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(54) **SELECTION OF B CELLS WITH SPECIFICITY OF INTEREST: METHOD OF PREPARATION AND USE**

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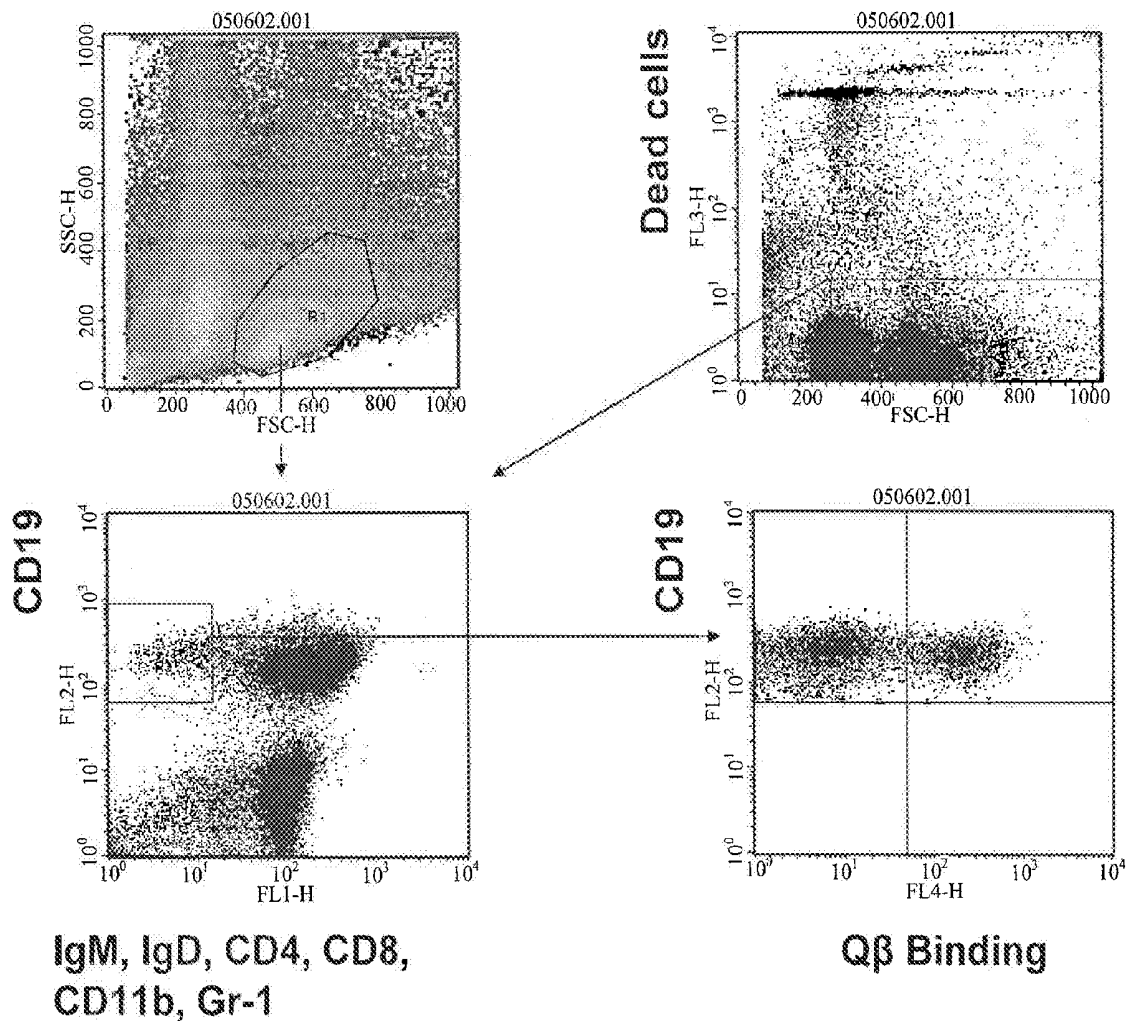
(57) **ABSTRACT**

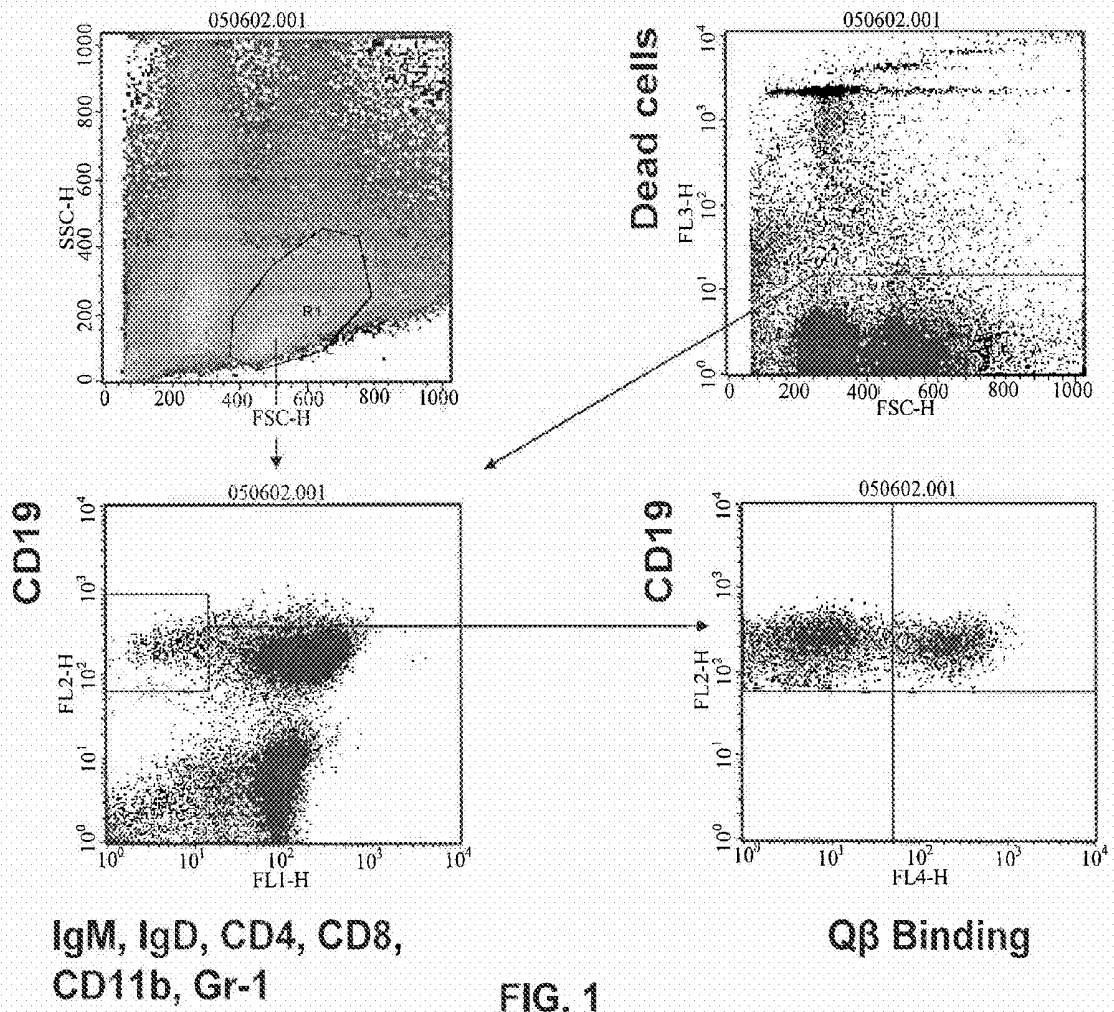
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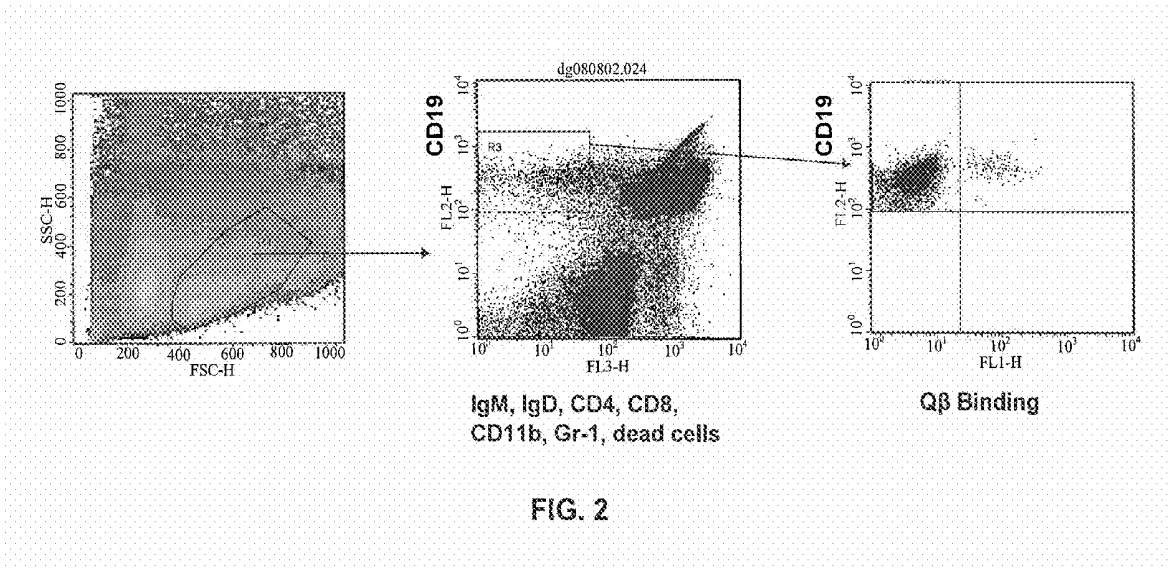
The present invention is related to the fields of molecular biology, virology, immunology and medicine. The invention provides methods using a composition comprising an ordered and repetitive antigen or antigenic determinant array for visualization and selection of B cells specific for the antigen. These B cells are useful for the production of monoclonal antibodies used for therapy, diagnostic or research purposes.

Related U.S. Application Data

(63) Continuation of application No. 10/556,904, filed on Nov. 21, 2006, now abandoned, filed as application No. PCT/EP2004/005208 on May 14, 2004.







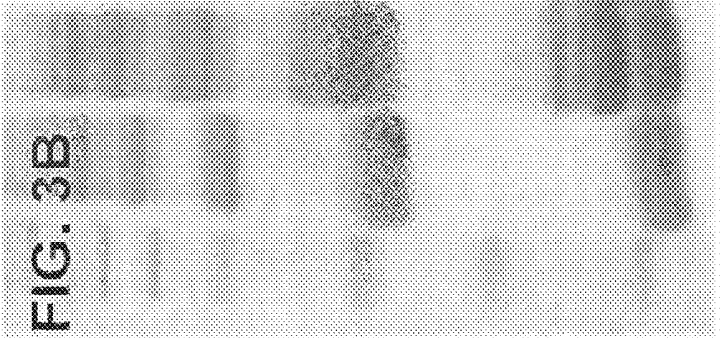
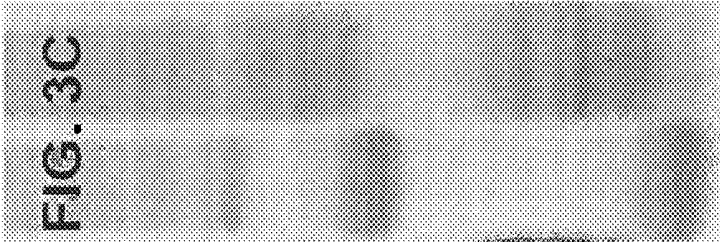
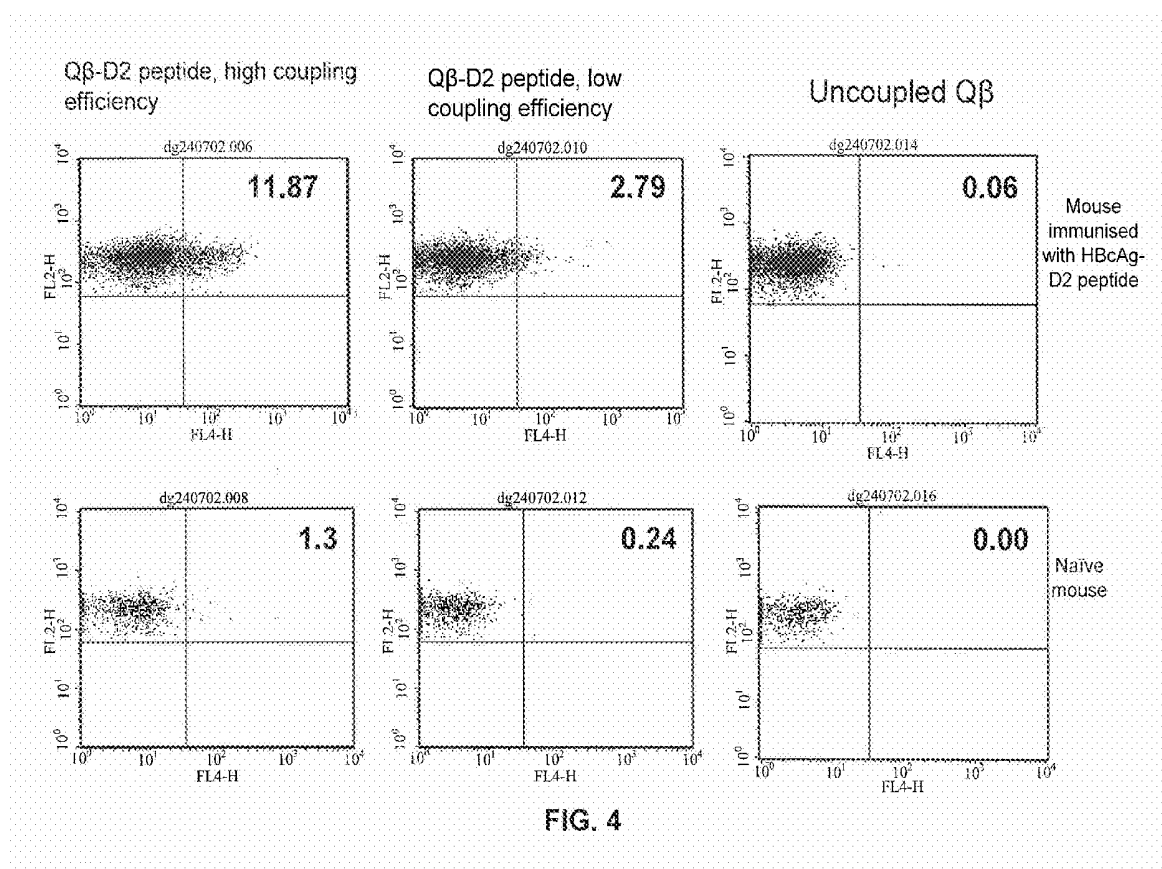


FIG. 3



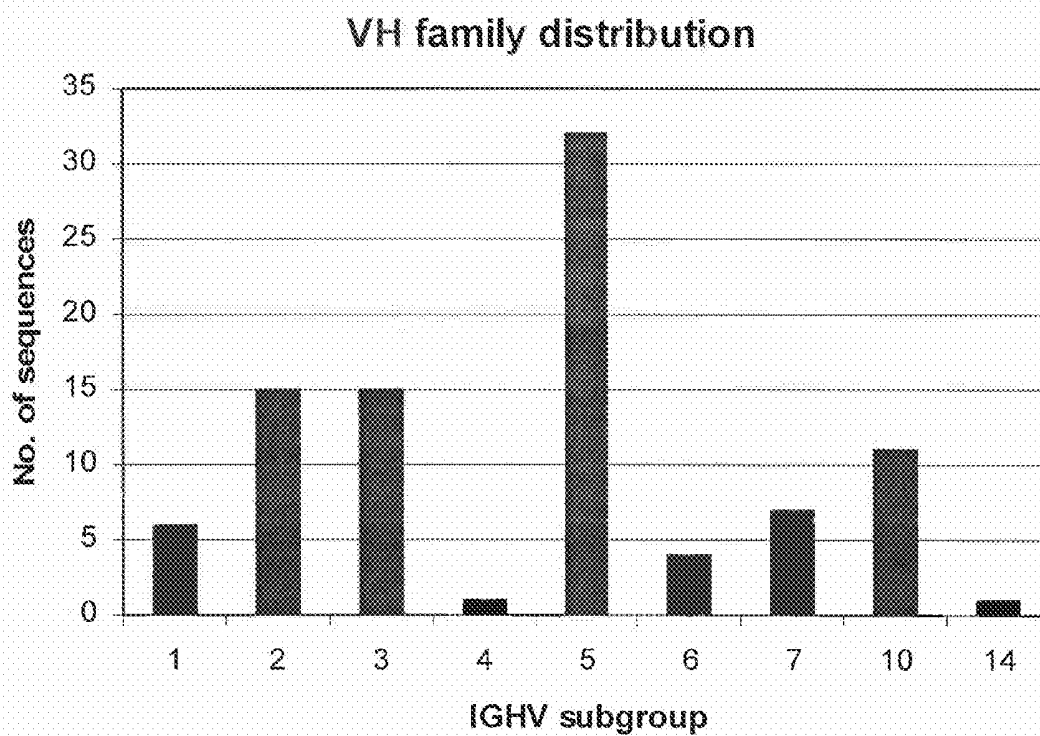
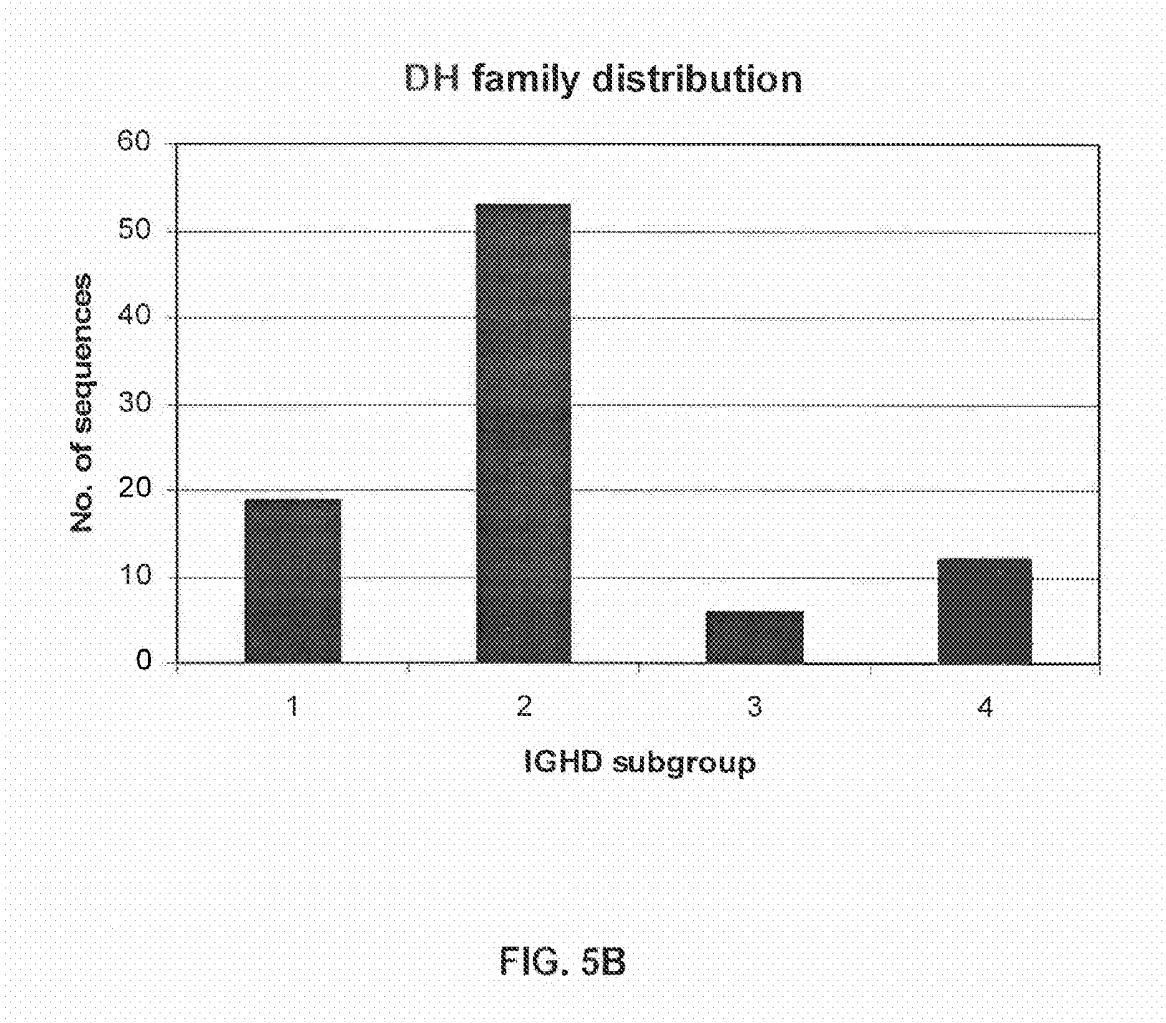
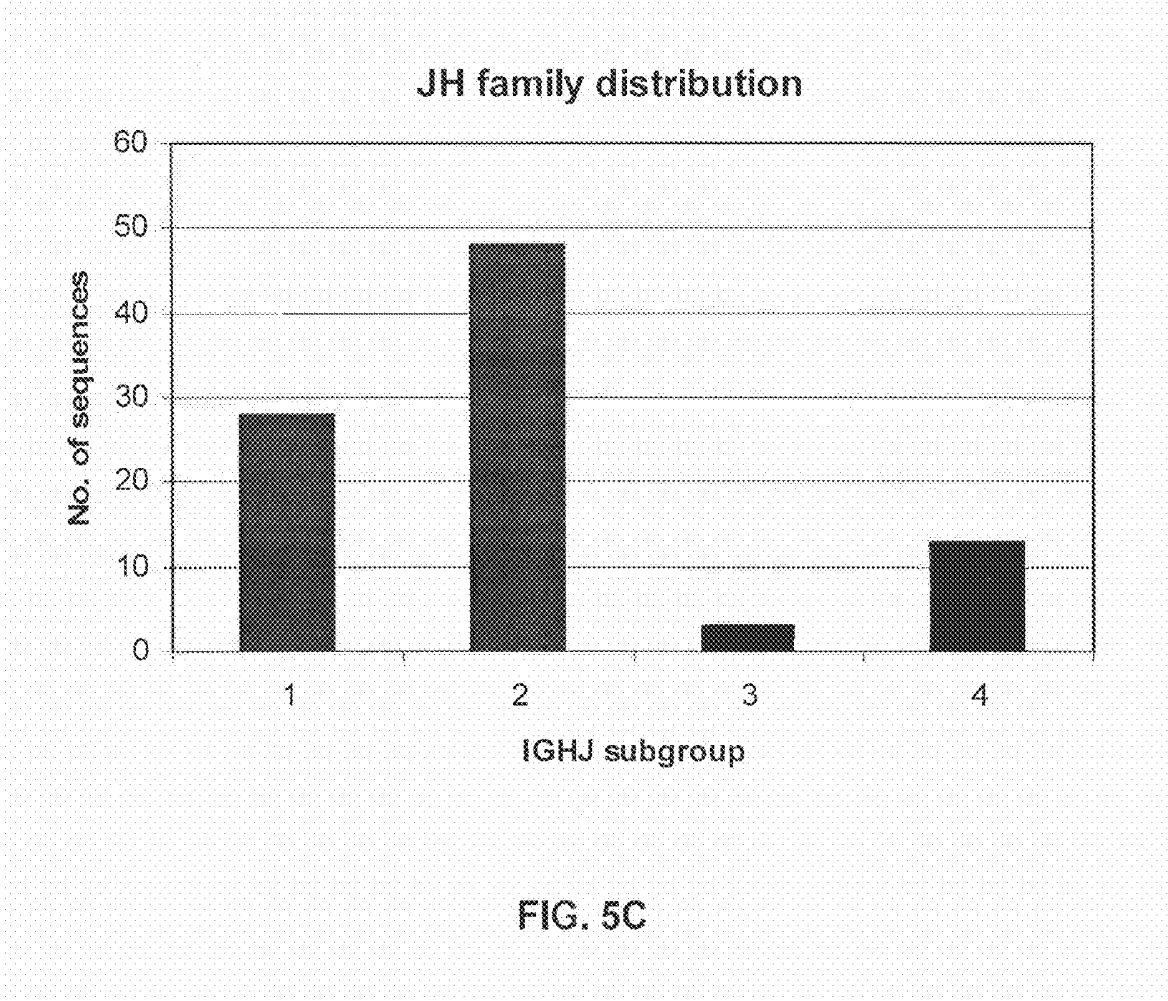


