctcaact cta 973