FIG. 5A





**SELECTION OF B CELLS WITH
SPECIFICITY OF INTEREST: METHOD OF
PREPARATION AND USE**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

[0001] This application is a continuation of U.S. application Ser. No. 10/556,904, filed Nov. 21, 2006, which is the U.S. National Phase of International Application No. PCT/EP04/005208, international filing date, May 14, 2004, which was published in the English language as WO 2004/102198 A3 on Nov. 25, 2004, and which claims the benefit of the filing date of U.S. Provisional Application No. 60/470,443, filed on May 15, 2003, the disclosures of each are entirely incorporated herein by reference in their entireties.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention is related to the fields of vaccinology, monoclonal antibodies and medicine. The invention provides methods for selecting B cells with a desired specificity using virus-like particles decorated with an antigen of choice as detection device. RNA can be isolated from such B cells for the generation of cDNA encoding the variable regions of immunoglobulins encoded by B cells for recombinant production of monoclonal antibodies. Alternatively, B cells may be fused in vitro with a fusion partner, allowing the generation of hybridomas secreting monoclonal antibodies of the desired specificity. Such monoclonal antibodies may be used for research purposes, diagnostic purposes or the treatment of diseases.

[0004] 2. Related Art

[0005] Monoclonal antibodies have become amongst the most efficient therapeutic regimens. Due to their enormous specificity and high affinity for the target structure recognized, monoclonal antibodies are ideal tools for diagnostic use or for use in research in general. In addition, due to their high specificity, monoclonal antibodies often exhibit a limited side-effect spectrum in vivo which makes them highly suitable for use in therapy. In addition, the mechanisms of action of monoclonal antibodies are manifold. On one hand, via their constant Fc parts, monoclonal antibodies interact with Fc receptors which allows for the recruitment of effector cells, such as natural killer (NK) cells or macrophages, to tissue recognized by the monoclonal antibodies, leading to destruction of the target tissue. This makes monoclonal antibodies powerful weapons against cancer. In addition, by radiolabeling monoclonal antibodies or by coupling toxins to monoclonal antibodies, the ability to destroy target tissues may be enhanced. With this regard, toxins that are activated only after cellular uptake seem to be particularly interesting. In addition, unlike most traditionally used small molecules, monoclonal antibodies are able to block protein-protein interactions in vivo, allowing to selectively interfere with the action of cytokines, chemokines, hormones etc. This unique feature of monoclonal antibodies is responsible for their broad usefulness in treating a vast number of diseases.

[0006] Generation of monoclonal antibodies has first been described by Kohler and Milstein (Kohler, G. and Milstein, C. (1975) *Nature* 256 (5517):495-7) using the hybridoma technology and since then has become a standard procedure in the lab. The hybridoma technology enables one to immortalize individual B cells, and thereby allows one to expand a popu-

lation of individual B cell clones to obtain sufficient antibodies so that the immortalized population can be screened to isolate those B cells producing antibodies having a particular antigen specificity. The B cell hybrids of interest can be grown in a large scale to make large quantities of homogeneous monoclonal antibodies, which are useful for diagnostic and therapeutic purposes. Hybridoma technology generally works best for preparing purely murine monoclonal antibodies. Hybrids made from fusing human B cells with human or murine myeloma cells are generally unstable, and tend to lose the human chromosomes and the ability to produce antibodies. Transforming human B cells with the Epstein-Barr virus (EBV) offers an alternative way to immortalize them. However, the transformation frequency is relatively low and the transformants are also not stable and often lose antibody-producing ability.

[0007] Therefore, production of monoclonal antibodies has remained a tedious process that is very time consuming. Specifically, mice have to be multiply immunized before spleen cells are randomly fused with non-Ig secreting myeloma cells leading to immortalization of the B cell fusion partner. However, since specific B cells are not extensively enriched in this process, many hybridomas have to be screened, subcloned, and re-screened before specific monoclonal antibodies may be isolated. In addition, only monoclonal antibodies exhibiting a high affinity are interesting for most purposes. However, before the affinity of the antibodies can be assessed, the cells producing these antibodies need to be clonal. This makes it necessary that many more hybridomas have to be generated, analysed subcloned etc than would really be necessary, since the affinity of the monoclonal antibodies can only be determined definitively at the final step.

[0008] A further problem is that the diversity of the immune system means that lymphocytes recognizing a particular antigen are rare. Estimations of the frequencies of cells specific for one antigen used to range from 10^{-5} to 10^{-6} , based for example on limiting dilution analyses. For a number of biological and physical reasons immunofluorescence, either with antigens or antibodies, shows considerable variation in intensity. This makes it technically difficult to identify accurately rare cells of interest at frequencies below 10^{-3} to 10^{-4} . Apart from that basic limitation, it is extremely time consuming to analyze a sufficient number of rare cells to obtain a reliable result. In addition, the cytometry of B lymphocytes according to antigen specificity is a problem of biology, because B cells that bind to one particular antigen often occur at frequencies of 1-10/ml blood, thus making the availability of sufficient blood for analysis a limiting factor.

[0009] Various methods have been employed to enrich the desired specific B cells when they occur at low frequency. These methods can be used to enrich the desired B cells before directly isolating RNA and cDNA encoding the variable regions of the monoclonal antibodies of interest whether one is attempting to isolate these fragments by hybridoma fusion technology, EBV transformation, or the combinatorial library methodology. These enrichment methods include fluorescence-activated cell sorting (FACS) (Dangl and Herzenberg (1982), *J. Immunol. Methods* 52, 1-14; Hoven et al. (1989), *J. Immunol. Methods* 117, 275-284), panning against antigen-coated plastic surface, binding to antigen-coated magnetic beads, or resetting with antigen-coated red blood cells.

[0010] These procedures for enriching antigen-specific B cells, however, all suffer from a certain degree of nonspeci-

ficity and background noise. For example, panning or absorbing to plates or beads yields from about one to several percent of nonspecific binding. Rosetting of cells by antigen-coated red blood cells also has about the same degree of nonspecific activity. For cell sorting using FACS, the nonspecific sorting will depend on the stringency of the gate setting, but it usually ranges from 0.1 to several percent depending on the nature of the antigen. Background noise in an FACS apparatus arises primarily from two sources. One source of noise is exhibited by certain activated cells or proliferating cells of various leukocyte subpopulations that contain high concentrations of certain metabolites, which cause these cells to exhibit autofluorescence even in the absence of fluorochrome labeling. Another possible source of background noise arises because some of the activated cells, and some monocytes and macrophages, possess sticky cellular plasmamembranes. Fluorescent probes will non-specifically adhere to the sticky plasmamembrane and create an additional source of background fluorescence in the cell sample. Furthermore, background noise can be caused by the presence of antibodies, specific for the immunizing/boosting antigen, which are present in the spleen cell suspension of immunized mice and which form immune complexes with the antigen-fluorochrome and bind to Fc receptors present on all B cells.

[0011] To overcome the problem of nonspecificity and background noise various methods have been developed that use for example at least two antigen probes that are labeled with different fluorochromes to label and specifically select B cells expressing antibodies of high affinity for the antigen of interest using the fluorescence-sorting technique FACS (U.S. Pat. No. 5,256,542). Another example is the use of 'parallel' cell-sorting technology (MACS), providing a nonoptical (in this case magnetic) label to enrich antigen-binding cells to make them detectable by flow cytometry and to isolate them for proof of specificity (Irsch et al., (1995), *Immunotechnology*, 1(2):115-25).

[0012] However, all the above described methods lack a certain degree of efficiency and specificity and further lack the differentiation between the selection for high affinity antigen-specific B cells and low affinity antigen-specific B cells. In particular, the methods known in the art all have the disadvantage that many hybridoma cells have to be generated, analyzed, subcloned, and re-screened before specific monoclonal antibodies may be isolated. This makes the known methods very time consuming and the affinity of the monoclonal antibodies can only be determined definitively at the final step. Thus, efficient methods for the selection of specific B cells are needed in the field in order to facilitate and hasten the production of monoclonal antibodies. Particularly, a method is needed that allows identification of monoclonal antibodies prior to the generation of hybridoma cells. In addition, a method is needed that allows specific detection, selection and isolation of B cells that express high affinity monoclonal antibodies.

SUMMARY OF THE INVENTION

[0013] The present invention provides a method for the visualization, characterization and isolation of single antigen-specific B cells which are in particularly useful to facilitate and hasten the production of monoclonal antibodies, in particular of high affinity monoclonal antibodies, for diagnostic or therapeutic use.

[0014] The present invention provides methods based on compositions exhibiting antigens specifically coupled to

them that allow detection and isolation of B cells specifically binding an antigen of choice. The compositions used in the present invention comprise antigens or antigenic determinants of interest which are bound to a core particle having a structure with an inherent repetitive organization, and hereby in particular to virus-like-particles (VLP's) and subunits of VLP's, respectively, leading to highly ordered and repetitive conjugates representing potent immunogens for the induction of antibodies specific for the antigen of interest. In particular, the compositions used in the method of the present invention allow for the detection, selection and isolation of either all antigen-specific B cells or of high affinity antigen-specific B cells. These selected B cells may be used for the production of monoclonal antibodies by means of generating hybridomas or isolating the genetic elements encoding the immunoglobulins expressed by the B cell. Thus, the present invention provides efficient methods for the isolation of single specific B cells which are used to facilitate and hasten the production of monoclonal antibodies. Particularly, the method allows the identification of monoclonal antibodies prior to the generation of hybridoma cells.

[0015] The present invention, thus, provides a method for selecting at least one antigen-specific B cell from a mixture of cells, said method comprising: (A) providing a mixture of cells comprising B cells; (B) providing a first composition comprising: (a) a first core particle with at least one first attachment site; and (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of: (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and (ii) an attachment site naturally occurring with said antigen or antigenic determinant, wherein said second attachment site is capable of association to said first attachment site; and wherein said antigen or antigenic determinant and said first core particle interact through said association to form an ordered and repetitive antigen array; (C) contacting said mixture of cells with said first composition; (D) labeling said first composition with a first labeling compound; (E) labeling said B cells in said mixture of cells with a second labeling compound; and (F) selecting at least one B cell which is positive for said first and said second labeling compound. Preferred embodiments of first core particles suitable for use in the present invention are a virus, a virus-like particle, in particular a Hepatitis B virus core antigen, a bacteriophage, a bacterial pilus or flagella, a viral capsid particle, a virus-like particle (VLP) of a RNA-phage, in particular a VLP of the RNA phage ϕ 8, or any recombinant form of the aforementioned first core particles, or any other core particle having an inherent repetitive structure capable of forming an ordered and repetitive antigen array in accordance with the present invention.

[0016] WO 00/32227, WO01/85208, and in particular WO 02/056905 describe compositions and processes for the production of ordered and repetitive antigen or antigenic determinant arrays. The compositions comprise a core particle, such as a virus or a virus-like particle, to which at least one antigen or one antigenic determinant, is associated by way of at least one non-peptide bond leading to the ordered and repetitive antigen array. Virus-like particles (VLPs) are supermolecular structures built in a symmetric manner from many protein molecules of one or more types. They lack the viral genome and, therefore, are noninfectious. VLPs can often be produced in large quantities by heterologous expression and can be easily purified. Examples of VLPs may include, with-

out limitation, the capsid proteins of Hepatitis B virus (Ulrich, et al., *Virus Res.* 50:141-182 (1998)), measles virus (Warnes, et al., *Gene* 160:173-178 (1995)), Sindbis virus, rotavirus (U.S. Pat. No. 5,071,651 and U.S. Pat. No. 5,374,426), foot-and-mouth-disease virus (Twomey, et al., *Vaccine* 13:1603-1610, (1995)), Norwalk virus (Jiang, X., et al., *Science* 250:1580-1583 (1990); Matsui, S. M., et al., *J. Clin. Invest.* 87:1456-1461 (1991)), the retroviral GAG protein (WO 96/30523), the retrotransposon Ty protein p1, the surface protein of Hepatitis B virus (WO 92/11291) and human papilloma virus (WO 98/15631).

[0017] VLPs exhibit the same structure as viruses. Most viruses are particulate structures and exhibit a highly repetitive surface. Due to the repetitiveness of their surface, viruses are able to efficiently cross-link B cell receptors and trigger strong B cell responses. In addition, as previously shown, viruses may bind with high efficiency to specific B cells allowing to selectively detect anti-viral B cells in histology (Bachmann, M F. et al., (1996) *J Exp Med.*, 183(5):2259-69) or using flowcytometry (Youngman, K R. Et al., (2002) *J Immunol.* 168(5):2173-81). The detection of bound virus was feasible since the viruses served as a signal amplification tool; one virus binding to a B cell exhibits several hundred epitopes that may be detected by secondary reagents.

[0018] In one aspect of the present invention, the second attachment site of the first composition used for the method of the invention is capable of association to said first attachment site through at least one covalent bond, preferably through at least one non-peptide bond.

[0019] The first composition used for the method of the invention may comprise an antigen or antigenic determinant that may be a recombinant antigen or a synthetic peptide. In particular, it may be selected from the group consisting of polypeptides, carbohydrates, steroid hormones, organic molecules, inorganic molecules, viruses, bacteria, parasites, prions, tumors, self-molecules, non-peptide hapten molecules, and allergens. In one aspect of the present invention, the antigen or antigenic determinant is attached to said first core particle at high density allowing efficient selection of all antigen-specific B cells. In another aspect of the present invention, the antigen or antigenic determinant is attached to said first core particle at low density allowing for specific selection of high affinity antigen-specific B cells.

[0020] In one embodiment of the present invention, said selecting at least one B cell which is positive for said first and said second labeling compound is effected by using a first device capable of detecting said first labeling compound and a second device capable of detecting said second labeling compound.

[0021] In a preferred embodiment, said first labeling compound is a first fluorochrome and said second labeling compound is a second fluorochrome, said first fluorochrome yielding a color different from said second fluorochrome upon activation, and wherein said first device capable of detecting said first labeling compound and said second device capable of detecting said second labeling compound is a fluorescence activated cell sorting apparatus (FACS).

[0022] In a further aspect of the present invention, said labeling of said first composition is effected prior to contacting said mixture with said first composition. In another aspect of the invention, said labeling of said first composition is effected after contacting said mixture with said first composition, preferably with at least one antibody probe, wherein said probe comprises an antibody which is specific for said

first composition, preferably specific for said core particle of said first composition, said antibody being conjugated with said first labeling compound. In another preferred embodiment, said labeling effected after contacting said mixture with said first composition is effected with at least one first antibody probe, wherein said first probe comprises a first antibody which is specific for said first composition, preferably specific for said first core particle of said first composition, and at least one second antibody probe, wherein said second probe comprises a second antibody which is specific for said first antibody, said second antibody being conjugated with said first labeling compound.

[0023] In a further aspect, said labeling said B cells in said mixture of cells with a second labeling compound may be effected with a first set of at least one additional first targeting molecule, wherein said first targeting molecule is specific for at least one B cell marker, and wherein said first targeting molecule is labeled with a second labeling compound.

[0024] In still a further embodiment, the method of the present invention further comprises labeling said mixture with a second set of at least one second additional targeting molecule, wherein said at least one second targeting molecule is specific for at least one marker unique for cells other than isotype-switched B cells, and wherein said at least one second targeting molecule is labeled with a third labeling compound.

[0025] In yet another aspect of the invention, the method of the invention further comprises an additional step of adding a dead cell marker to said mixture of cells.

[0026] The method of the present invention further comprises the step of verifying specific antibody production of said selected at least one antigen-specific B cell. In a preferred embodiment, said verifying is effected by ELISA.

[0027] In a preferred aspect of the method of the present invention, said mixture of cells is a mixture of splenocytes from immunized animals, said animals being immunized with a second composition comprising: (a) a second core particle with at least one first attachment site; and (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of: (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and (ii) an attachment site naturally occurring with said antigen or antigenic determinant, wherein said second attachment site is capable of association to said first attachment site; wherein said antigen or antigenic determinant and said second core particle interact through said association to form an ordered and repetitive antigen array. In a preferred embodiment, said second core particle is different from said first core particle. In a further embodiment, said second core particle is the same as said first core particle. Preferred embodiments of second core particles suitable for use in the present invention are a virus, a virus-like particle, in particular a Hepatitis B virus core antigen, a bacteriophage, a bacterial pilus or flagella, a viral capsid particle, a virus-like particle (VLP) of a RNA-phage, in particular a VLP of the RNA-phage Q β , or any recombinant form of the aforementioned first core particles, or any other core particle having an inherent repetitive structure capable of forming an ordered and repetitive antigen array in accordance with the present invention. In a preferred embodiment, the second composition used for the method of the invention comprises the same antigen or antigenic determinant as the antigen or antigenic determinant of the first composition. In another embodiment, the second composition used for the method of the invention comprises a

different antigen or antigenic determinant as the antigen or antigenic determinant of the first composition.

[0028] The present invention further provides an antigen-specific B cell selected by any of the methods of the invention.

[0029] In a further aspect, the present invention provides a method for generating monoclonal antibodies, comprising providing at least one antigen-specific B cell selected by any of the methods of the invention and fusing said at least one antigen-specific B cell with a myeloma cell line. In a preferred embodiment, the antigen-specific B cell used for fusing with a myeloma cell line is selected from a mixture of cells from immunized animals.

[0030] In another embodiment, the present invention provides a method for generating monoclonal antibodies or antibody fragments comprising isolating genetic elements encoding the immunoglobulin or parts of the immunoglobulin expressed by said at least one antigen-specific B cell selected by a method of the invention and further expressing said genetic elements.

[0031] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0032] FIG. 1 shows FACS staining of specific B cells with VLPs and anti-VLP antiserum. Lymphocytes were selected on the basis of their forward and side scatter and dead cells (PI+) were excluded. Isotype-switched B cells (CD19+IgM-IgD-) were distinguished from naive B cells, T cells, macrophages and granulocytes with a negative selection step, in which IgM+, IgD+, CD4+, CD8+CD11b+ and Gr-1+ cells were gated out. Switched B cells were analysed for Q β -binding.

[0033] FIG. 2 shows staining of specific B cells with labelled VLPs. Lymphocytes were selected on the basis of their forward and side scatter. Isotype-switched B cells (CD19+IgM-IgD-) were distinguished from naive B cells, T cells, macrophages, granulocytes and dead cells with a negative selection step, in which IgM+, IgD+, CD4+, CD8+, CD11b+, Gr-1+ and PI+ cells were excluded. Switched B cells were analysed for Q β -binding.

[0034] FIG. 3 shows coupling of peptide to Q β with high (A) or low (B) efficiency and to HBcAg (C).

[0035] FIG. 4 shows FACS staining of specific B cells with peptide-coupled VLPs. Isotype-switched B cells were identified as in FIG. 1 and binding to D2-peptide coupled with high (left) or low (middle) efficiency to Q β , as well as binding to uncoupled Q β (right), was assessed. High affinity peptide-specific B cells were selected using Q β exhibiting few peptides coupled to it. Background staining in unimmunised mice is shown (lower panels).

DETAILED DESCRIPTION OF THE INVENTION

[0036] Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can be used in the

practice or testing of the present invention, the preferred methods and materials are hereinafter described.

1. DEFINITIONS

[0037] Amino acid linker: An “amino acid linker”, or also just termed “linker” within this specification, as used herein, either associates the antigen or antigenic determinant with the second attachment site, or more preferably, already comprises or contains the second attachment site, typically—but not necessarily—as one amino acid residue, preferably as a cysteine residue. The term “amino acid linker” as used herein, however, does not intend to imply that such an amino acid linker consists exclusively of amino acid residues, even if an amino acid linker consisting of amino acid residues is a preferred embodiment of the present invention. The amino acid residues of the amino acid linker are, preferably, composed of naturally occurring amino acids or unnatural amino acids known in the art, all-L or all-D or mixtures thereof. However, an amino acid linker comprising a molecule with a sulfhydryl group or cysteine residue is also encompassed within the invention. Such a molecule comprise preferably a C1-C6 alkyl-, cycloalkyl (C5,C6), aryl or heteroaryl moiety. However, in addition to an amino acid linker, a linker comprising preferably a C1-C6 alkyl-, cycloalkyl-(C5,C6), aryl- or heteroaryl-moiety and devoid of any amino acid(s) shall also be encompassed within the scope of the invention. Association between the antigen or antigenic determinant or optionally the second attachment site and the amino acid linker is preferably by way of at least one covalent bond, more preferably by way of at least one peptide bond.

[0038] Animal: As used herein, the term “animal” is meant to include, for example, humans, sheep, horses, cattle, pigs, dogs, cats, rats, mice, birds, reptiles, fish, insects and arachnids.

[0039] Antibody: As used herein, the term “antibody” refers to molecules which are capable of binding an epitope or antigenic determinant. The term is meant to include whole antibodies and antigen-binding fragments thereof including single-chain antibodies. Most preferably the antibodies are human antigen binding antibody fragments and include, but are not limited to, Fab, Fab' and F(ab')₂, Fd, single-chain Fvs (scFv), single-chain antibodies, disulfide-linked Fvs (sdFv) and fragments comprising either a V_L or V_H domain. The antibodies can be from any animal origin including birds and mammals. Preferably, the antibodies are human, murine, rabbit, goat, guinea pig, camel, horse or chicken. As used herein, “human” antibodies include antibodies having the amino acid sequence of a human immunoglobulin and include antibodies isolated from human immunoglobulin libraries or from animals transgenic for one or more human immunoglobulins and that do not express endogenous immunoglobulins, as described, for example, in U.S. Pat. No. 5,939,598 by Kucherlapati et al.

[0040] Antigen: As used herein, the term “antigen” refers to a molecule capable of being bound by an antibody or a T cell receptor (TCR) if presented by MHC molecules. The term “antigen”, as used herein, also encompasses T-cell epitopes. An antigen is additionally capable of being recognized by the immune system and/or being capable of inducing a humoral immune response and/or cellular immune response leading to the activation of B- and/or T-lymphocytes. This may, however, require that, at least in certain cases, the antigen contains or is linked to a Th cell epitope and is given in adjuvant. An antigen can have one or more epitopes (B- and T-epitopes).

The specific reaction referred to above is meant to indicate that the antigen will preferably react, typically in a highly selective manner, with its corresponding antibody or TCR and not with the multitude of other antibodies or TCRs which may be evoked by other antigens. Antigens as used herein may also be mixtures of several individual antigens.

[0041] A “microbial antigen” as used herein is an antigen of a microorganism and includes, but is not limited to, infectious virus, infectious bacteria, parasites and infectious fungi. Such antigens include the intact microorganism as well as natural isolates and fragments or derivatives thereof and also synthetic or recombinant compounds which are identical to or similar to natural microorganism antigens and induce an immune response specific for that microorganism. A compound is similar to a natural microorganism antigen if it induces an immune response (humoral and/or cellular) to a natural microorganism antigen. Such antigens are used routinely in the art and are well known to the skilled artisan.

[0042] Antigenic determinant: As used herein, the term “antigenic determinant” is meant to refer to that portion of an antigen that is specifically recognized by either B- or T-lymphocytes. B-lymphocytes respond to foreign antigenic determinants via antibody production, whereas T-lymphocytes are the mediator of cellular immunity. Thus, antigenic determinants or epitopes are those parts of an antigen that are recognized by antibodies, or in the context of an MHC, by T-cell receptors.

[0043] Antigen presenting cell: As used herein, the term “antigen presenting cell” is meant to refer to a heterogeneous population of leucocytes or bone marrow derived cells which possess an immunostimulatory capacity. For example, these cells are capable of generating peptides bound to MHC molecules that can be recognized by T cells. The term is synonymous with the term “accessory cell” and includes, for example, Langerhans’ cells, interdigitating cells, B cells and macrophages. Under some conditions, epithelial, endothelial cells and other, non-bone marrow derived cells may also serve as antigen presenting cells.

[0044] Association: As used herein, the term “association” as it applies to the first and second attachment sites, refers to the binding of the first and second attachment sites that is preferably by way of at least one non-peptide bond. The nature of the association may be covalent, ionic, hydrophobic, polar or any combination thereof, preferably the nature of the association is covalent.

[0045] Attachment Site, First: As used herein, the phrase “first attachment site” refers to an element of non-natural or natural origin, to which the second attachment site located on the antigen or antigenic determinant may associate. The first attachment site may be a protein, a polypeptide, an amino acid, a peptide, a sugar, a polynucleotide, a natural or synthetic polymer, a secondary metabolite or compound (biotin, fluorescein, retinol, digoxigenin, metal ions, phenylmethylsulfonylfluoride), or a combination thereof, or a chemically reactive group thereof. The first attachment site is located, typically and preferably on the surface, of the core particle such as, preferably the virus-like particle. Multiple first attachment sites are present on the surface of the core and virus-like particle, respectively, typically in a repetitive configuration.

[0046] Attachment Site, Second: As used herein, the phrase “second attachment site” refers to an element associated with the antigen or antigenic determinant to which the first attachment site located on the surface of the core particle and

virus-like particle, respectively, may associate. The second attachment site of the antigen or antigenic determinant may be a protein, a polypeptide, a peptide, a sugar, a polynucleotide, a natural or synthetic polymer, a secondary metabolite or compound (biotin, fluorescein, retinol, digoxigenin, metal ions, phenylmethylsulfonylfluoride), or a combination thereof, or a chemically reactive group thereof. At least one second attachment site is present on the antigen or antigenic determinant. The term “antigen or antigenic determinant with at least one second attachment site” refers, therefore, to an antigen or antigenic construct comprising at least the antigen or antigenic determinant and the second attachment site. However, in particular for a second attachment site, which is of non-natural origin, i.e. not naturally occurring within the antigen or antigenic determinant, these antigen or antigenic constructs comprise an “amino acid linker”.

[0047] B cell: As used herein, the term “B cell” refers to a cell produced in the bone marrow of an animal expressing membrane-bound antibody specific for an antigen. Following interaction with the antigen it differentiates into a plasma cell producing antibodies specific for the antigen or into a memory B cell. “B cell” and “B lymphocyte” is used interchangeably. Naïve as well as activated B cells are within the scope of the invention.

[0048] Antigen-specific B cell: As used herein, the term “antigen-specific B cell” refers to a B cell which expresses antibodies that are able to distinguish between the antigen of interest and other antigens and which specifically bind to that antigen of interest with high or low affinity but which do not bind to other antigens.

[0049] Positive B cell: As used herein, the term “positive B cell” means any B cell which is labeled with any one of the labeling compounds of the invention and which is selected or sorted or otherwise separated from a mixture of cells by a device capable of detecting said labeling compound. For example, a B cell which is positive for the first labeling compound of the invention is a B cell which is labeled with a first labeling compound and which is selected by the device capable of detecting said first labeling compound.

[0050] Switched B cell: As used herein, the term “switched B cell” refers to activated B cells which have undergone isotype switching or class switching to secrete antibodies of different isotypes: IgG, IgA, and IgE. Isotype switching does not affect antibody specificity significantly, but alters the effector functions that an antibody can engage. Isotype switching occurs by recombination involving the deletion of DNA between the rearranged V region and the selected C-region exon at so-called S regions (see Janeway et al., Immunobiology, 5th edition, 2001, New York and London, Garland Publishing). Markers for cells other than switched B cells suitable for use in the present invention include, but are not limited to IgD, IgM, CD2, CD3, CD4, CD8, CD11b, Gr-1, Thy-1.

[0051] B cell marker: As used herein, the term “B cell marker” refers to surface molecules on the B cells which are specific for antigen-specific IgG-producing B cells. B cell markers suitable for use in the present invention include, but are not limited to surface IgG, kappa and lambda chains, Ig-alpha, Ig-beta, CD19, Ia, Fc receptors, B220 (CD45R), CD20, CD21, CD22, CD23, CD79 alpha/beta, CD81 (TAPA-1) or any other CD antigen specific for B cells.

[0052] Bound: As used herein, the term “bound” refers to binding or attachment that may be covalent, e.g., by chemical coupling, or non-covalent, e.g., ionic interactions,

hydrophobic interactions, hydrogen bonds, etc. Covalent bonds can be, for example, ester, ether, phosphoester, amide, peptide, imide, carbon-sulfur bonds, carbon-phosphorus bonds, and the like. The term "bound" is broader than and includes terms such as "coupled," "fused" and "attached".

[0053] Coat protein(s): As used herein, the term "coat protein(s)" refers to the protein(s) of a bacteriophage or a RNA-phage capable of being incorporated within the capsid assembly of the bacteriophage or the RNA-phage. However, when referring to the specific gene product of the coat protein gene of RNA-phages the term "CP" is used. For example, the specific gene product of the coat protein gene of RNA-phage Q β is referred to as "Q β CP", whereas the "coat proteins" of bacteriophage Q β comprise the "Q β CP" as well as the A1 protein. The capsid of Bacteriophage Q β is composed mainly of the Q β CP, with a minor content of the A1 protein. Likewise, the VLP Q β coat protein contains mainly Q β CP, with a minor content of A1 protein.

[0054] Core particle: As used herein, the term "core particle" refers to a rigid structure with an inherent repetitive organization. A core particle as used herein may be the product of a synthetic process or the product of a biological process.

[0055] Coupled: The term "coupled", as used herein, refers to attachment by covalent bonds or by strong non-covalent interactions, typically and preferably to attachment by covalent bonds. Any method normally used by those skilled in the art for the coupling of biologically active materials can be used in the present invention.

[0056] Dead cell marker: As used herein, the term "dead cell marker" refers to markers which specifically label dead cells. Dead cell markers suitable for use in the present invention include, but are not limited to propidium iodide (PI), YO Pro1 (YO-PRO®-1 iodide (491/509)), 7-AAD (7-aminoactinomycin D), EMA (ethidium monoazide bromide), BIS-Oxonol, To-Pro-3 (see Molecular Probes (Cat No T-3605)), RB2Z.

[0057] High density: As used herein, the term "high density" refers to high amounts of antigen presented on the surface of a core particle.

[0058] Low density: As used herein, the term "low density" refers to low amounts of antigen presented on the surface of a core particle.

[0059] Device capable of detecting: As used herein, the term "device capable of detecting" refers to a device or an apparatus that is capable of detecting, or otherwise identifying a labeling compound, such as e.g. a fluorochrome, or a magnetic particle. A device capable of detecting a fluorochrome may include without limitation a fluorescence activated cell sorting apparatus (FACS). A device capable of detecting a magnetic particle may include without limitation a magnetic cell sorting apparatus (MACS).

[0060] Epitope: As used herein, the term "epitope" refers to continuous or discontinuous portions of a polypeptide having antigenic or immunogenic activity in an animal, preferably a mammal, and most preferably in a human. An epitope is recognized by an antibody or a T cell through its T cell receptor in the context of an MHC molecule. An "immunogenic epitope," as used herein, is defined as a portion of a polypeptide that elicits an antibody response or induces a T-cell response in an animal, as determined by any method known in the art. (See, for example, Geysen et al., *Proc. Natl. Acad. Sci. USA* 81:3998-4002 (1983)). The term "antigenic epitope," as used herein, is defined as a portion of a protein to

which an antibody can immunospecifically bind its antigen as determined by any method well known in the art. Immunospecific binding excludes non-specific binding but does not necessarily exclude cross-reactivity with other antigens. Antigenic epitopes need not necessarily be immunogenic. Antigenic epitopes can also be T-cell epitopes, in which case they can be bound immunospecifically by a T-cell receptor within the context of an MHC molecule.

[0061] An epitope can comprise 3 amino acids in a spatial conformation which is unique to the epitope. Generally, an epitope consists of at least about 5 such amino acids, and more usually, consists of at least about 8-10 such amino acids. If the epitope is an organic molecule, it may be as small as Nitrophenyl.

[0062] Fusion: As used herein, the term "fusion" refers to the combination of amino acid sequences of different origin in one polypeptide chain by in-frame combination of their coding nucleotide sequences. The term "fusion" explicitly encompasses internal fusions, i.e., insertion of sequences of different origin within a polypeptide chain, in addition to fusion to one of its termini.

[0063] Immune response: As used herein, the term "immune response" refers to a humoral immune response and/or cellular immune response leading to the activation or proliferation of B- and/or T-lymphocytes and/or antigen presenting cells. In some instances, however, the immune responses may be of low intensity and become detectable only when using at least one substance in accordance with the invention. "Immunogenic" refers to an agent used to stimulate the immune system of a living organism, so that one or more functions of the immune system are increased and directed towards the immunogenic agent. An "immunogenic polypeptide" is a polypeptide that elicits a cellular and/or humoral immune response, whether alone or linked to a carrier in the presence or absence of an adjuvant. Preferably, antigen presenting cell may be activated.

[0064] A substance which "enhances" an immune response refers to a substance in which an immune response is observed that is greater or intensified or deviated in any way with the addition of the substance when compared to the same immune response measured without the addition of the substance. For example, the lytic activity of cytotoxic T cells can be measured, e.g. using a ⁵¹Cr release assay, in samples obtained with and without the use of the substance during immunization. The amount of the substance at which the CTL lytic activity is enhanced as compared to the CTL lytic activity without the substance is said to be an amount sufficient to enhance the immune response of the animal to the antigen. In a preferred embodiment, the immune response is enhanced by a factor of at least about 2, more preferably by a factor of about 3 or more. The amount or type of cytokines secreted may also be altered. Alternatively, the amount of antibodies induced or their subclasses may be altered.

[0065] Immunization: As used herein, the terms "immunize" or "immunization" or related terms refer to conferring the ability to mount a substantial immune response (comprising antibodies and/or cellular immunity such as effector CTL) against a target antigen or epitope. These terms do not require that complete immunity be created, but rather that an immune response be produced which is substantially greater than baseline. For example, a mammal may be considered to be immunized against a target antigen if the cellular and/or humoral immune response to the target antigen occurs following the application of methods of the invention.

[0066] Labeling compound: As used herein, the term “labeling compound” refers to a compound used to label the first composition, the B cell markers, or markers for cells other than switched B cells of the invention either directly or indirectly through, for example, a tag, antibody, dioxigenin, or biotin. Such labels suitable for use in the present invention are well known in the art and include, but are not limited to fluorescent materials (e.g. PerCP, Allophycocyanin (APC), texas red, rhodamine, Cy3, Cy5, Cy5.5, Cy7, Alexa Fluor Dyes, phycoerythrin (PE), green fluorescent protein (GFP), a tandem dye (e.g. PE-Cy5), fluorescein isothiocyanate (FITC)), magnetic beads, radiolabel (e.g. ^{131}I -labeled antibody, ^{90}Y (a pure beta emitter)-labeled antibody, ^{211}At -labeled antibody), an enzyme, avidin or biotin, or any other tag or label known in the art useful for labeling the composition of the invention. The first composition of the invention may be labeled prior to or after contacting said mixture of cells with said first composition. If said first composition is labeled prior to contacting said mixture of cells with said first composition, said first composition is labeled with a first labeling compound selected from the group consisting of without limitation avidin or biotin, dioxigenin, flag tag or any other tag known in the art. In addition, to detect said first labeling compound, the B cell in the mixture of cells is labeled after contacting said mixture of cells with labeled streptavidin, anti-dioxigenin, anti-flag or any other anti-tag. The first composition of the invention may also be labeled after contacting said mixture of cells with said first composition with a first antibody specific for said first composition, specific for the B cell markers, or specific for markers for cells other than switched B cells of the invention, said first antibody being labeled with labels selected from the group consisting of without limitation fluorescent materials, magnetic particles or radiolabels. Alternatively, said first composition may further be labeled after contacting the mixtures of cells with said first composition with a first antibody specific for said first composition, specific for the B cell markers, or specific for markers for cells other than switched B cells of the invention, and further with a second antibody specific for said first antibody, said second antibody being labeled with labels selected from the group consisting of without limitation fluorescent materials, magnetic particles or radiolabels. In a preferred embodiment, the first, second, and third fluorochrome of the invention may yield different colors upon activation.

[0067] Mixture of cells: As used herein, the term “mixture of cells” refers to any mixture of cells comprising B cells, preferably to a cell suspension of cells of the peripheral lymphoid organs or of peripheral blood cells. Cells of the peripheral lymphoid organs may include without limitation splenocytes from the spleen or lymphocytes from lymph nodes. Cells used for the method of the present invention are from animals, preferably mammals, even more preferably from mammals immunized with an antigen of interest, preferably immunized with the second composition of the invention.

[0068] Natural origin: As used herein, the term “natural origin” means that the whole or parts thereof are not synthetic and exist or are produced in nature.

[0069] Non-natural: As used herein, the term generally means not from nature, more specifically, the term means from the hand of man.

[0070] Non-natural origin: As used herein, the term “non-natural origin” generally means synthetic or not from nature; more specifically, the term means from the hand of man.

[0071] Ordered and repetitive antigen or antigenic determinant array: As used herein, the term “ordered and repetitive antigen or antigenic determinant array” generally refers to a repeating pattern of antigen or antigenic determinant, characterized by a uniform spacial arrangement of the antigens or antigenic determinants with respect to the core particle. In one embodiment of the invention, the repeating pattern may be a geometric pattern. Examples of suitable ordered and repetitive antigen or antigenic determinant arrays are those which possess strictly repetitive paracrystalline orders of antigens or antigenic determinants, preferably with spacings of 0.5 to 30 nanometers, more preferably 5 to 15 nanometers.

[0072] Pili: As used herein, the term “pili” (singular being “pilus”) refers to extracellular structures of bacterial cells composed of protein monomers (e.g., pilin monomers) which are organized into ordered and repetitive patterns. Further, pili are structures which are involved in processes such as the attachment of bacterial cells to host cell surface receptors, inter-cellular genetic exchanges, and cell-cell recognition. Examples of pili include Type-1 pili, P-pili, F1C pili, S-pili, and 987P-pili. Additional examples of pili are set out below.

[0073] Pilus-like structure: As used herein, the phrase “pilus-like structure” refers to structures having characteristics similar to that of pili and composed of protein monomers. One example of a “pilus-like structure” is a structure formed by a bacterial cell which expresses modified pilin proteins that do not form ordered and repetitive arrays but that are essentially identical to those of natural pili. Another example for a “pilus-like structure” is a structure formed by a bacterial cell which expresses modified pilin proteins that do form ordered and repetitive arrays but that have different symmetrical properties compared to those of natural pili.

[0074] Polypeptide: As used herein, the term “polypeptide” refers to a molecule composed of monomers (amino acids) linearly linked by amide bonds (also known as peptide bonds). It indicates a molecular chain of amino acids and does not refer to a specific length of the product. Thus, peptides, oligopeptides and proteins are included within the definition of polypeptide. This term is also intended to refer to post-expression modifications of the polypeptide, for example, glycosylations, acetylations, phosphorylations, and the like. A recombinant or derived polypeptide is not necessarily translated from a designated nucleic acid sequence. It may also be generated in any manner, including chemical synthesis.

[0075] Residue: As used herein, the term “residue” is meant to mean a specific amino acid in a polypeptide backbone or side chain.

[0076] Self antigen: As used herein, the term “self antigen” refers to proteins encoded by the host’s DNA and products generated by proteins or RNA encoded by the host’s DNA are defined as self. In addition, proteins that result from a combination of two or several self-molecules or that represent a fraction of a self-molecule and proteins that have a high homology two self-molecules as defined above (>95%, preferably >97%, more preferably >99%) may also be considered self.

[0077] Specific antibody: As used herein, the term “specific antibody” refers to antibodies which are able to distinguish between the antigen of interest and other antigens and which specifically bind to that antigen of interest with high or low affinity.

[0078] Treatment: As used herein, the terms “treatment”, “treat”, “treated” or “treating” refer to prophylaxis and/or

therapy. When used with respect to an infectious disease, for example, the term refers to a prophylactic treatment which increases the resistance of a subject to infection with a pathogen or, in other words, decreases the likelihood that the subject will become infected with the pathogen, or show signs of illness attributable to the infection, as well as a treatment after the subject has become infected in order to fight the infection, e.g., reduce or eliminate the infection or prevent it from becoming worse.

[0079] Virus-like particle (VLP): As used herein, the term “virus-like particle” refers to a structure resembling a virus particle. Moreover, a virus-like particle in accordance with the invention is non replicative and noninfectious since it lacks all or part of the viral genome, in particular the replicative and infectious components of the viral genome. A virus-like particle in accordance with the invention may contain nucleic acid distinct from their genome. A typical and preferred embodiment of a virus-like particle in accordance with the present invention is a viral capsid such as the viral capsid of the corresponding virus, bacteriophage, or RNA-phage. The terms “viral capsid” or “capsid”, as interchangeably used herein, refer to a macromolecular assembly composed of viral protein subunits. Typically and preferably, the viral protein subunits assemble into a viral capsid and capsid, respectively, having a structure with an inherent repetitive organization, wherein said structure is, typically, spherical or tubular. For example, the capsids of RNA-phages or HBcAg’s have a spherical form of icosahedral symmetry. The term “capsid-like structure” as used herein, refers to a macromolecular assembly composed of viral protein subunits resembling the capsid morphology in the above defined sense but deviating from the typical symmetrical assembly while maintaining a sufficient degree of order and repetitiveness.

[0080] Virus-like particle of a bacteriophage: As used herein, the term “virus-like particle of a bacteriophage” refers to a virus-like particle resembling the structure of a bacteriophage, being non replicative and noninfectious, and lacking at least the gene or genes encoding for the replication machinery of the bacteriophage, and typically also lacking the gene or genes encoding the protein or proteins responsible for viral attachment to or entry into the host. This definition should, however, also encompass virus-like particles of bacteriophages, in which the aforementioned gene or genes are still present but inactive, and, therefore, also leading to non-replicative and noninfectious virus-like particles of a bacteriophage.

[0081] VLP of RNA phage coat protein: The capsid structure formed from the self-assembly of 180 subunits of RNA phage coat protein and optionally containing host RNA is referred to as a “VLP of RNA phage coat protein”. A specific example is the VLP of Q β coat protein. In this particular case, the VLP of Q β coat protein may either be assembled exclusively from Q β CP subunits (generated by expression of a Q β CP gene containing, for example, a TAA stop codon precluding any expression of the longer A1 protein through suppression, see Kozlovska, T. M., et al., *Intervirology* 39: 9-15 (1996)), or additionally contain A1 protein subunits in the capsid assembly.

[0082] Virus particle: The term “virus particle” as used herein refers to the morphological form of a virus. In some virus types it comprises a genome surrounded by a protein capsid; others have additional structures (e.g., envelopes, tails, etc.).

[0083] Non-enveloped viral particles are made up of a proteinaceous capsid that surrounds and protects the viral genome. Enveloped viruses also have a capsid structure surrounding the genetic material of the virus but, in addition, have a lipid bilayer envelope that surrounds the capsid. In a preferred embodiment of the invention, the VLP’s are free of a lipoprotein envelope or a lipoprotein-containing envelope. In a further preferred embodiment, the VLP’s are free of an envelope altogether.

[0084] One, a, or an: When the terms “one,” “a,” or “an” are used in this disclosure, they mean “at least one” or “one or more,” unless otherwise indicated.

[0085] As will be clear to those skilled in the art, certain embodiments of the invention involve the use of recombinant nucleic acid technologies such as cloning, polymerase chain reaction, the purification of DNA and RNA, the expression of recombinant proteins in prokaryotic and eukaryotic cells, etc. Such methodologies are well known to those skilled in the art and can be conveniently found in published laboratory methods manuals (e.g., Sambrook, J. et al., eds., *MOLECULAR CLONING, A LABORATORY MANUAL*, 2nd. edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989); Ausubel, F. et al., eds., *CURRENT PROTOCOLS IN MOLECULAR BIOLOGY*, John H. Wiley & Sons, Inc. (1997)). Fundamental laboratory techniques for working with tissue culture cell lines (Celis, J., ed., *CELL BIOLOGY*, Academic Press, 2nd edition, (1998)) and antibody-based technologies (Harlow, E. and Lane, D., “Antibodies: A Laboratory Manual,” Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y. (1988); Deutscher, M. P., “Guide to Protein Purification,” *Meth. Enzymol.* 128, Academic Press San Diego (1990); Scopes, R. K., “Protein Purification Principles and Practice,” 3rd ed., Springer-Verlag, New York (1994)) are also adequately described in the literature, all of which are incorporated herein by reference.

2. METHODS FOR DETECTION OF SPECIFIC B CELLS

[0086] The disclosed invention provides methods for detection, selection and isolation of specific B cells from animals or humans using compositions comprising, or alternatively consisting of a repetitive core structure such as a virus or a virus-like particle and an antigen coupled, fused or attached otherwise to the core particle. The present invention, thus, provides a method for selecting at least one antigen-specific B cell from a mixture of cells, said method comprising, or alternatively consisting essentially of, or alternatively consisting of: (A) providing a mixture of cells comprising B cells; (B) providing a first composition comprising, or alternatively consisting essentially of, or alternatively consisting of: (a) a first core particle with at least one first attachment site; and (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of: (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and (ii) an attachment site naturally occurring with said antigen or antigenic determinant, wherein said second attachment site is capable of association to said first attachment site; and wherein said antigen or antigenic determinant and said first core particle interact through said association to form an ordered and repetitive antigen array; (C) contacting said mixture of cells with said first composition; (D) labeling said first composition with a first labeling compound; (E) labeling said B cells in said mixture of cells with

a second labeling compound; and (F) selecting at least one B cell which is positive for the first and said second labeling compound.

[0087] In a first step of the method of the present invention, a mixture of cells comprising B cells is provided. Any mixture of cells comprising B cells can be used for the method of the present invention, preferably a cell suspension of cells of the peripheral lymphoid organs or of peripheral blood cells. Cells of the peripheral lymphoid organs may include without limitation splenocytes from the spleen or lymphocytes from lymph nodes. Cells from any organ may be used for the method of the present invention which may include without limitation cells from the bone marrow, gut, or lung. Cells used for the method of the present invention are from animals, preferably mammals, even more preferably from mammals immunized with an antigen of interest, preferably immunized with the second composition of the invention. In a preferred aspect of the method of the present invention, said mixture of cells is a mixture of splenocytes from immunized animals, said animals being immunized with a second composition comprising, or alternatively consisting essentially of, or alternatively consisting of: (a) a second core particle with at least one first attachment site; and (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of: (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and (ii) an attachment site naturally occurring with said antigen or antigenic determinant, wherein said second attachment site is capable of association to said first attachment site; wherein said antigen or antigenic determinant and said second core particle interact through said association to form an ordered and repetitive antigen array. In a preferred embodiment, said second core particle is different from said first core particle. In a further embodiment, said second core particle is the same as said first core particle. In a preferred embodiment, the second composition used for the method of the invention comprises the same antigen or antigenic determinant as the antigen or antigenic determinant of the first composition. Alternatively, the second composition used for the method of the invention comprises a different antigen or antigenic determinant as the antigen or antigenic determinant of the first composition.

[0088] In another embodiment of the method of the present invention, said mixture of cells is contacted with at least one first composition of the invention. Typically and preferably, said contacting may include without limitation adding, mixing, incubating, or otherwise bringing the first composition together with said mixture of cells. In one embodiment, said first composition may be added to said mixture of cells. In another embodiment, said mixture of cells may be mixed with said first composition. In yet another embodiment, said mixture of cells may be incubated with said first composition of the invention.

[0089] In one aspect of the present invention, said labeling of said first composition is effected prior to contacting said mixture of cells with said first composition. Said first composition may be labeled directly with for example a fluorochrome, a magnetic label or a radioactively labeled tag, or it may be labeled indirectly prior to said incubation, with a labeling compound which may be selected from the group consisting of without limitation avidin or biotin, dioxigenin, flag tag or any other tag, and after said incubation with labeled streptavidin, anti-dioxigenin, anti-flag or any other anti-tag. For one preferred embodiment, said first composition, pref-

erably the first core particle of said first composition, is biotinylated prior to contacting said mixture with said first composition. After said contacting said mixture of cells with said first composition, labeled streptavidin, preferably fluorochrome labeled streptavidin, is added to said mixture of cells which binds to said biotinylated first composition which has specifically bound to B cells which are specific for the antigen or antigenic determinant of said first composition.

[0090] In another aspect of the invention, said labeling of said first composition is effected after contacting said mixture with said first composition, preferably with at least one antibody probe, wherein said probe comprises an antibody which is specific for said first composition, preferably specific for said core particle of said first composition, said antibody being conjugated with said first labeling compound. Said first labeling compound may be selected from the group consisting of without limitation fluorescent materials or a first fluorochrome (e.g. texas red, rhodamine, Cy5, phycoerythrin (PE), green fluorescent protein (GFP), a tandem dye (e.g. PE-Cy5), fluorescein isothiocyanate (FITC)), magnetic beads, radiolabel (e.g. ^{131}I -labeled antibody, ^{90}Y (a pure beta emitter)-labeled antibody, ^{211}At -labeled antibody), an enzyme, avidin or biotin, or any other tag or label known in the art useful for labeling the composition of the invention. Typically and preferably, said antibody which is specific for said first composition may be a monoclonal or polyclonal antibody specific for said core particle of said first composition, preferably a polyclonal anti-Q β , or an anti-HBcAg antibody from any species, preferably from a mammal, more preferably from a human, mouse, rat, rabbit, goat, guinea pig, camel, donkey, horse or chicken.

[0091] In another preferred embodiment, said labeling effected after contacting said mixture with said first composition is effected with at least one first antibody probe, wherein said first probe comprises a first antibody, preferably an unlabeled first antibody, which is specific for said first composition, preferably specific for said first core particle of said first composition, and at least one second antibody probe, wherein said second probe comprises a second antibody which is specific for said first antibody, said second antibody being conjugated with said first labeling compound. Typically and preferably, said second antibody which is specific for said first antibody may be a monoclonal or polyclonal antibody conjugated with a labeling compound which recognizes the species of the first antibody and may be selected without limitation from the group consisting of anti-rat, anti-mouse, anti-rabbit, anti-goat, or anti-donkey immunoglobulin antibodies.

[0092] In a preferred embodiment, said first antibody is specific for said first core particle. Alternatively, said first antibody is specific for the antigen or antigenic determinant of the first composition. The use of a first antibody specific for the first core particle of the invention makes the method of the invention particularly useful for the detection and isolation of B cells expressing unknown or unavailable antibodies. Thus, the present invention provides a general method for detecting, selecting and isolating an antigen-specific B cell for the use of the production of any monoclonal antibodies of interest.

[0093] In a further aspect of the present invention said labeling said B cells in said mixture of cells is effected with a first set of at least one first targeting molecule, wherein said first targeting molecule is specific for at least one B cell marker, and wherein said first targeting molecule is labeled

with said second labeling compound. Said first targeting molecule may be any molecule which is specific for at least one B cell marker, preferably an antibody or an F(ab')₂ molecule specific for IgG conjugated with a second labeling compound. Alternatively, labeling said B cells in said mixture of cells is effected with a first targeting molecule which is a first antibody specific for said at least one B cell marker, and with at least one second antibody probe, wherein said second probe comprises a second antibody which is specific for said first antibody, said second antibody being conjugated with said second labeling compound. Said second labeling compound may be selected from the group consisting of without limitation fluorescent materials or fluorochrome (e.g. texas red, rhodamine, Cy5, phycoerythrin (PE), green fluorescent protein (GFP), a tandem dye (e.g. PE-Cy5), fluorescein isothiocyanate (FITC)), magnetic beads, radiolabel (e.g. ¹³¹I-labeled antibody, ⁹⁰Y (a pure beta emitter)-labeled antibody, ²¹¹At-labeled antibody), or any label known in the art useful for labeling at least one B cell marker of the invention. Preferably, said second labeling compound is a second fluorochrome. Even more preferably, said second fluorochrome may yield a color different from that of said first fluorochrome upon activation. A B cell marker can be any surface molecule on B cells which is specific for antigen-specific IgG-producing B cells. A B cell marker can be selected from the group consisting of without limitation the surface IgG, kappa and lambda chains, Ig-alpha, Ig-beta, CD19, Ia, Fc receptors, B220 (CD45R), CD20, CD21, CD22, CD23, CD79 alpha/beta, CD81 (TAPA-1), any other CD antigen specific for B cells, or any other marker specific for B cells known in the art. Preferably, said B cell marker is CD19. In another preferred embodiment, said fluorescence conjugated first targeting molecule is a phycoerythrin-conjugated anti-CD19 antibody. In another embodiment, more than one targeting molecule specific for a B cell may be used.

[0094] In still a further embodiment, the method of the present invention further comprises labeling said mixture with a second set of at least one second additional targeting molecule, wherein said at least one second targeting molecule is specific for at least one marker unique for cells other than isotype-switched B cells, and wherein said at least one second targeting molecule is labeled with a third labeling compound. Said second targeting molecule may be any molecule which is specific for at least one marker unique for cells other than isotype-switched B cells, preferably an antibody conjugated with a third labeling compound. Said third labeling compound may be selected from the group consisting of without limitation fluorescent material or a third fluorochrome (e.g. texas red, rhodamine, Cy5, phycoerythrin (PE), green fluorescent protein (GFP), a tandem dye (e.g. PE-Cy5), fluorescein isothiocyanate (FITC)), magnetic beads, radiolabel (e.g. ¹³¹I-labeled antibody, ⁹⁰Y (a pure beta emitter)-labeled antibody, ²¹¹At-labeled antibody), or any label known in the art useful for labeling at least one B cell marker of the invention. Preferably, said third labeling compound is a third fluorochrome. More preferably, said third fluorochrome may yield a color different from that of said first and said second fluorochrome. Markers for cells other than isotype-switched B cells may be selected from the group consisting of without limitation IgD, IgM, CD2, CD3, CD4, CD8, CD11b, Gr-1, Thy-1. However, any other markers for isotype-switched B cells known in the art can be used for the method of the present invention. Said second set of at least one second additional targeting molecule may be a set of one or more than

one additional targeting molecule. In a preferred embodiment, said second set of additional targeting molecules comprises a mixture of FITC-conjugated antibodies containing anti-IgD, anti-IgM, anti-CD4, anti-CD8, anti-CD11b, and anti-Gr-1 antibodies. The use of more than one different second targeting molecule specific for cells other than isotype-switched B cells is advantageous to efficiently separate isotype-switched B cells from cells other than isotype-switched B cells, and in particular, to minimize background staining.

[0095] In another embodiment, the present invention may further comprise adding a dead cell marker to said mixture of cells. Dead cell markers are markers which specifically label dead cells. Such markers may be selected from the group consisting of without limitation propidium iodide (PI), YO Pro1 (YO-PRO®-1 iodide (491/509)), 7-AAD (7-aminoactinomycin D), EMA (ethidium monoazide bromide), BIS-Oxonol, To-Pro-3 (see Molecular Probes (Cat No T-3605)), RB2Z.

[0096] In a preferred embodiment, the method of the invention comprises the step of selecting at least one B cell which is positive for said first and said second labeling compound. "Positive" B cells means any B cell which is labeled with any one of the labeling compounds of the invention and which is selected or sorted or otherwise separated from a mixture of cells by a device capable of detecting said labeling compound. In a more preferred embodiment, the present invention comprises the step of selecting B cells which are positive for said first and said second labeling compound, but eliminating and not selecting those cells which are positive for said third labeling compound of the invention. In an even more preferred embodiment, the present invention comprises the step of selecting B cells which are positive for said first and said second labeling compound, but eliminating and not selecting those cells which are positive for said third labeling compound of the invention and eliminating and not selecting those cells which are positive for the dead cell marker.

[0097] In one embodiment of the present invention, said selecting at least one B cell which is positive for said first and said second labeling compound is effected by using a first device capable of detecting said first labeling compound and a second device capable of detecting said second labeling compound. Any device capable of detecting a labeling compound known in the art may be useful for the method of the invention. A device capable of detecting a fluorochrome may be selected from the group consisting of without limitation a fluorescence activated cell sorting apparatus (FACS) (Dangl and Herzenberg (1982), *J. Immunol. Methods* 52, 1-14; or Marder et al., (1990), *Cytometry* 11: 498-505). A device capable of detecting a magnetic particle may include without limitation a magnetic cell sorting apparatus (MACS) (Irsch et al., (1995), *Immunotechnology*, 1(2):115-25). Typically and preferably, said fluorescence activated cell sorting may be performed with a fluorescence activated cell sorting apparatus (for example FACS Vantage or Star Plus™ from Becton Dickinson (Foster City, Calif.), or Epics C from Coulter Epics Division (Hiialeah, Fla.)), which can sort individual cells into wells of 8x12 well microculture plates. Any combination of hereinabove mentioned devices capable of detecting a labeling compound of the invention is within the scope of the invention.

[0098] In one embodiment of the present invention, said device capable of detecting said first labeling compound is a fluorescence activated cell sorting apparatus (FACS) and said

first labeling compound is a first fluorochrome. In another embodiment, said first and said second labeling compounds are fluorochromes, said first fluorochrome yielding a color different from said second fluorochrome upon activation, and said device capable of detecting said first and said second labeling compound is a fluorescence activated cell sorting apparatus (FACS). Alternatively, said first labeling compound is a magnetic label and said device capable of detecting said first labeling compound is a magnetic cell sorting apparatus (MACS), and said second labeling compounds is a fluorochrome and said device capable of detecting said second labeling compound is a fluorescence activated cell sorting apparatus (FACS). In yet another embodiment, said first labeling compound is a first fluorochrome and said device capable of detecting said first labeling compound is a fluorescence activated cell sorting apparatus (FACS), and said second labeling compound is a magnetic label and said device capable of detecting said second labeling compound is a magnetic cell sorting apparatus (MACS).

[0099] In one aspect of the invention, said third labeling compound is a third fluorochrome, and the device capable of detecting said third labeling compound is a fluorescence activated cell sorting apparatus (FACS). In one embodiment, said first, said second, and said third labeling compounds of the invention are first, second and third fluorochromes, said third fluorochrome yielding a color different from said first and said second fluorochrome upon activation. In another embodiment, said first and said third labeling compounds of the invention are fluorochromes and said second labeling compound is a magnetic label, said third fluorochrome yielding a color different from said first fluorochrome upon activation. In yet another embodiment, said first labeling compound of the invention is a magnetic label and said second and third labeling compounds are fluorochromes, said third fluorochrome yielding a color different from said second fluorochrome upon activation. In another aspect of the invention, said third labeling compound is a magnetic label and said device capable of detecting said third labeling compound is a magnetic cell sorting apparatus (MACS).

[0100] In a preferred embodiment of the invention, said first labeling compound is a first fluorochrome, said second labeling compound is a second fluorochrome, and said third labeling compound is a third fluorochrome, said first, second, and third fluorochromes yielding different colors upon activation, and wherein said device capable of detecting said first, second, and third labeling compound is a fluorescence activated cell sorting apparatus (FACS), preferably a FACS Vantage. The usage of a FACS Vantage is particularly advantageous for the sorting and isolation of single antigen-specific B cells into separate compartments or wells, and in particular for the subsequent generation of monoclonal antibodies, and no further step of isolating the single antigen-specific B cell is needed. However, in a further embodiment, the method of the invention further comprises the step of isolating at least one antigen-specific B cell which is positive for said first and said second labeling compound.

[0101] In one embodiment, the method of the present invention further comprises the step of verifying specific antibody production of said selected at least one antigen-specific B cell. Typically and preferably, the method for verifying the specificity and affinity of the specific antibodies produced by the selected B cells may be selected from the group consisting without limitation of ELISA (enzyme-

linked immunosorbent assay), or any method capable of detecting enzymatic reactions, or RIA (radioimmunoassay).

[0102] The present invention further provides an antigen-specific B cell selected by any method of the invention. Said antigen-specific B cell may specifically express antibodies that are able to distinguish between the antigen of interest and other antigens and which specifically bind to that antigen of interest with high or low affinity but which do not bind other antigens. Thus said B cells selected by any method of the invention may be used for the production of monoclonal antibodies of interest. Thus, the present invention further provides a method for generating monoclonal antibodies, comprising providing at least one antigen-specific B cell selected by the method of the invention and fusing said at least one antigen-specific B cell with a myeloma cell line.

[0103] In a further aspect, the present invention provides a method for generating monoclonal antibodies or antibody fragments comprising isolating at least one genetic element encoding the immunoglobulin or parts of the immunoglobulin expressed by said at least one antigen-specific B cell selected by the method of the invention and expressing said genetic elements. Typically and preferably, said genetic elements of the selected antigen-specific B cell may be selected from the group consisting of without limitation the V_H gene segment, the V_L gene segment, the V_H nucleotide sequence, the V_L nucleotide sequence, or any part of the immunoglobulin expressed by the selected antigen-specific B cell. Preferably, RNA is isolated from the selected antigen-specific B cell for the generation of cDNA encoding the variable region of immunoglobulin encoded by said B cell for recombinant production of monoclonal antibodies. In a further embodiment, said genetic elements are amplified by PCR. Techniques such as PCR that can be performed on single B cells to amplify the V_H and V_L segments are well known in the art (Chiang et al., (1989), *Biotechniques*, 7(4):360-6).

[0104] In yet a further embodiment, said genetic elements may be expressed as a fusion molecule. Alternatively, the selected antigen-specific B cell may be fused in vitro with a fusion partner, allowing the generation of hybridomas secreting monoclonal antibodies of the desired specificity.

[0105] Monoclonal antibodies can be obtained by injecting mice with the second composition of the invention comprising a second core particle and at least one antigen, subsequently verifying the presence of antibody production by removing a serum sample, removing the spleen to obtain B-lymphocytes, selecting an antigen-specific B cell by a method of the invention, fusing the selected B-lymphocytes with myeloma cells to produce hybridomas, culturing the clones that produce antibodies to the antigen, and isolating the antibodies from the hybridoma cultures.

[0106] Monoclonal antibodies can be isolated and purified from hybridoma cultures by a variety of well-established techniques. Such isolation techniques include affinity chromatography with Protein-A Sepharose, size-exclusion chromatography, and ion-exchange chromatography. See, for example, Coligan at pages 2.7.1-2.7.12 and pages 2.9.1-2.9.3. Also, see Baines et al., "Purification of Immunoglobulin G (IgG)," in *METHODS IN MOLECULAR BIOLOGY*, VOL. 10, pages 79-104 (The Humana Press, Inc. 1992). Suitable host mammals for the production of antibodies include, but are not limited to, humans, rats, mice, rabbits, and goats.

[0107] In accordance with the present invention, functional antibody fragments also can be utilized. The fragments are produced by methods that include digestion with enzymes

such as pepsin or papain and/or cleavage of disulfide bonds by chemical reduction. Alternatively, antibody fragments encompassed by the present invention can be synthesized using an automated peptide synthesizer such as those supplied commercially by Applied Biosystems, Multiple Peptide Systems and others, or they may be produced manually, using techniques well known in the art. See Geysen et al., *J. Immunol. Methods* 102: 259 (1978). Direct determination of the amino acid sequences of the variable regions of the heavy and light chains of the monoclonal antibodies according to the invention can be carried out using conventional techniques.

[0108] A fragment according to the present invention can be an Fv fragment. An Fv fragment of an antibody is made up of the variable region of the heavy chain (Vh) of an antibody and the variable region of the light chain of an antibody (Vl). Proteolytic cleavage of an antibody can produce double chain Fv fragments in which the Vh and Vl regions remain non-covalently associated and retain antigen binding capacity. Fv fragments also include recombinant single chain antibody molecules in which the light and heavy chain variable regions are connected by a peptide linker. See Skerra, et al. *Science*, 240, 1038-41 (1988). Antibody fragments according to the invention also include Fab, Fab', F(ab).sub.2, and F(ab').sub.2, which lack the Fc fragment of an intact antibody.

[0109] Monoclonal antibodies obtained by a method of the invention may be used for research purposes, diagnostic purposes or the treatment of diseases.

3. COMPOSITIONS USED FOR THE METHOD OF THE INVENTION

[0110] In one embodiment of the method of the present invention, a first composition is provided comprising, or alternatively consisting essentially of, or alternatively consisting of: (a) a first core particle with at least one first attachment site; and (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of: (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and (ii) an attachment site naturally occurring with said antigen or antigenic determinant, wherein said second attachment site is capable of association to said first attachment site; and wherein said antigen or antigenic determinant and said first core particle interact through said association to form an ordered and repetitive antigen array.

[0111] In a further aspect of the method of the present invention, a mixture of cells is provided, preferably but not necessarily a mixture of splenocytes from immunized animals, said animals being immunized with a second composition comprising, or alternatively consisting essentially of, or alternatively consisting of: (a) a second core particle with at least one first attachment site; and (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of: (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and (ii) an attachment site naturally occurring with said antigen or antigenic determinant, wherein said second attachment site is capable of association to said first attachment site; wherein said antigen or antigenic determinant and said second core particle interact through said association to form an ordered and repetitive antigen array. In a preferred embodiment, said second core particle is different from said first core particle. Alternatively, said second core particle is the same as said first

core particle. In a preferred embodiment, the second composition used for the method of the invention comprises the same antigen or antigenic determinant as the antigen or antigenic determinant of the first composition. Alternatively, the second composition used for the method of the invention comprises a different antigen or antigenic determinant as the antigen or antigenic determinant of the first composition.

[0112] Preferred embodiments of core particles of any one of the compositions suitable for use in the present invention are a virus, a virus-like particle, in particular a Hepatitis B virus core antigen, a bacteriophage, a bacterial pilus or flagella, a viral capsid particle, a virus-like particle of a RNA-phage, in particular a virus-like particle of a RNA-phage Q β , or any recombinant form of the aforementioned core particles, or any other core particle having an inherent repetitive structure capable of forming an ordered and repetitive antigen array in accordance with the present invention. More specifically, said composition of the invention may comprise, or alternatively consist of, a virus-like particle and at least one antigen or antigenic determinant, wherein the at least one antigen or antigenic determinant is bound to the virus-like particle so as to form an ordered and repetitive antigen-VLP-array. Furthermore, the invention conveniently enables the practitioner to construct such a composition, inter alia, for the use for methods for detection, selection and isolation of antigen-specific B cells.

[0113] In one embodiment, the first and/or the second core particle comprises, alternatively essentially consists of, or alternatively consists of a virus, a bacterial pilus, a structure formed from bacterial pilin, a bacteriophage, a virus-like particle, a viral capsid particle or a recombinant form thereof. Any virus known in the art having an ordered and repetitive coat and/or core protein structure may be selected as a core particle of the invention; examples of suitable viruses include sindbis and other alphaviruses, rhabdoviruses (e.g. vesicular stomatitis virus), picornaviruses (e.g., human rhino virus, Aichi virus), togaviruses (e.g., rubella virus), orthomyxoviruses (e.g., Thogoto virus, Batken virus, fowl plague virus), polyomaviruses (e.g., polyomavirus BK, polyomavirus JC, avian polyomavirus BFDV), parvoviruses, rotaviruses, Norwalk virus, foot and mouth disease virus, a retrovirus, Hepatitis B virus, Tobacco mosaic virus, Flock House Virus, and human Papillomavirus, and preferably a RNA phage, bacteriophage Q β , bacteriophage R17, bacteriophage M11, bacteriophage MX1, bacteriophage NL95, bacteriophage fr, bacteriophage GA, bacteriophage SP, bacteriophage MS2, bacteriophage f2, bacteriophage PP7 (for example, see Table 1 in Bachmann, M. F. and Zinkernagel, R. M., *Immunol. Today* 17:553-558 (1996)).

[0114] In a further embodiment, the genetic engineering of a virus is utilized to create a fusion between an ordered and repetitive viral envelope protein and a first attachment site comprising a heterologous protein, peptide, antigenic determinant or a reactive amino acid residue of choice. Other genetic manipulations known to those in the art may be included in the construction of the inventive compositions; for example, it may be desirable to restrict the replication ability of the recombinant virus through genetic mutation. Furthermore, the virus used for the present invention is, preferably, replication incompetent due to chemical or physical inactivation or, as indicated, due to lack of a replication competent genome. The viral protein selected for fusion to the first attachment site should have an organized and repetitive structure. Such an organized and repetitive structure includes

paracrystalline organizations with a spacing of 0.5-30 nm, preferably 5-15 nm, on the surface of the virus. The creation of this type of fusion protein will result in multiple, ordered and repetitive first attachment sites on the surface of the virus and reflect the normal organization of the native viral protein. As will be understood by those in the art, the first attachment site may be or be a part of any suitable protein, polypeptide, sugar, polynucleotide, peptide (amino acid), natural or synthetic polymer, a secondary metabolite or combination thereof that may serve to specifically attach the antigen or antigenic determinant leading an ordered and repetitive antigen array.

[0115] In another embodiment of the invention, the first and/or second core particle is a recombinant alphavirus, and more specifically, a recombinant Sindbis virus. Alphaviruses are positive stranded RNA viruses that replicate their genomic RNA entirely in the cytoplasm of the infected cell and without a DNA intermediate (Strauss, J. and Strauss, E., *Microbiol. Rev.* 58:491-562 (1994)). Several members of the alphavirus family, Sindbis (Xiong, C. et al., *Science* 243: 1188-1191 (1989); Schlesinger, S., *Trends Biotechnol.* 11:18-22 (1993)), Semliki Forest Virus (SFV) (Liljeström, P. & Garoff, H., *Bio/Technology* 9:1356-1361 (1991)) and others (Davis, N. L. et al., *Virology* 171:189-204 (1989)), have received considerable attention for use as virus-based expression vectors for a variety of different proteins (Lundstrom, K., *Curr. Opin. Biotechnol.* 8:578-582 (1997); Liljeström, P., *Curr. Opin. Biotechnol.* 5:495-500 (1994)) and as candidates for vaccine development. Recently, a number of patents have issued directed to the use of alphaviruses for the expression of heterologous proteins and the development of vaccines (see U.S. Pat. Nos. 5,766,602; 5,792,462; 5,739,026; 5,789,245 and 5,814,482). The construction of the alphaviral core particles of the invention may be done by means generally known in the art of recombinant DNA technology, as described by the aforementioned articles, which are incorporated herein by reference.

[0116] A variety of different recombinant host cells can be utilized to produce a viral-based core particle for antigen or antigenic determinant attachment. For example, alphaviruses are known to have a wide host range; Sindbis virus infects cultured mammalian, reptilian, and amphibian cells, as well as some insect cells (Clark, H., *J. Natl. Cancer Inst.* 51:645 (1973); Leake, C., *J. Gen. Virol.* 35:335 (1977); Stollar, V. in *THE TOGAVIRUSES*, R. W. Schlesinger, Ed., Academic Press, (1980), pp. 583-621). Thus, numerous recombinant host cells can be used in the practice of the invention. BHK, COS, Vero, HeLa and CHO cells are particularly suitable for the production of heterologous proteins because they have the potential to glycosylate heterologous proteins in a manner similar to human cells (Watson, E. et al., *Glycobiology* 4:227, (1994)) and can be selected (Zang, M. et al., *Bio/Technology* 13:389 (1995)) or genetically engineered (Renner W. et al., *Biotech. Bioeng.* 4:476 (1995); Lee K. et al. *Biotech. Bioeng.* 50:336 (1996)) to grow in serum-free medium, as well as in suspension.

[0117] Introduction of the polynucleotide vectors into host cells can be effected by methods described in standard laboratory manuals (see, e.g., Sambrook, J. et al., eds., *MOLECULAR CLONING, A LABORATORY MANUAL*, 2nd. edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989), Chapter 9; Ausubel, F. et al., eds., *CURRENT PROTOCOLS IN MOLECULAR BIOLOGY*, John H. Wiley & Sons, Inc. (1997), Chapter 16), including methods such as electropora-

tion, DEAE-dextran mediated transfection, transfection, microinjection, cationic lipid-mediated transfection, transduction, scrape loading, ballistic introduction, and infection. Methods for the introduction of exogenous DNA sequences into host cells are discussed in Felgner, P. et al., U.S. Pat. No. 5,580,859.

[0118] Packaged RNA sequences can also be used to infect host cells. These packaged RNA sequences can be introduced to host cells by adding them to the culture medium. For example, the preparation of non-infective alphaviral particles is described in a number of sources, including "Sindbis Expression System", Version C (Invitrogen Catalog No. K750-1).

[0119] When mammalian cells are used as recombinant host cells for the production of viral-based core particles, these cells will generally be grown in tissue culture. Methods for growing cells in culture are well known in the art (see, e.g., Celis, J., ed., *CELL BIOLOGY*, Academic Press, 2nd edition, (1998); Sambrook, J. et al., eds., *MOLECULAR CLONING, A LABORATORY MANUAL*, 2nd. edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989); Ausubel, F. et al., eds., *CURRENT PROTOCOLS IN MOLECULAR BIOLOGY*, John H. Wiley & Sons, Inc. (1997); Freshney, R., *CULTURE OF ANIMAL CELLS*, Alan R. Liss, Inc. (1983)).

[0120] Further examples of RNA viruses suitable for use as core particle in the present invention include, but are not limited to, the following: members of the family Reoviridae, including the genus Orthoreovirus (multiple serotypes of both mammalian and avian retroviruses), the genus Orbivirus (Bluetongue virus, Eugenangee virus, Kemerovo virus, African horse sickness virus, and Colorado Tick Fever virus), the genus Rotavirus (human rotavirus, Nebraska calf diarrhea virus, murine rotavirus, simian rotavirus, bovine or ovine rotavirus, avian rotavirus); the family Picornaviridae, including the genus Enterovirus (poliovirus, Coxsackie virus A and B, enteric cytopathic human orphan (ECHO) viruses, hepatitis A, C, D, E and G viruses, Simian enteroviruses, Murine encephalomyelitis (ME) viruses, Poliovirus muris, Bovine enteroviruses, Porcine enteroviruses, the genus Cardiovirus (Encephalomyocarditis virus (EMC), Mengovirus), the genus Rhinovirus (Human rhinoviruses including at least 113 subtypes; other rhinoviruses), the genus Aphovirus (Foot and Mouth disease (FMDV); the family Calciviridae, including Vesicular exanthema of swine virus, San Miguel sea lion virus, Feline picornavirus and Norwalk virus; the family Togaviridae, including the genus Alphavirus (Eastern equine encephalitis virus, Semliki forest virus, Sindbis virus, Chikungunya virus, O'Nyong-Nyong virus, Ross river virus, Venezuelan equine encephalitis virus, Western equine encephalitis virus), the genus Flavivirus (Mosquito borne yellow fever virus, Dengue virus, Japanese encephalitis virus, St. Louis encephalitis virus, Murray Valley encephalitis virus, West Nile virus, Kunjin virus, Central European tick borne virus, Far Eastern tick borne virus, Kyasanur forest virus, Louping III virus, Powassan virus, Omsk hemorrhagic fever virus), the genus Rubivirus (Rubella virus), the genus Pestivirus (Mucosal disease virus, Hog cholera virus, Border disease virus); the family Bunyaviridae, including the genus Bunyavirus (Bunyamwera and related viruses, California encephalitis group viruses), the genus Phlebovirus (Sandfly fever Sicilian virus, Rift Valley fever virus), the genus Nairovirus (Crimean-Congo hemorrhagic fever virus, Nairobi sheep disease virus), and the genus Uukuvirus (Uukuniemi and related viruses); the family Orthomyxoviri-

dae, including the genus Influenza virus (Influenza virus type A, many human subtypes); Swine influenza virus, and Avian and Equine Influenza viruses; influenza type B (many human subtypes), and influenza type C (possible separate genus); the family paramyxoviridae, including the genus Paramyxovirus (Parainfluenza virus type 1, Sendai virus, Hemadsorption virus, Parainfluenza viruses types 2 to 5, Newcastle Disease Virus, Mumps virus), the genus Morbillivirus (Measles virus, subacute sclerosing panencephalitis virus, distemper virus, Rinderpest virus), the genus Pneumovirus (respiratory syncytial virus (RSV), Bovine respiratory syncytial virus and Pneumonia virus of mice); forest virus, Sindbis virus, Chikungunya virus, O'Nyong-Nyong virus, Ross river virus, Venezuelan equine encephalitis virus, Western equine encephalitis virus), the genus Flavivirus (Mosquito borne yellow fever virus, Dengue virus, Japanese encephalitis virus, St. Louis encephalitis virus, Murray Valley encephalitis virus, West Nile virus, Kunjin virus, Central European tick borne virus, Far Eastern tick borne virus, Kyasanur forest virus, Louping III virus, Powassan virus, Omsk hemorrhagic fever virus), the genus Rubivirus (Rubella virus), the genus Pestivirus (Mucosal disease virus, Hog cholera virus, Border disease virus); the family Bunyaviridae, including the genus Bunyavirus (Bunyamwera and related viruses, California encephalitis group viruses), the genus Phlebovirus (Sandfly fever Sicilian virus, Rift Valley fever virus), the genus Nairovirus (Crimean-Congo hemorrhagic fever virus, Nairobi sheep disease virus), and the genus Uukuvirus (Uukuniemi and related viruses); the family Orthomyxoviridae, including the genus Influenza virus (Influenza virus type A, many human subtypes); Swine influenza virus, and Avian and Equine Influenza viruses; influenza type B (many human subtypes), and influenza type C (possible separate genus); the family paramyxoviridae, including the genus Paramyxovirus (Parainfluenza virus type 1, Sendai virus, Hemadsorption virus, Parainfluenza viruses types 2 to 5, Newcastle Disease Virus, Mumps virus), the genus Morbillivirus (Measles virus, subacute sclerosing panencephalitis virus, distemper virus, Rinderpest virus), the genus Pneumovirus (respiratory syncytial virus (RSV), Bovine respiratory syncytial virus and Pneumonia virus of mice); the family Rhabdoviridae, including the genus Vesiculovirus (VSV), Chandipura virus, Flanders-Hart Park virus), the genus Lyssavirus (Rabies virus), fish Rhabdoviruses and, filoviruses (Marburg virus and Ebola virus); the family Arenaviridae, including Lymphocytic choriomeningitis virus (LCM), Tacaribe virus complex, and Lassa virus; the family Coronaviridae, including Infectious Bronchitis Virus (IBV), Mouse Hepatitis virus, Human enteric corona virus, and Feline infectious peritonitis (Feline coronavirus).

[0121] Illustrative DNA viruses that may be used as core particles include, but are not limited to: the family Poxviridae, including the genus Orthopoxvirus (Variola major, Variola minor, Monkey pox Vaccinia, Cowpox, Buffalopox, Rabbitpox, Ectromelia), the genus Leporipoxvirus (Myxoma, Fibroma), the genus Avipoxvirus (Fowlpox, other avian poxvirus), the genus Capripoxvirus (sheeppox, goatpox), the genus Suipoxvirus (Swinpox), the genus Parapoxvirus (contagious postular dermatitis virus, pseudocowpox, bovine papular stomatitis virus); the family Iridoviridae (African swine fever virus, Frog viruses 2 and 3, Lymphocystis virus of fish); the family Herpesviridae, including the alpha-Herpesviruses (Herpes Simplex Types 1 and 2, Varicella-Zoster, Equine abortion virus, Equine herpes virus 2 and 3, pseudo-

rabies virus, infectious bovine keratoconjunctivitis virus, infectious bovine rhinotracheitis virus, feline rhinotracheitis virus, infectious laryngotracheitis virus) the Beta-herpesviruses (Human cytomegalovirus and cytomegaloviruses of swine, monkeys and rodents); the gamma-herpesviruses (Epstein-Barr virus (EBV), Marek's disease virus, Herpes saimiri, Herpesvirus ateles, Herpesvirus sylvilagus, guinea pig herpes virus, Lucke tumor virus); the family Adenoviridae, including the genus Mastadenovirus (Human subgroups A, B, C, D and E and ungrouped; simian adenoviruses (at least 23 serotypes), infectious canine hepatitis, and adenoviruses of cattle, pigs, sheep, frogs and many other species, the genus Aviadenovirus (Avian adenoviruses); and non-cultivable adenoviruses; the family Papoviridae, including the genus Papillomavirus (Human papilloma viruses, bovine papilloma viruses, Shope rabbit papilloma virus, and various pathogenic papilloma viruses of other species), the genus Polyomavirus (polyomavirus, Simian vacuolating agent (SV-40), Rabbit vacuolating agent (RKV), K virus, BK virus, JC virus, and other primate polyoma viruses such as Lymphotropic papilloma virus); the family Parvoviridae including the genus Adeno-associated viruses, the genus Parvovirus (Feline panleukopenia virus, bovine parvovirus, canine parvovirus, Aleutian mink disease virus, etc.). Finally, DNA viruses may include viruses such as chronic infectious neuropathic agents (CHINA virus).

[0122] In other embodiments, a bacterial pilin, a subportion of a bacterial pilin, or a fusion protein which contains either a bacterial pilin or subportion thereof is used to prepare compositions of the invention. Examples of pilin proteins include pilins produced by *Escherichia coli*, *Haemophilus influenzae*, *Neisseria meningitidis*, *Neisseria gonorrhoeae*, *Caulobacter crescentus*, *Pseudomonas stutzeri*, and *Pseudomonas aeruginosa*. The amino acid sequences of pilin proteins suitable for use with the present invention include those set out in GenBank reports AJ000636 (SEQ ID NO:1), AJ132364 (SEQ ID NO:2), AF229646 (SEQ ID NO:3), AF051814 (SEQ ID NO:4), AF051815 (SEQ ID NO:5), and X00981 (SEQ ID NO:6), the entire disclosures of which are incorporated herein by reference.

[0123] Bacterial pilin proteins are generally processed to remove N-terminal leader sequences prior to export of the proteins into the bacterial periplasm. Further, as one skilled in the art would recognize, bacterial pilin proteins used to prepare compositions of the invention will generally not have the naturally present leader sequence.

[0124] One specific example of a pilin protein suitable for use in the present invention is the P-pilin of *E. coli* (GenBank report AF237482 (SEQ ID NO:7)). A preferred example of a Type-1 *E. coli* pilin suitable for use with the invention is a pilin having the amino acid sequence set out in GenBank report P04128 (SEQ ID NO:8), which is encoded by nucleic acid having the nucleotide sequence set out in GenBank report M27603 (SEQ ID NO:9). The entire disclosures of these GenBank reports are incorporated herein by reference. Again, the mature form of the above referenced protein would generally be used to prepare compositions of the invention.

[0125] Bacterial pilins or pilin subportions suitable for use in the practice of the present invention will generally be able to associate to form ordered and repetitive antigen arrays.

[0126] Methods for preparing pili and pilus-like structures in vitro are known in the art (Bullitt et al., *Proc. Natl. Acad. Sci. USA* 93:12890-12895 (1996), for example, describe the in vitro reconstitution of *E. coli* P-pili subunits. Furthermore,

Eshdat et al., *J. Bacteriol.* 148:308-314 (1981) describe methods suitable for dissociating Type-1 pili of *E. coli* and the reconstitution of pili).

[0127] Further, using, for example, conventional genetic engineering and protein modification methods, pilin proteins may be modified to contain a first attachment site to which an antigen or antigenic determinant is linked through a second attachment site. Alternatively, antigens or antigenic determinants can be directly linked through a second attachment site to amino acid residues which are naturally resident in the pilin proteins. These modified pilin proteins may then be used in compositions of the invention.

[0128] Bacterial pilin proteins used to prepare compositions of the invention may be modified in a manner similar to that described herein for HBcAg. For example, cysteine and lysine residues may be either deleted or substituted with other amino acid residues and first attachment sites may be added to these proteins. Further, pilin proteins may either be expressed in modified form or may be chemically modified after expression. Similarly, intact pili may be harvested from bacteria and then modified chemically.

[0129] In another embodiment, pili or pilus-like structures are harvested from bacteria (e.g., *E. coli*) and used to form compositions of the invention. One preferred example of pili suitable for preparing compositions is the Type-1 pilus of *E. coli*, which is formed from pilin monomers having the amino acid sequence set out in SEQ ID NO:8.

[0130] A number of methods for harvesting bacterial pili are known in the art. Bullitt and Makowski (*Biophys. J.* 74:623-632 (1998)), for example, describe a pilus purification method for harvesting P-pili from *E. coli*.

[0131] Once harvested, pili or pilus-like structures may be modified in a variety of ways. For example, a first attachment site can be added to the pili to which antigens or antigenic determinants may be attached through a second attachment site. In other words, bacterial pili or pilus-like structures can be harvested and modified to lead to ordered and repetitive antigen arrays.

[0132] Antigens or antigenic determinants could be linked to naturally occurring cysteine residues or lysine residues present in Pili or pilus-like structures. In such instances, the high order and repetitiveness of a naturally occurring amino acid residue would guide the coupling of the antigens or antigenic determinants to the pili or pilus-like structures. For example, the pili or pilus-like structures could be linked to the second attachment sites of the antigens or antigenic determinants using a heterobifunctional cross-linking agent.

[0133] When structures which are naturally synthesized by organisms (e.g., pili) are used to prepare compositions of the invention, it will often be advantageous to genetically engineer these organisms so that they produce structures having desirable characteristics. For example, when Type-1 pili of *E. coli* are used, the *E. coli* from which these pili are harvested may be modified so as to produce structures with specific characteristics. Examples of possible modifications of pilin proteins include the insertion of one or more lysine residues, the deletion or substitution of one or more of the naturally resident lysine residues, and the deletion or substitution of one or more naturally resident cysteine residues (e.g., the cysteine residues at positions 44 and 84 in SEQ ID NO:8).

[0134] Further, additional modifications can be made to pilin genes which result in the expression products containing a first attachment site other than a lysine residue (e.g., a FOS or JUN domain). Of course, suitable first attachment sites will generally be limited to those which do not prevent pilin proteins from forming pili or pilus-like structures suitable for use in compositions of the invention.

[0135] Pilin genes which naturally reside in bacterial cells can be modified in vivo (e.g., by homologous recombination) or pilin genes with particular characteristics can be inserted into these cells. For examples, pilin genes could be introduced into bacterial cells as a component of either a replicable cloning vector or a vector which inserts into the bacterial chromosome. The inserted pilin genes may also be linked to expression regulatory control sequences (e.g., a lac operator).

[0136] Further preferred compositions used for the method of the invention comprising, alternatively consisting essentially of, or alternatively consisting of pili or pilus-like structures as first and/or second core particle are described in WO 01/85208 and WO 02/056905, the disclosure of which are herewith incorporated by reference in its entirety.

[0137] In additional, the antigen or antigenic determinant can be linked to bacterial pili or pilus-like structures by a bond which is not a peptide bond, bacterial cells which produce pili or pilus-like structures used in the compositions of the invention can be genetically engineered to generate pilin proteins which are fused to an antigen or antigenic determinant. Such fusion proteins which form pili or pilus-like structures are suitable for use in the method of the invention.

[0138] Virus-like particles (VLPs) in the context of the present application refer to structures resembling a virus particle but which are not pathogenic. In general, virus-like particles lack the viral genome and, therefore, are noninfectious. Also, virus-like particles can be produced in large quantities by heterologous expression and can be easily purified.

[0139] In a preferred embodiment, the virus-like particle is a recombinant virus-like particle. The skilled artisan can produce VLPs using recombinant DNA technology and virus coding sequences which are readily available to the public. For example, the coding sequence of a virus envelope or core protein can be engineered for expression in a baculovirus expression vector using a commercially available baculovirus vector, under the regulatory control of a virus promoter, with appropriate modifications of the sequence to allow functional linkage of the coding sequence to the regulatory sequence. The coding sequence of a virus envelope or core protein can also be engineered for expression in a bacterial expression vector, for example.

[0140] Examples of VLPs include, but are not limited to, the capsid proteins of Hepatitis B virus (Ulrich, et al., *Virus Res.* 50:141-182 (1998)), measles virus (Warnes, et al., *Gene* 160:173-178 (1995)), Sindbis virus, rotavirus (U.S. Pat. No. 5,071,651 and U.S. Pat. No. 5,374,426), foot-and-mouth-disease virus (Twomey, et al., *Vaccine* 13:1603-1610, (1995)), Norwalk virus (Jiang, X., et al., *Science* 250:1580-1583 (1990); Matsui, S. M., et al., *J. Clin. Invest.* 87:1456-1461 (1991)), the retroviral GAG protein (WO 96/30523), the retrotransposon Ty protein p1, the surface protein of Hepatitis B virus (WO 92/11291), human papilloma virus (WO 98/15631), RNA phages, Ty, fr-phage, GA-phage, AP205-phage, and Q β -phage.

[0141] As will be readily apparent to those skilled in the art, the VLP of the invention is not limited to any specific form. The particle can be synthesized chemically or through a biological process, which can be natural or non-natural. By way of example, this type of embodiment includes a virus-like particle or a recombinant form thereof.

[0142] In a more specific embodiment, the VLP can comprise, or alternatively essentially consist of, or alternatively consist of recombinant polypeptides, or fragments thereof, being selected from recombinant polypeptides of Rotavirus, recombinant polypeptides of Norwalk virus, recombinant polypeptides of Alphavirus, recombinant polypeptides of Foot and Mouth Disease virus, recombinant polypeptides of

measles virus, recombinant polypeptides of Sindbis virus, recombinant polypeptides of Polyoma virus, recombinant polypeptides of Retrovirus, recombinant polypeptides of Hepatitis B virus (e.g., a HBcAg), recombinant polypeptides of Tobacco mosaic virus, recombinant polypeptides of Flock House Virus, recombinant polypeptides of human Papillomavirus, recombinant polypeptides of bacteriophages, recombinant polypeptides of RNA phages, recombinant polypeptides of Ty, recombinant polypeptides of fr-phage, recombinant polypeptides of GA-phage, recombinant polypeptides of AP205-phage, and recombinant polypeptides of Q β -phage. The virus-like particle can further comprise, or alternatively essentially consist of, or alternatively consist of, one or more fragments of such polypeptides, as well as variants of such polypeptides. Variants of polypeptides can share, for example, at least 80%, 85%, 90%, 95%, 97%, or 99% identity at the amino acid level with their wild-type counterparts.

[0143] In a preferred embodiment, the virus-like particle comprises, consists essentially of, or alternatively consists of recombinant proteins, or fragments thereof, of a RNA-phage. Preferably, the RNA-phage is selected from the group consisting of a) bacteriophage Q β ; b) bacteriophage R17; c) bacteriophage fr; d) bacteriophage GA; e) bacteriophage SP; f) bacteriophage MS2; g) bacteriophage M11; h) bacteriophage MX1; i) bacteriophage NL95; j) bacteriophage f2; k) bacteriophage PP7; and l) bacteriophage AP205.

[0144] In another preferred embodiment of the present invention, the virus-like particle comprises, or alternatively consists essentially of, or alternatively consists of recombinant proteins, or fragments thereof, of the RNA-bacteriophage Q β or of the RNA-bacteriophage fr.

[0145] In a further preferred embodiment of the present invention, the recombinant proteins comprise, or alternatively consist essentially of, or alternatively consist of coat proteins of RNA phages.

[0146] RNA-phage coat proteins forming capsids or VLP's, or fragments of the bacteriophage coat proteins compatible with self-assembly into a capsid or a VLP, are, therefore, further preferred embodiments of the present invention. Bacteriophage Q β coat proteins, for example, can be expressed recombinantly in *E. coli*. Further, upon such expression these proteins spontaneously form capsids. Additionally, these capsids form a structure with an inherent repetitive organization.

[0147] Specific preferred examples of bacteriophage coat proteins which can be used to prepare compositions of the invention include the coat proteins of RNA bacteriophages such as bacteriophage Q β (SEQ ID NO:10; PIR Database, Accession No. VCBPQ β referring to Q β CP and SEQ ID NO: 11; Accession No. AAA16663 referring to Q β A1 protein), bacteriophage R17 (SEQ ID NO:12; PIR Accession No. VCBPR7), bacteriophage fr (SEQ ID NO:13; PIR Accession No. VCBPFR), bacteriophage GA (SEQ ID NO:14; GenBank Accession No. NP-040754), bacteriophage SP (SEQ ID NO:15; GenBank Accession No. CAA30374 referring to SP CP and SEQ ID NO: 16; Accession No. NP_695026 referring to SP A1 protein), bacteriophage MS2 (SEQ ID NO:17; PIR Accession No. VCBPM2), bacteriophage M11 (SEQ ID NO:18; GenBank Accession No. AAC06250), bacteriophage MX1 (SEQ ID NO:19; GenBank Accession No. AAC14699), bacteriophage NL95 (SEQ ID NO:20; GenBank Accession No. AAC14704), bacteriophage f2 (SEQ ID NO: 21; GenBank Accession No. P03611), bacteriophage PP7 (SEQ ID NO: 22), bacteriophage AP205 (SEQ ID NO: 81). Furthermore, the A1 protein of bacteriophage Q β or C-terminal truncated forms missing as much as 100, 150 or 180 amino acids from its C-terminus may be incorporated in a capsid assembly

of Q β coat proteins. Generally, the percentage of Q β A1 protein relative to Q β CP in the capsid assembly will be limited, in order to ensure capsid formation.

[0148] Q β coat protein has been found to self-assemble into capsids when expressed in *E. coli* (Kozlovskaya T M. et al., *GENE* 137: 133-137 (1993)). The capsid contains 180 copies of the coat protein, which are linked in covalent pentamers and hexamers by disulfide bridges (Golmohammadi, R. et al., *Structure* 4: 543-5554 (1996)) leading to a remarkable stability of the capsid of Q β coat protein. Q β capsid protein also shows unusual resistance to organic solvents and denaturing agents. Surprisingly, we have observed that DMSO and acetonitrile concentrations as high as 30%, and Guanidinium concentrations as high as 1 M do not affect the stability of the capsid.

[0149] Upon expression in *E. coli*, the N-terminal methionine of Q β coat protein is usually removed, as we observed by N-terminal Edman sequencing as described in Stoll, E., et al., *J. Biol. Chem.* 252:990-993 (1977). VLP composed from Q β coat proteins where the N-terminal methionine has not been removed, or VLPs comprising a mixture of Q β coat proteins where the N-terminal methionine is either cleaved or present are also within the scope of the present invention.

[0150] Further preferred virus-like particles of RNA-phages, in particular of Q β , as first and/or second core particle in accordance of this invention are disclosed in WO 02/056905, the disclosure of which is herewith incorporated by reference in its entirety.

[0151] Further RNA phage coat proteins have also been shown to self-assemble upon expression in a bacterial host (Kastelein, R A. et al., *Gene* 23: 245-254 (1983), Kozlovskaya, T M. et al., *Dokl. Akad. Nauk SSSR* 287: 452-455 (1986), Adhin, M.R. et al., *Virology* 170: 238-242 (1989), Ni, C.Z., et al., *Protein Sci.* 5: 2485-2493 (1996), Priano, C., et al., *J. Mol. Biol.* 249: 283-297 (1995)). The Q β phage capsid contains, in addition to the coat protein, the so called read-through protein A1 and the maturation protein A2. A1 is generated by suppression at the UGA stop codon and has a length of 329 aa. The capsid of phage Q β recombinant coat protein typically and preferably used in the invention is devoid of the A2 lysis protein, and contains RNA from the host. The coat protein of RNA phages is an RNA binding protein, and interacts with the stem loop of the ribosomal binding site of the replicase gene acting as a translational repressor during the life cycle of the virus. The sequence and structural elements of the interaction are known (Witherell, G W. & Uhlenbeck, O C. *Biochemistry* 28: 71-76 (1989); Lim F., et al., *J. Biol. Chem.* 271: 31839-31845 (1996)). The stem loop and RNA in general are known to be involved in the virus assembly (Golmohammadi, R. et al., *Structure* 4: 543-5554 (1996)).

[0152] In a further preferred embodiment, the virus-like particle comprises, or alternatively consists essentially of, or alternatively consists of recombinant proteins, or fragments thereof, of a RNA-phage, wherein the recombinant proteins comprise, consist essentially of or alternatively consist of mutant coat proteins of a RNA phage, preferably of mutant coat proteins of the RNA phages mentioned above. In another preferred embodiment, the mutant coat proteins of the RNA phage have been modified by removal of at least one lysine residue by way of substitution, or by addition of at least one lysine residue by way of substitution; alternatively, the mutant coat proteins of the RNA phage have been modified by deletion of at least one lysine residue, or by addition of at least one lysine residue by way of insertion.

[0153] In another preferred embodiment, the virus-like particle comprises, or alternatively consists essentially of, or

alternatively consists of recombinant proteins, or fragments thereof, of the RNA-bacteriophage Q β , wherein the recombinant proteins comprise, or alternatively consist essentially of, or alternatively consist of coat proteins having an amino acid sequence of SEQ ID NO:10, or a mixture of coat proteins having amino acid sequences of SEQ ID NO:10 and of SEQ ID NO: 11 or mutants of SEQ ID NO: 11 and wherein the N-terminal methionine is preferably cleaved.

[0154] In a further preferred embodiment, the virus-like particle comprises, consists essentially of or alternatively consists of recombinant proteins of Q β , or fragments thereof, wherein the recombinant proteins comprise, or alternatively consist essentially of, or alternatively consist of mutant Q β coat proteins. In another preferred embodiment, these mutant coat proteins have been modified by removal of at least one lysine residue by way of substitution, or by addition of at least one lysine residue by way of substitution. Alternatively, these mutant coat proteins have been modified by deletion of at least one lysine residue, or by addition of at least one lysine residue by way of insertion.

[0155] Four lysine residues are exposed on the surface of the capsid of Q β coat protein. Q β mutants, for which exposed lysine residues are replaced by arginines can also be used for the present invention. The following Q β coat protein mutants and mutant Q β VLP's can, thus, be used in the practice of the invention: "Q β -240" (Lys13-Arg; SEQ ID NO:23), "Q β -243" (Asn 10-Lys; SEQ ID NO:24), "Q β -250" (Lys 2-Arg, Lys13-Arg; SEQ ID NO:25), "Q β -251" (SEQ ID NO:26) and "Q β -259" (Lys 2-Arg, Lys16-Arg; SEQ ID NO:27). Thus, in further preferred embodiment of the present invention, the virus-like particle comprises, consists essentially of or alternatively consists of recombinant proteins of mutant Q β coat proteins, which comprise proteins having an amino acid sequence selected from the group of a) the amino acid sequence of SEQ ID NO:23; b) the amino acid sequence of SEQ ID NO:24; c) the amino acid sequence of SEQ ID NO:25; d) the amino acid sequence of SEQ ID NO:26; and e) the amino acid sequence of SEQ ID NO:27. The construction, expression and purification of the above indicated Q β coat proteins, mutant Q β coat protein VLP's and capsids, respectively, are described in Example 18 of WO 02/056905.

[0156] In a further preferred embodiment of the present invention, the virus-like particle comprises, or alternatively consists essentially of, or alternatively consists of recombinant proteins of Q β , or fragments thereof, wherein the recombinant proteins comprise, consist essentially of or alternatively consist of a mixture of either one of the foregoing Q β mutants and the corresponding A1 protein.

[0157] In a further preferred embodiment, the virus-like particle comprises, or alternatively essentially consists of, or alternatively consists of recombinant proteins, or fragments thereof, of RNA-phage AP205.

[0158] The AP205 genome consists of a maturation protein, a coat protein, a replicase and two open reading frames not present in related phages; a lysis gene and an open reading frame playing a role in the translation of the maturation gene (Klovins, J., et al., *J. Gen. Virol.* 83: 1523-33 (2002)). AP205 coat protein can be expressed from plasmid pAP283-58 (SEQ ID NO: 79), which is a derivative of pQb10 (Kozlovskaya, T. M. et al., *Gene* 137:133-37 (1993)), and which contains an AP205 ribosomal binding site. Alternatively, AP205 coat protein may be cloned into pQb185, downstream of the ribosomal binding site present in the vector. Both approaches lead to expression of the protein and formation of capsids. Vectors pQb10 and pQb185 are vectors derived from pGEM vector, and expression of the cloned genes in these vectors is controlled by the trp promoter (Kozlovskaya, T. M. et al., *Gene*

137:133-37 (1993)). Plasmid pAP283-58 (SEQ ID NO:79) comprises a putative AP205 ribosomal binding site in the following sequence, which is downstream of the XbaI site, and immediately upstream of the ATG start codon of the AP205 coat protein: tctagaATTTTCTGCGCACCCATC-CCGGGTGGCGCCCAAAGTGAGGAAAATCACat g (bases 77-133 of SEQ ID NO: 79). The vector pQb185 comprises a Shine Delagarno sequence downstream from the XbaI site and upstream of the start codon (tctagaTTAAC-CCAACGCGTAGGAGTCAGGCCatg, (SEQ ID NO: 80), Shine Delagarno sequence underlined).

[0159] In a further preferred embodiment of the present invention, the virus-like particle comprises, or alternatively essentially consists of, or alternatively consists of recombinant coat proteins, or fragments thereof, of the RNA-phage AP205.

[0160] This preferred embodiment of the present invention, thus, comprises AP205 coat proteins that form capsids. Such proteins are recombinantly expressed, or prepared from natural sources. AP205 coat proteins produced in bacteria spontaneously form capsids, as evidenced by Electron Microscopy (EM) and immunodiffusion. The structural properties of the capsid formed by the AP205 coat protein (SEQ ID NO: 81) and those formed by the coat protein of the AP205 RNA phage are nearly indistinguishable when seen in EM. AP205 VLPs are highly immunogenic, and can be linked with antigens and/or antigenic determinants to generate constructs displaying the antigens and/or antigenic determinants oriented in a repetitive manner. High titers are elicited against the so displayed antigens showing that bound antigens and/or antigenic determinants are accessible for interacting with antibody molecules and are immunogenic.

[0161] In a further preferred embodiment of the present invention, the virus-like particle comprises, or alternatively essentially consists of, or alternatively consists of recombinant mutant coat proteins, or fragments thereof, of the RNA-phage AP205.

[0162] Assembly-competent mutant forms of AP205 VLPs, including AP205 coat protein with the substitution of proline at amino acid 5 to threonine (SEQ ID NO: 82), may also be used in the practice of the invention and leads to a further preferred embodiment of the invention. These VLPs, AP205 VLPs derived from natural sources, or AP205 viral particles, may be bound to antigens to produce ordered repetitive arrays of the antigens in accordance with the present invention.

[0163] AP205 P5-T mutant coat protein can be expressed from plasmid pAP281-32 (SEQ ID No. 83), which is derived directly from pQb185, and which contains the mutant AP205 coat protein gene instead of the Q β coat protein gene. Vectors for expression of the AP205 coat protein are transfected into *E. coli* for expression of the AP205 coat protein.

[0164] Methods for expression of the coat protein and the mutant coat protein, respectively, leading to self-assembly into VLPs, as well as the coupling of antigens or antigenic determinants to those preferred VLPs, are described in Examples 2-11 of the co-pending U.S. provisional application 60/396,126 which is incorporated herewith by reference in its entirety. Suitable *E. coli* strains include, but are not limited to, *E. coli* K802, JM 109, RR1. Suitable vectors and strains and combinations thereof can be identified by testing expression of the coat protein and mutant coat protein, respectively, by SDS-PAGE and capsid formation and assembly by optionally first purifying the capsids by gel filtration and subsequently testing them in an immunodiffusion assay (Ouchterlony test) or Electron Microscopy (Kozlovskaya, T. M., et al., *Gene* 137:133-37 (1993)).

[0165] AP205 coat proteins expressed from the vectors pAP283-58 and pAP281-32 may be devoid of the initial Methionine amino-acid, due to processing in the cytoplasm of *E. coli*. Cleaved, uncleaved forms of AP205 VLP, or mixtures thereof are further preferred embodiments of the invention.

[0166] In a further preferred embodiment of the present invention, the virus-like particle comprises, or alternatively essentially consists of, or alternatively consists of a mixture of recombinant coat proteins, or fragments thereof, of the RNA-phage AP205 and of recombinant mutant coat proteins, or fragments thereof, of the RNA-phage AP205.

[0167] In a further preferred embodiment of the present invention, the virus-like particle comprises, or alternatively essentially consists of, or alternatively consists of fragments of recombinant coat proteins or recombinant mutant coat proteins of the RNA-phage AP205.

[0168] Recombinant AP205 coat protein fragments capable of assembling into a VLP and a capsid, respectively are also useful in the practice of the invention. These fragments may be generated by deletion, either internally or at the termini of the coat protein and mutant coat protein, respectively. Insertions in the coat protein and mutant coat protein sequence or fusions of antigen sequences to the coat protein and mutant coat protein sequence, and compatible with assembly into a VLP, are further embodiments of the invention and lead to chimeric AP205 coat proteins, and particles, respectively. The outcome of insertions, deletions and fusions to the coat protein sequence and whether it is compatible with assembly into a VLP can be determined by electron microscopy.

[0169] The particles formed by the AP205 coat protein, coat protein fragments and chimeric coat proteins described above, can be isolated in pure form by a combination of fractionation steps by precipitation and of purification steps by gel filtration using e.g. Sepharose CL-4B, Sepharose CL-2B, Sepharose CL-6B columns and combinations thereof. Other methods of isolating virus-like particles are known in the art, and may be used to isolate the virus-like particles (VLPs) of bacteriophage AP205. For example, the use of ultracentrifugation to isolate VLPs of the yeast retrotransposon Ty is described in U.S. Pat. No. 4,918,166, which is incorporated by reference herein in its entirety.

[0170] The crystal structure of several RNA bacteriophages has been determined (Golmohammadi, R. et al., *Structure* 4:543-554 (1996)). Using such information, surface exposed residues can be identified and, thus, RNA-phage coat proteins can be modified such that one or more reactive amino acid residues can be inserted by way of insertion or substitution. As a consequence, those modified forms of bacteriophage coat proteins can also be used for the present invention. Thus, variants of proteins which form capsids or capsid-like structures (e.g., coat proteins of bacteriophage Q β , bacteriophage R17, bacteriophage fr, bacteriophage GA, bacteriophage SP, and bacteriophage MS2) can also be used to prepare compositions of the present invention.

[0171] Although the sequence of the variant proteins discussed above will differ from their wild-type counterparts, these variant proteins will generally retain the ability to form capsids or capsid-like structures. Thus, the invention further includes compositions which further includes variants of proteins which form capsids or capsid-like structures, as well as methods for preparing such compositions individual protein subunits used to prepare such compositions, and nucleic acid molecules which encode these protein subunits. Thus, included within the scope of the invention are variant forms of

wild-type proteins which form capsids or capsid-like structures and retain the ability to associate and form capsids or capsid-like structures.

[0172] As a result, the invention further includes compositions comprising proteins, which comprise, or alternatively consist essentially of, or alternatively consist of amino acid sequences which are at least 80%, 85%, 90%, 95%, 97%, or 99% identical to wild-type proteins which form ordered arrays and having an inherent repetitive structure, respectively.

[0173] Further included within the scope of the invention are nucleic acid molecules which encode proteins used to prepare compositions of the present invention.

[0174] In other embodiments, the invention further includes compositions comprising proteins, which comprise, or alternatively consist essentially of, or alternatively consist of amino acid sequences which are at least 80%, 85%, 90%, 95%, 97%, or 99% identical to any of the amino acid sequences shown in SEQ ID NOs:10-27.

[0175] Proteins suitable for use in the present invention also include C-terminal truncation mutants of proteins which form capsids or capsid-like structures, or VLP's. Specific examples of such truncation mutants include proteins having an amino acid sequence shown in any of SEQ ID NOs:10-27 where 1, 2, 5, 7, 9, 10, 12, 14, 15, or 17 amino acids have been removed from the C-terminus. Typically, these C-terminal truncation mutants will retain the ability to form capsids or capsid-like structures.

[0176] Further proteins suitable for use in the present invention also include N-terminal truncation mutants of proteins which form capsids or capsid-like structures. Specific examples of such truncation mutants include proteins having an amino acid sequence shown in any of SEQ ID NOs:10-27 where 1, 2, 5, 7, 9, 10, 12, 14, 15, or 17 amino acids have been removed from the N-terminus. Typically, these N-terminal truncation mutants will retain the ability to form capsids or capsid-like structures.

[0177] Additional proteins suitable for use in the present invention include N- and C-terminal truncation mutants which form capsids or capsid-like structures. Suitable truncation mutants include proteins having an amino acid sequence shown in any of SEQ ID NOs:10-27 where 1, 2, 5, 7, 9, 10, 12, 14, 15, or 17 amino acids have been removed from the N-terminus and 1, 2, 5, 7, 9, 10, 12, 14, 15, or 17 amino acids have been removed from the C-terminus. Typically, these N-terminal and C-terminal truncation mutants will retain the ability to form capsids or capsid-like structures.

[0178] The invention further includes compositions comprising proteins which comprise, or alternatively consist essentially of, or alternatively consist of, amino acid sequences which are at least 80%, 85%, 90%, 95%, 97%, or 99% identical to the above described truncation mutants.

[0179] The invention thus includes compositions prepared from proteins which form capsids or VLP's, methods for preparing these compositions from individual protein subunits and VLP's or capsids, methods for preparing these individual protein subunits, nucleic acid molecules which encode these subunits, and methods for vaccinating and/or eliciting immunological responses in individuals using these compositions of the present invention.

[0180] As previously stated, the invention includes virus-like particles or recombinant forms thereof. In one further preferred embodiment, the particles used in compositions of the invention are composed of a Hepatitis B core protein (HBcAg) or a fragment of a HBcAg. In a further embodiment, the particles used in compositions of the invention are composed of a Hepatitis B core protein (HBcAg) or a fragment of

a HBcAg protein, which has been modified to either eliminate or reduce the number of free cysteine residues. Zhou et al. (*J. Virol.* 66:5393-5398 (1992)) demonstrated that HBcAgs which have been modified to remove the naturally resident cysteine residues retain the ability to associate and form capsids. Thus, VLP's suitable for use in compositions of the invention include those comprising modified HBcAgs, or fragments thereof, in which one or more of the naturally resident cysteine residues have been either deleted or substituted with another amino acid residue (e.g., a serine residue).

[0181] The HBcAg is a protein generated by the processing of a Hepatitis B core antigen precursor protein. A number of isotypes of the HBcAg have been identified and their amino acids sequences are readily available to those skilled in the art. In most instances, compositions of the invention will be prepared using the processed form of a HBcAg (i.e., a HBcAg from which the N-terminal leader sequence of the Hepatitis B core antigen precursor protein have been removed).

[0182] Further, when HBcAgs are produced under conditions where processing will not occur, the HBcAgs will generally be expressed in "processed" form. For example, when an *E. coli* expression system directing expression of the protein to the cytoplasm is used to produce HBcAgs of the invention, these proteins will generally be expressed such that the N-terminal leader sequence of the Hepatitis B core antigen precursor protein is not present.

[0183] The preparation of Hepatitis B virus-like particles, which can be used for the present invention, is disclosed, for example, in WO 00/32227, and hereby in particular in Examples 17 to 19 and 21 to 24, as well as in WO 01/85208, and hereby in particular in Examples 17 to 19, 21 to 24, 31 and 41, and in WO 02/056905. For the latter application, it is in particular referred to Example 23, 24, 31 and 51. All three documents are explicitly incorporated herein by reference.

[0184] The present invention also includes HBcAg variants which have been modified to delete or substitute one or more additional cysteine residues. It is known in the art that free cysteine residues can be involved in a number of chemical side reactions. These side reactions include disulfide exchanges, reaction with chemical substances or metabolites that are, for example, injected or formed in a combination therapy with other substances, or direct oxidation and reaction with nucleotides upon exposure to UV light. Toxic adducts could thus be generated, especially considering the fact that HBcAgs have a strong tendency to bind nucleic acids. The toxic adducts would thus be distributed between a multiplicity of species, which individually may each be present at low concentration, but reach toxic levels when together.

[0185] In view of the above, one advantage to the use of HBcAgs in compositions which have been modified to remove naturally resident cysteine residues is that sites to which toxic species can bind when antigens or antigenic determinants are attached would be reduced in number or eliminated altogether.

[0186] A number of naturally occurring HBcAg variants suitable for use in the practice of the present invention have been identified. Yuan et al., (*J. Virol.* 73:10122-10128 (1999)), for example, describe variants in which the isoleucine residue at position corresponding to position 97 in SEQ ID NO:28 is replaced with either a leucine residue or a phenylalanine residue. The amino acid sequences of a number of HBcAg variants, as well as several Hepatitis B core antigen precursor variants, are disclosed in GenBank reports AAF121240 (SEQ ID NO:29), AF121239 (SEQ ID NO:30), X85297 (SEQ ID NO:31), X02496 (SEQ ID NO:32), X85305 (SEQ ID NO:33), X85303 (SEQ ID NO:34),

AF151735 (SEQ ID NO:35), X85259 (SEQ ID NO:36), X85286 (SEQ ID NO:37), X85260 (SEQ ID NO:38), X85317 (SEQ ID NO:39), X85298 (SEQ ID NO:40), AF043593 (SEQ ID NO:41), M20706 (SEQ ID NO:42), X85295 (SEQ ID NO:43), X80925 (SEQ ID NO:44), X85284 (SEQ ID NO:45), X85275 (SEQ ID NO:46), X72702 (SEQ ID NO:47), X85291 (SEQ ID NO:48), X65258 (SEQ ID NO:49), X85302 (SEQ ID NO:50), M32138 (SEQ ID NO:51), X85293 (SEQ ID NO:52), X85315 (SEQ ID NO:53), U95551 (SEQ ID NO:54), X85256 (SEQ ID NO:55), X85316 (SEQ ID NO:56), X85296 (SEQ ID NO:57), AB033559 (SEQ ID NO:58), X59795 (SEQ ID NO:59), X85299 (SEQ ID NO:60), X85307 (SEQ ID NO:61), X65257 (SEQ ID NO:62), X85311 (SEQ ID NO:63), X85301 (SEQ ID NO:64), X85314 (SEQ ID NO:65), X85287 (SEQ ID NO:66), X85272 (SEQ ID NO:67), X85319 (SEQ ID NO:68), AB010289 (SEQ ID NO:69), X85285 (SEQ ID NO:70), AB010289 (SEQ ID NO:71), AF121242 (SEQ ID NO:72), M90520 (SEQ ID NO:73), P03153 (SEQ ID NO:74), AF110999 (SEQ ID NO:75), and M95589 (SEQ ID NO:76), the disclosures of each of which are incorporated herein by reference. These HBcAg variants differ in amino acid sequence at a number of positions, including amino acid residues which corresponds to the amino acid residues located at positions 12, 13, 21, 22, 24, 29, 32, 33, 35, 38, 40, 42, 44, 45, 49, 51, 57, 58, 59, 64, 66, 67, 69, 74, 77, 80, 81, 87, 92, 93, 97, 98, 100, 103, 105, 106, 109, 113, 116, 121, 126, 130, 133, 135, 141, 147, 149, 157, 176, 178, 182 and 183 in SEQ ID NO:77. Further HBcAg variants suitable for use in the compositions of the invention, and which may be further modified according to the disclosure of this specification are described in WO 01/98333, WO 00/177158 and WO 00/214478.

[0187] As noted above, generally processed HBcAgs (i.e., those which lack leader sequences) will be used in the compositions of the invention. The present invention includes compositions which comprise the above described variant HBcAgs.

[0188] Whether the amino acid sequence of a polypeptide has an amino acid sequence that is at least 80%, 85%, 90%, 95%, 97% or 99% identical to one of the above wild-type amino acid sequences, or a subportion thereof, can be determined conventionally using known computer programs such the Bestfit program. When using Bestfit or any other sequence alignment program to determine whether a particular sequence is, for instance, 95% identical to a reference amino acid sequence, the parameters are set such that the percentage of identity is calculated over the full length of the reference amino acid sequence and that gaps in homology of up to 5% of the total number of amino acid residues in the reference sequence are allowed.

[0189] The HBcAg variants and precursors having the amino acid sequences set out in SEQ ID NOs: 29-72 and 73-76 are relatively similar to each other. Thus, reference to an amino acid residue of a HBcAg variant located at a position which corresponds to a particular position in SEQ ID NO:77, refers to the amino acid residue which is present at that position in the amino acid sequence shown in SEQ ID NO:77. The homology between these HBcAg variants is for the most part high enough among Hepatitis B viruses that infect mammals so that one skilled in the art would have little difficulty reviewing both the amino acid sequence shown in SEQ ID NO:77 and that of a particular HBcAg variant and identifying "corresponding" amino acid residues. Furthermore, the HBcAg amino acid sequence shown in SEQ ID NO:73, which shows the amino acid sequence of a HBcAg

derived from a virus which infect woodchucks, has enough homology to the HBcAg having the amino acid sequence shown in SEQ ID NO:77 that it is readily apparent that a three amino acid residue insert is present in SEQ ID NO:64 between amino acid residues 155 and 156 of SEQ ID NO:77.

[0190] The invention also includes compositions which comprise HBcAg variants of Hepatitis B viruses which infect birds, as well as compositions which comprise fragments of these HBcAg variants. For these HBcAg variants one, two, three or more of the cysteine residues naturally present in these polypeptides could be either substituted with another amino acid residue or deleted prior to their inclusion in compositions of the invention.

[0191] As discussed above, the elimination of free cysteine residues reduces the number of sites where toxic components can bind to the HBcAg, and also eliminates sites where cross-linking of lysine and cysteine residues of the same or of neighboring HBcAg molecules can occur. Therefore, in another embodiment of the present invention, one or more cysteine residues of the Hepatitis B virus capsid protein have been either deleted or substituted with another amino acid residue.

[0192] In other embodiments, compositions of the invention will contain HBcAgs from which the C-terminal region (e.g., amino acid residues 145-185 or 150-185 of SEQ ID NO:77) has been removed. Thus, additional modified HBcAgs suitable for use in the practice of the present invention include C-terminal truncation mutants. Suitable truncation mutants include HBcAgs where 1, 5, 10, 15, 20, 25, 30, 34, 35, amino acids have been removed from the C-terminus.

[0193] HBcAgs suitable for use in the practice of the present invention also include N-terminal truncation mutants. Suitable truncation mutants include modified HBcAgs where 1, 2, 5, 7, 9, 10, 12, 14, 15, or 17 amino acids have been removed from the N-terminus.

[0194] Further HBcAgs suitable for use in the practice of the present invention include N- and C-terminal truncation mutants. Suitable truncation mutants include HBcAgs where 1, 2, 5, 7, 9, 10, 12, 14, 15, and 17 amino acids have been removed from the N-terminus and 1, 5, 10, 15, 20, 25, 30, 34, 35 amino acids have been removed from the C-terminus.

[0195] The invention further includes compositions comprising HBcAg polypeptides comprising, or alternatively essentially consisting of, or alternatively consisting of, amino acid sequences which are at least 80%, 85%, 90%, 95%, 97%, or 99% identical to the above described truncation mutants.

[0196] In certain embodiments of the invention, a lysine residue is introduced into a HBcAg polypeptide, to mediate the binding of the antigen or antigenic determinant to the VLP of HBcAg. In preferred embodiments, compositions of the invention are prepared using a HBcAg comprising, or alternatively consisting of, amino acids 1-144, or 1-149, or 1-185 of SEQ ID NO:77, which is modified so that the amino acids corresponding to positions 79 and 80 are replaced with a peptide having the amino acid sequence of Gly-Gly-Lys-Gly-Gly (SEQ ID NO:138), resulting in the HBcAg variant having the amino acid sequence of SEQ ID NO: 78. In further preferred embodiments, the cysteine residues at positions 48 and 107 of SEQ ID NO:77 are mutated to serine (SEQ ID NO: 139). The invention further includes compositions comprising the corresponding polypeptides having amino acid sequences shown in any of SEQ ID NOs:29-74, which also have above noted amino acid alterations. Further included within the scope of the invention are additional HBcAg variants which are capable of associating to form a capsid or VLP and have the above noted amino acid alterations. Thus, the invention further includes compositions comprising HBcAg

polypeptides which comprise, or alternatively consist of, amino acid sequences which are at least 80%, 85%, 90%, 95%, 97% or 99% identical to any of the wild-type amino acid sequences, and forms of these proteins which have been processed, where appropriate, to remove the N-terminal leader sequence and modified with above noted alterations.

[0197] Compositions of the invention may comprise mixtures of different HBcAgs. Thus, these compositions may be composed of HBcAgs which differ in amino acid sequence. For example, compositions could be prepared comprising a "wild-type" HBcAg and a modified HBcAg in which one or more amino acid residues have been altered (e.g., deleted, inserted or substituted).

[0198] In a further preferred embodiment of the present invention, the at least one antigen or antigenic determinant is bound to said first and/or second core particle and virus-like particle, respectively, by at least one covalent bond. Preferably, the least one antigen or antigenic determinant is bound to the core particle and virus-like particle, respectively, by at least one covalent bond, said covalent bond being a non-peptide bond leading to a core particle-antigen ordered and repetitive array and a antigen-VLP-array or -conjugate, respectively. This antigen-VLP array and conjugate, respectively, has typically and preferably a repetitive and ordered structure since the at least one, but usually more than one, antigen or antigenic determinant is bound to the VLP in an oriented manner. Preferably, more than 10, 20, 40, 80, 120 antigens or antigenic determinants or proteins are bound to the VLP. The formation of a repetitive and ordered antigen-VLP array and conjugate, respectively, is ensured by an oriented and directed as well as defined binding and attachment, respectively, of the at least one antigen or antigenic determinant to the VLP as will become apparent in the following. Furthermore, the typical inherent highly repetitive and organized structure of the VLP's advantageously contributes to the display of the antigen or antigenic determinant in a highly ordered and repetitive fashion leading to a highly organized and repetitive antigen-VLP array and conjugate, respectively.

[0199] Preferably, the antigen or antigenic determinant is bound to the core particle and VLP, respectively, by way of chemical cross-linking, typically and preferably by using a heterobifunctional cross-linker. In preferred embodiments, the hetero-bifunctional cross-linker contains a functional group which can react with preferred first attachment sites, i.e. with the side-chain amino group of lysine residues of the core particle and the VLP or at least one VLP subunit, respectively, and a further functional group which can react with a preferred second attachment site, i.e. a cysteine residue naturally present, made available for reaction by reduction, or engineered on the antigen or antigenic determinant, and optionally also made available for reaction by reduction. Methods of binding of antigen or antigenic determinant to core particles and VLPs, respectively, are disclosed in WO 00/32227, in WO 01/85208, and in WO 02/056905, the disclosures of which are herewith incorporated by reference in its entirety. The first step of the procedure, typically called the derivatization, is the reaction of the core particle or the VLP with the cross-linker. The product of this reaction is an activated core particle or activated VLP, also called activated carrier. In the second step, unreacted cross-linker is removed using usual methods such as gel filtration or dialysis. In the third step, the antigen or antigenic determinant is reacted with the activated carrier, and this step is typically called the coupling step. Unreacted antigen or antigenic determinant may be optionally removed in a fourth step, for example by dialysis. Several hetero-bifunctional cross-linkers are known to the art. These include the preferred cross-linkers SMPH (Pierce),

Sulfo-MBS, Sulfo-EMCS, Sulfo-GMBS, Sulfo-SIAB, Sulfo-SMPB, Sulfo-SMCC, SVSB, SIA and other cross-linkers available for example from the Pierce Chemical Company (Rockford, Ill., USA), and having one functional group reactive towards amino groups and one functional group reactive towards cysteine residues. The above mentioned cross-linkers all lead to formation of a thioether linkage. Another class of cross-linkers suitable in the practice of the invention is characterized by the introduction of a disulfide linkage between the antigen or antigenic determinant and the core particle or VLP upon coupling. Preferred cross-linkers belonging to this class include for example SPDP and Sulfo-LC-SPDP (Pierce). The extent of derivatization of the core particle and VLP, respectively, with cross-linker can be influenced by varying experimental conditions such as the concentration of each of the reaction partners, the excess of one reagent over the other, the pH, the temperature and the ionic strength. The degree of coupling, i.e. the amount of antigen or antigenic determinants per subunits of the core particle and VLP, respectively, can be adjusted by varying the experimental conditions described above to match the requirements of the method of the invention. Solubility of the antigen or antigenic determinant may impose a limitation on the amount of antigen or antigenic determinant that can be coupled on each subunit, and in those cases where the obtained composition would be insoluble, where reducing the amount of antigen or antigenic determinants per subunit is beneficial, preferably for the specific detection and isolation of high affinity B cells, and thus for the selection of B cells which express antibodies which bind antigens with high affinity. In a preferred embodiment of the invention, the antigen or antigenic determinant may be coupled, fused, or otherwise attached to the core particle at high density for efficient isolation of all antigen-specific B cells. High density refers to high amounts of antigen presented on the surface of a core particle which can be measured by SDS gel electrophoresis. A method for high density coupling is described in Example 4. In another preferred embodiment of the invention, the antigen or antigenic determinant may be coupled, fused, or otherwise attached to the core particle at low density for specific isolation of high affinity B cells which are B cells having high binding strength for its antigen. Low density refers to low amounts of antigen presented on the surface of a core particle which can be measured by SDS gel electrophoresis. A method for low density coupling is described in Example 4.

[0200] A particularly favored method of binding of antigens or antigenic determinants to the core particle and the VLP, respectively, is the linking of a lysine residue on the surface of the core particle and the VLP, respectively, with a cysteine residue on the antigen or antigenic determinant. Thus, in a preferred embodiment of the present invention, the first attachment site is a lysine residue and the second attachment site is a cysteine residue. In some embodiments, engineering of an amino acid linker containing a cysteine residue, as a second attachment site or as a part thereof, to the antigen or antigenic determinant for coupling to the core particle and VLP, respectively, may be required. Alternatively, a cysteine may be introduced either by insertion or mutation within the antigen or antigenic determinant. Alternatively, the cysteine residue may be introduced by chemical coupling.

[0201] The selection of the amino acid linker will be dependent on the nature of the antigen and self-antigen. In general, flexible amino acid linkers are favored. Preferred embodiments of the amino acid linker are selected from the group consisting of: (a) CGG; (b) N-terminal gamma 1-linker; (c) N-terminal gamma 3-linker; (d) Ig hinge regions; (e) N-terminal glycine linkers; (f) $(G)_kC(G)_n$ with $n=0-12$ and $k=0-5$;

(g) N-terminal glycine-serine linkers; (h) $(G)_kC(G)_m(S)_l$ (GGGGS)_n with $n=0-3$, $k=0-5$, $m=0-10$, $l=0-2$ (SEQ ID NO: 84); (i) GGC; (k) GGC-NH₂; (l) C-terminal gamma 1-linker; (m) C-terminal gamma 3-linker; (n) C-terminal glycine linkers; (o) $(G)_mC(G)_k$ with $n=0-12$ and $k=0-5$; (p) C-terminal glycine-serine linkers; (q) $(G)_m(S)_l(GGGGS)_n(G)_oC(G)_k$ with $n=0-3$, $k=0-5$, $m=0-10$, $l=0-2$, and $o=0-8$ (SEQ ID NO: 85).

[0202] Further preferred examples of amino acid linkers are the hinge region of Immunoglobulins, glycine serine linkers (GGGGS)_n (SEQ ID NO: 86), and glycine linkers (G)_n, all further containing a cysteine residue as second attachment site and optionally further glycine residues. Typically preferred examples of said amino acid linkers are N-terminal gamma1: CGDKTHTSPP (SEQ ID NO: 87); C-terminal gamma 1: DKTHTSPPCG (SEQ ID NO: 88); N-terminal gamma 3: CGGPKPSTPPGSSGGAP (SEQ ID NO: 89); C-terminal gamma 3: PKPSTPPGSSGGAPGGCG (SEQ ID NO: 90); N-terminal glycine linker: GCGGGG (SEQ ID NO: 91); C-terminal glycine linker: GGGGCG (SEQ ID NO: 92); C-terminal glycine-lysine linker: GGKKGK (SEQ ID NO: 93); N-terminal glycine-lysine linker: CGKKGK (SEQ ID NO: 94).

[0203] In a further preferred embodiment of the present invention, GGCG (SEQ ID NO: 95), GGC or GGC-NH₂ ("NH₂" stands for amidation) linkers at the C-terminus of the peptide or CGG at its N-terminus are preferred as amino acid linkers. In general, glycine residues will be inserted between bulky amino acids and the cysteine to be used as second attachment site, to avoid potential steric hindrance of the bulkier amino acid in the coupling reaction.

[0204] Other methods of binding the antigen or antigenic determinant to the core particle and the VLP, respectively, include methods wherein the antigen or antigenic determinant is cross-linked to the core particle and the VLP, respectively, using the carbodiimide EDC, and NHS. Further examples hereto are disclosed in WO 02/056905, the disclosures of which is herewith incorporated by reference in its entirety. The antigen or antigenic determinant may also be first thiolated through reaction, for example with SATA, SATP or iminothiolane. The antigen or antigenic determinant, after deprotection if required, may then be coupled to the core particle and the VLP, respectively, as follows. After separation of the excess thiolation reagent, the antigen or antigenic determinant is reacted with the core particle and the VLP, respectively, previously activated with a hetero-bifunctional cross-linker comprising a cysteine reactive moiety, and therefore displaying at least one or several functional groups reactive towards cysteine residues, to which the thiolated antigen or antigenic determinant can react, such as described above. Optionally, low amounts of a reducing agent are included in the reaction mixture. In further methods, the antigen or antigenic determinant is attached to the core particle and the VLP, respectively, using a homo-bifunctional cross-linker such as glutaraldehyde, DSG, BM[PEO]₄, BS³, (Pierce Chemical Company, Rockford, Ill., USA) or other known homo-bifunctional cross-linkers with functional groups reactive towards amine groups or carboxyl groups of the core particle and the VLP, respectively.

[0205] In a further embodiment, the antigen or antigenic determinant is bound to the core particle and the VLP, respectively, through modification of the carbohydrate moieties present on glycosylated antigen or antigenic determinant and subsequent reaction with the core particle and the VLP, respectively. Preferred examples of this type of binding are described in WO 02/056905, the disclosures of which is herewith incorporated by reference in its entirety.

[0206] Other methods of binding the VLP to an antigen or antigenic determinant include methods where the core particle and the VLP, respectively, is biotinylated, and the antigen or antigenic determinant expressed as a streptavidin-fusion protein, or methods wherein both the antigen or antigenic determinants and the core particle and the VLP, respectively, are biotinylated, for example as described in WO 00/23955. In this case, the antigen or antigenic determinant may be first bound to streptavidin or avidin by adjusting the ratio of antigen or antigenic determinant to streptavidin such that free binding sites are still available for binding of the core particle and the VLP, respectively, which is added in the next step. Alternatively, all components may be mixed in a "one pot" reaction. Other ligand-receptor pairs, where a soluble form of the receptor and of the ligand is available, and are capable of being cross-linked to the core particle and the VLP, respectively, or the antigen or antigenic determinant, may be used as binding agents for binding the antigen or antigenic determinant to the core particle and the VLP, respectively. Alternatively, either the ligand or the receptor may be fused to the antigen or antigenic determinant and so mediate binding to the core particle and the VLP, respectively, chemically bound or fused either to the receptor, or the ligand respectively. Fusion may also be effected by insertion or substitution.

[0207] One or several antigen molecules, can be attached to one subunit of the capsid or VLP of RNA phages coat proteins, preferably through the exposed lysine residues of the VLP of RNA phages, if sterically allowable. A specific feature of the VLP of the coat protein of RNA phages and in particular of the Q β coat protein VLP is thus the possibility to couple several antigens per subunit. This allows for the generation of a dense antigen array.

[0208] In a preferred embodiment of the invention, the binding and attachment, respectively, of the at least one antigen or antigenic determinant to the core particle and the virus-like particle, respectively, is by way of interaction and association, respectively, between at least one first attachment site of the virus-like particle and at least one second attachment of the antigen or antigenic determinant.

[0209] VLPs or capsids of Q β coat protein display a defined number of lysine residues on their surface, with a defined topology with three lysine residues pointing towards the interior of the capsid and interacting with the RNA, and four other lysine residues exposed to the exterior of the capsid. These defined properties favor the attachment of antigens to the exterior of the particle, rather than to the interior of the particle where the lysine residues interact with RNA. VLPs of other RNA phage coat proteins also have a defined number of lysine residues on their surface and a defined topology of these lysine residues.

[0210] In further preferred embodiments of the present invention, the first attachment site is a lysine residue and/or the second attachment comprises sulfhydryl group or a cysteine residue. In a very preferred embodiment of the present invention, the first attachment site is a lysine residue and the second attachment is a cysteine residue.

[0211] In very preferred embodiments of the invention, the antigen or antigenic determinant is bound via a cysteine residue, either naturally present on the antigen or antigenic determinant or engineered, to lysine residues of the VLP of RNA phage coat protein, and in particular to the VLP of Q β coat protein.

[0212] Another advantage of the VLPs derived from RNA phages is their high expression yield in bacteria that allows production of large quantities of material at affordable cost.

[0213] As indicated, the inventive conjugates and arrays, respectively, differ from prior art conjugates in their highly

organized structure, dimensions, and in the repetitiveness of the antigen on the surface of the array. Moreover, the use of the VLPs as carriers allow the formation of robust antigen arrays and conjugates, respectively, with variable antigen density. In particular, the use of VLP's of RNA phages, and hereby in particular the use of the VLP of RNA phage Q β coat protein allows to achieve very high epitope density. The preparation of compositions of VLPs of RNA phage coat proteins with a high epitope density can be effected by using the teaching of this application.

[0214] The second attachment site, as defined herein, may be either naturally or non-naturally present with the antigen or the antigenic determinant. In the case of the absence of a suitable natural occurring second attachment site on the antigen or antigenic determinant, such a, then non-natural second attachment has to be engineered to the antigen.

[0215] As described above, four lysine residues are exposed on the surface of the VLP of Q β coat protein. Typically these residues are derivatized upon reaction with a cross-linker molecule. In the instance where not all of the exposed lysine residues can be coupled to an antigen, the lysine residues which have reacted with the cross-linker are left with a cross-linker molecule attached to the ϵ -amino group after the derivatization step. This leads to disappearance of one or several positive charges, which may be detrimental to the solubility and stability of the VLP. By replacing some of the lysine residues with arginines, as in the disclosed Q β coat protein mutants described below, we prevent the excessive disappearance of positive charges since the arginine residues do not react with the cross-linker. Moreover, replacement of lysine residues by arginines may lead to more defined antigen arrays, as fewer sites are available for reaction to the antigen.

[0216] Accordingly, exposed lysine residues were replaced by arginines in the following Q β coat protein mutants and mutant Q β VLPs disclosed in this application: Q β -240 (Lys13-Arg; SEQ ID NO:23), Q β -250 (Lys 2-Arg, Lys13-Arg; SEQ ID NO:25) and Q β -259 (Lys 2-Arg, Lys16-Arg; SEQ ID NO:27). The constructs were cloned, the proteins expressed, the VLPs purified and used for coupling to peptide and protein antigens, as described in WO 02/056905. Q β -251 (SEQ ID NO:26) was also constructed, and guidance on how to express, purify and couple the VLP of Q β -251 coat protein can be found in WO 02/056905.

[0217] In a further embodiment, we disclose a Q β mutant coat protein with one additional lysine residue, suitable for obtaining even higher density arrays of antigens. This mutant Q β coat protein, Q β -243 (Asn 10-Lys; SEQ ID NO:24), was cloned, the protein expressed, and the capsid or VLP isolated and purified as described in WO 02/056905, showing that introduction of the additional lysine residue is compatible with self-assembly of the subunits to a capsid or VLP. Thus, antigen or antigenic determinant arrays and conjugates, respectively, may be prepared using VLP of Q β coat protein mutants. Further particularly favored methods of attachment of antigens to VLPs, and in particular to VLPs of RNA phage coat proteins are disclosed in WO 02/056905, the disclosures of which is herewith incorporated by reference in its entirety.

[0218] Epitope density on the VLP of RNA phage coat proteins can be modulated by the choice of cross-linker and other reaction conditions. For example, the cross-linkers Sulfo-GMBS and SMPH typically allow reaching high epitope density. Derivatization is positively influenced by high concentration of reactants, and manipulation of the reaction conditions can be used to control the number of antigens coupled to VLPs of RNA phage coat proteins, and in particular to VLPs of Q β coat protein.

[0219] The selection and/or design of a non-natural second attachment site and preferred embodiments of second attachment sites are also disclosed in WO 02/056905.

[0220] In the most preferred embodiments, the at least one antigen or antigenic determinant comprises a single second attachment site or a single reactive attachment site capable of association with the first attachment sites on the core particle and the VLPs or VLP subunits, respectively. This ensures a defined and uniform binding and association, respectively, of the at least one, but typically more than one, preferably more than 10, 20, 40, 80, 120 antigens to the core particle and VLP, respectively. The provision of a single second attachment site or a single reactive attachment site on the antigen, thus, ensures a single and uniform type of binding and association, respectively leading to a very highly ordered and repetitive array. For example, if the binding and association, respectively, is effected by way of a lysine- (as the first attachment site) and cysteine- (as a second attachment site) interaction, it is ensured, in accordance with this preferred embodiment of the invention, that only one cysteine residue per antigen, independent whether this cysteine residue is naturally or non-naturally present on the antigen, is capable of binding and associating, respectively, with the VLP and the first attachment site of the core particle, respectively.

[0221] In a further preferred embodiment of the method of the invention, the at least one antigen or antigenic determinant is fused to the core particle and the virus-like particle, respectively. As outlined above, a VLP is typically composed of at least one subunit assembling into a VLP. Thus, in again a further preferred embodiment of the invention, the at least one antigen or antigenic determinant is fused to at least one subunit of the virus-like particle or of a protein capable of being incorporated into a VLP generating a chimeric VLP-subunit-antigen protein fusion.

[0222] Fusion of the antigen or antigenic determinant can be effected by insertion into the VLP subunit sequence, or by fusion to either the N- or C-terminus of the VLP-subunit or protein capable of being incorporated into a VLP. Hereinafter, when referring to fusion proteins of a peptide to a VLP subunit, the fusion to either ends of the subunit sequence or internal insertion of the peptide within the subunit sequence are encompassed.

[0223] Fusion may also be effected by inserting the antigen or antigenic determinant sequences into a variant of a VLP subunit where part of the subunit sequence has been deleted, that are further referred to as truncation mutants. Truncation mutants may have N- or C-terminal, or internal deletions of part of the sequence of the VLP subunit. For example, the specific VLP HBcAg with, for example, deletion of amino acid residues 79 to 81 is a truncation mutant with an internal deletion. Fusion of antigens to either the N- or C-terminus of the truncation mutants VLP-subunits also lead to embodiments of the invention. Likewise, fusion of an epitope into the sequence of the VLP subunit may also be effected by substitution, where for example for the specific VLP HBcAg, amino acids 79-81 are replaced with a foreign epitope. Thus, fusion, as referred to hereinafter, may be effected by insertion of the antigen sequence in the sequence of a VLP subunit, by substitution of part of the sequence of the VLP subunit with the antigen sequence, or by a combination of deletion, substitution or insertions.

[0224] The chimeric antigen-VLP subunit will be in general capable of self-assembly into a VLP. VLP displaying epitopes fused to their subunits are also herein referred to as

chimeric VLPs. As indicated, the virus-like particle comprises or alternatively is composed of at least one VLP subunit. In a further embodiment of the invention, the virus-like particle comprises or alternatively is composed of a mixture of chimeric VLP subunits and non-chimeric VLP subunits, i.e. VLP subunits not having an antigen fused thereto, leading to so called mosaic particles. This may be advantageous to ensure formation of and assembly to a VLP. In those embodiments, the proportion of chimeric VLP-subunits may be 1, 2, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95% or higher.

[0225] Flanking amino acid residues may be added to either end of the sequence of the peptide or epitope to be fused to either end of the sequence of the subunit of a VLP, or for internal insertion of such peptidic sequence into the sequence of the subunit of a VLP. Glycine and serine residues are particularly favored amino acids to be used in the flanking sequences added to the antigen to be fused. Glycine residues confer additional flexibility, which may diminish the potentially destabilizing effect of fusing a foreign sequence into the sequence of a VLP subunit.

[0226] In a specific embodiment of the invention, the VLP is a Hepatitis B core antigen VLP. Fusion proteins to either the N-terminus of a HBcAg (Neyrinck, S. et al., *Nature Med.* 5:1157-1163 (1999)) or insertions in the so called major immunodominant region (MIR) have been described (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001)), WO 01/98333), and are preferred embodiments of the invention. Naturally occurring variants of HBcAg with deletions in the MIR have also been described (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001), which is expressly incorporated by reference in their entirety), and fusions to the N- or C-terminus, as well as insertions at the position of the MIR corresponding to the site of deletion as compared to a wt HBcAg are further embodiments of the invention. Fusions to the C-terminus have also been described (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001)). One skilled in the art will easily find guidance on how to construct fusion proteins using classical molecular biology techniques (Sambrook, J. et al., eds., *Molecular Cloning, A Laboratory Manual*, 2nd. edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989), Ho et al., *Gene* 77:51 (1989)). Vectors and plasmids encoding HBcAg and HBcAg fusion proteins and useful for the expression of a HBcAg and HBcAg fusion proteins have been described (Pumpens, P. & Grens, E. *Intervirology* 44: 98-114 (2001), Neyrinck, S. et al., *Nature Med.* 5:1157-1163 (1999)) and can be used in the practice of the invention. The insertion of an epitope into the MIR of HBcAg, resulting in a chimeric self-assembling HbcAg, is explicitly disclosed in Example 2. An important factor for the optimization of the efficiency of self-assembly and of the display of the epitope to be inserted in the MIR of HBcAg is the choice of the insertion site, as well as the number of amino acids to be deleted from the HBcAg sequence within the MIR (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001); EP 421'635; U.S. Pat. No. 6,231,864) upon insertion, or in other words, which amino acids form HBcAg are to be substituted with the new epitope. For example, substitution of HBcAg amino acids 76-80, 79-81, 79-80, 75-85 or 80-81 with foreign epitopes has been described (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001); EP0421635; U.S. Pat. No. 6,231,864). HBcAg contains a long arginine tail (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001)) which is dispensable for capsid assembly and capable of binding nucleic acids (Pumpens, P. and Grens, E., *Intervirology* 44:98-114 (2001)). HBcAg either comprising or lacking this arginine tail are both embodiments of the invention.

[0227] In a further preferred embodiment of the invention, the VLP is a VLP of a RNA phage. The major coat proteins of RNA phages spontaneously assemble into VLPs upon expression in bacteria, and in particular in *E. coli*. Specific examples of bacteriophage coat proteins which can be used to prepare compositions of the invention include the coat proteins of RNA bacteriophages such as bacteriophage Q β (SEQ ID NO:10; PIR Database, Accession No. VCBPQ β referring to Q β CP and SEQ ID NO: 11; Accession No. AAA16663 referring to Q β A1 protein), bacteriophage fr (SEQ ID NO:13; PIR Accession No. VCBPFR), and bacteriophage AP205 (SEQ ID NO: 81).

[0228] In a more preferred embodiment, the at least one antigen is fused to a Q β coat protein. Fusion protein constructs wherein epitopes have been fused to the C-terminus of a truncated form of the A1 protein of Q β , or inserted within the A1 protein have been described (Kozlovskaja, T. M., et al., *Intervirology*, 39:9-15 (1996)). The A1 protein is generated by suppression at the UGA stop codon and has a length of 329 aa, or 328 aa, if the cleavage of the N-terminal methionine is taken into account. Cleavage of the N-terminal methionine before an alanine (the second amino acid encoded by the Q β CP gene) usually takes place in *E. coli*, and such is the case for N-termini of the Q β coat proteins CP. The part of the A1 gene, 3' of the UGA amber codon encodes the CP extension, which has a length of 195 amino acids. Insertion of the at least one antigen between position 72 and 73 of the CP extension leads to further embodiments of the invention (Kozlovskaja, T. M., et al., *Intervirology* 39:9-15 (1996)). Fusion of an antigen at the C-terminus of a C-terminally truncated Q β A1 protein leads to further preferred embodiments of the invention. For example, Kozlovskaja et al., (*Intervirology*, 39: 9-15 (1996)) describe Q β A1 protein fusions where the epitope is fused at the C-terminus of the Q β CP extension truncated at position 19.

[0229] As described by Kozlovskaja et al. (*Intervirology*, 39: 9-15 (1996)), assembly of the particles displaying the fused epitopes typically requires the presence of both the A1 protein-antigen fusion and the wt CP to form a mosaic particle. However, embodiments comprising virus-like particles, and hereby in particular the VLPs of the RNA phage Q β coat protein, which are exclusively composed of VLP subunits having at least one antigen fused thereto, are also within the scope of the present invention.

[0230] The production of mosaic particles may be effected in a number of ways. Kozlovskaja et al., *Intervirology*, 39:9-15 (1996), describe two methods, which both can be used in the practice of the invention. In the first approach, efficient display of the fused epitope on the VLPs is mediated by the expression of the plasmid encoding the Q β A1 protein fusion having a UGA stop codon between CP and CP extension in a *E. coli* strain harboring a plasmid encoding a cloned UGA suppressor tRNA which leads to translation of the UGA codon into Trp (pISM3001 plasmid (Smiley B. K., et al., *Gene* 134:33-40 (1993))). In another approach, the CP gene stop codon is modified into UAA, and a second plasmid expressing the A1 protein-antigen fusion is cotransformed. The second plasmid encodes a different antibiotic resistance and the origin of replication is compatible with the first plasmid (Kozlovskaja, T. M., et al., *Intervirology* 39:9-15 (1996)). In a third approach, CP and the A1 protein-antigen fusion are encoded in a bicistronic manner, operatively linked to a promoter such as the Trp promoter, as described in FIG. 1 of Kozlovskaja et al., *Intervirology*, 39:9-15 (1996).

[0231] Further preferred embodiments of fusion of the at least one antigen to the VLP of the fr CP, to the coat protein of RNA phage MS-2, to a capsid protein of papillomavirus, and to a Ty protein capable of being incorporated into a Ty VLP, are disclosed in WO 02/056905, the disclosures of which is herewith incorporated by reference in its entirety.

[0232] Further VLPs suitable for fusion of antigens are, for example, Retrovirus-like-particles (WO9630523), HIV2 Gag (Kang, Y. C., et al, *Biol. Chem.* 380:353-364 (1999)), Cowpea Mosaic Virus (Taylor, K. M. et al., *Biol. Chem.* 380:387-392 (1999)), parvovirus VP2 VLP (Rueda, P. et al., *Virology* 263: 89-99 (1999)), HBsAg (U.S. Pat. No. 4,722,840, EP0201416B1).

[0233] Examples of chimeric VLPs suitable for the practice of the invention are also those described in *Intervirology* 39:1 (1996). Further examples of VLPs contemplated for use in the invention are: HPV-1, HPV-6, HPV-11, HPV-16, HPV-18, HPV-33, HPV-45, CRPV, COPV, HIV GAG, Tobacco Mosaic Virus. Virus-like particles of SV-40, Polyomavirus, Adenovirus, Herpes Simplex Virus, Rotavirus and Norwalk virus have also been made, and chimeric VLPs of those VLPs are also within the scope of the present invention.

[0234] The antigen or antigenic determinant of the first and second composition used in the method of the invention may be any antigen or antigenic determinant of known or yet unknown provenance. In a preferred embodiment, the antigen or antigenic determinant is a recombinant antigen or a synthetic peptide. In another embodiment, the antigen or antigenic determinant is isolated from a natural source. It may be selected from the group consisting of without limitation polypeptides, carbohydrates, steroid hormones, organic molecules, bacteria, viruses, parasites, prions, tumors, self-molecules, non-peptide hapten molecules, allergens, or any other pathogen, or any other molecular compound, including without limitation inorganic molecules, against which it is desirable to have monoclonal antibodies, or it can be a recombinant antigen obtained from expression of suitable nucleic acid coding therefore. The selection of the antigen is, of course, dependent upon the antigen-specific B cell desired to select and the antibody desired that is expressed by the selected antigen-specific B cell of the invention. In particular, antibodies are desired that can be used in methods of treatment for allergies, cancer, drug abuse or other diseases or conditions associated with self antigens.

[0235] The selection of antigens or antigenic determinants for compositions used in the methods of the invention for the selection of B cells expressing antibodies useful in methods of treatment for allergies would be known to those skilled in the medical arts treating such disorders. Representative examples of such antigens or antigenic determinants include the following: bee venom phospholipase A₂, Bet v I (birch pollen allergen), 5 Dol m V (white-faced hornet venom allergen), and Der p I (House dust mite allergen), as well as fragments of each which can be used to elicit immunological responses.

[0236] The selection of antigens or antigenic determinants for compositions used in the methods of the invention for the selection of B cells expressing antibodies useful in methods of treatment for cancer would be known to those skilled in the medical arts treating such disorders (see Renkvist et al., *Cancer Immunol. Immunother.* 50:3-15 (2001) which is incorporated by reference), and such antigens or antigenic determinants are included within the scope of the present invention. Representative examples of such types of antigens or anti-

genic determinants, described in WO 02/056905, include the following: Her2 (breast cancer); GD2 (neuroblastoma); EGF-R (malignant glioblastoma); CEA (medullary thyroid cancer); CD52 (leukemia); human melanoma protein gp100; human melanoma protein gp100 epitopes such as amino acids 154-162 (sequence: KTWGQYWQV) (SEQ ID NO: 120), 209-217 (ITDQVPFSV) (SEQ ID NO: 121), 280-288 (YLEPGPVTA) (SEQ ID NO: 122), 457-466 (LLDGTATLRL) (SEQ ID NO: 123) and 476-485 (VLYRYGSFSV) (SEQ ID NO: 124); human melanoma protein melan-A/MART-1; human melanoma protein melan-A/MART-1 epitopes such as amino acids 27-35 (AAGIGILTV) (SEQ ID NO: 125) and 32-40 (ILTVILGVL) (SEQ ID NO: 126); tyrosinase and tyrosinase related proteins (e.g., TRP-1 and TRP-2); tyrosinase epitopes such as amino acids 1-9 (MLLAVLYCL) (SEQ ID NO: 127) and 369-377 (YMDGTMSQV) (SEQ ID NO: 128); NA17-A nt protein; NA17-A nt protein epitopes such as amino acids 38-64 (VLPDVFIRC) (SEQ ID NO: 129); MAGE-3 protein; MAGE-3 protein epitopes such as amino acids 271-279 (FLWGPRLV) (SEQ ID NO: 130); other human tumors antigens, e.g. CEA epitopes such as amino acids 571-579 (YLSGANLNL) (SEQ ID NO: 131); p53 protein; p53 protein epitopes such as amino acids 65-73 (RMPEAAPPV) (SEQ ID NO: 132), 149-157 (STPPGTRV) (SEQ ID NO: 133) and 264-272 (LLGRNSFEV) (SEQ ID NO: 134); Her2/neu epitopes such as amino acids 369-377 (KIFGSLAFL) (SEQ ID NO: 135) and 654-662 (IISAVVGIL) (SEQ ID NO: 136); NY-ESO-1 peptides 157-165 and 157-167, 159-167; HPV16 E7 protein; HPV16 E7 protein epitopes such as amino acids 86-93 (TLGIVCPI) (SEQ ID NO: 137); as well as fragments of each which can be used to elicit immunological responses.

[0237] The selection of antigens or antigenic determinants for compositions used in the methods of the invention for the selection of B cells expressing antibodies useful in methods of treatment for drug addiction, in particular recreational drug addiction, would be known to those skilled in the medical arts treating such disorders. Representative examples of such antigens or antigenic determinants include, for example, opioids and morphine derivatives such as codeine, fentanyl, heroin, morphium and opium; stimulants such as amphetamine, cocaine, MDMA (methylenedioxyamphetamine), methamphetamine, methylphenidate and nicotine; hallucinogens such as LSD, mescaline and psilocybin; as well as cannabinoids such as hashish and marijuana.

[0238] The selection of antigens or antigenic determinants for compositions used in the methods of the invention for the selection of B cells expressing antibodies useful in methods of treatment for other diseases or conditions associated with self antigens would be also known to those skilled in the medical arts treating such disorders. Representative examples of such antigens or antigenic determinants are, for example, lymphotoxins (e.g. Lymphotoxin α (LT α), Lymphotoxin β (LT β), and lymphotoxin receptors, Receptor activator of nuclear factor kappaB ligand (RANKL), vascular endothelial growth factor (VEGF) and vascular endothelial growth factor receptor (VEGF-R), Interleukin 17 and amyloid beta peptide (A β_{1-42}), TNF α , MIF, MCP-1, SDF-1, Rank-L, M-CSF, Angiotensin II, Endoglin, Eotaxin, Ghrelin, BLC, CCL21, IL-13, IL-17, IL-5, IL-8, IL-15, Bradykinin, Resistin, LHRH, GHRH, GIH, CRH, TRH and Gastrin, as well as fragments of each which can be used to elicit immunological responses.

[0239] In a particular embodiment of the invention, the antigen or antigenic determinant is selected from the group

consisting of: (a) a recombinant polypeptide of HIV; (b) a recombinant polypeptide of Influenza virus (e.g., an Influenza virus M2 polypeptide or a fragment thereof); (c) a recombinant polypeptide of Hepatitis C virus; (d) a recombinant polypeptide of Hepatitis B virus (e) a recombinant polypeptide of *Toxoplasma*; (f) a recombinant polypeptide of *Plasmodium falciparum*; (g) a recombinant polypeptide of *Plasmodium vivax*; (h) a recombinant polypeptide of *Plasmodium ovale*; (i) a recombinant polypeptide of *Plasmodium malariae*; (j) a recombinant polypeptide of breast cancer cells; (k) a recombinant polypeptide of kidney cancer cells; (l) a recombinant polypeptide of prostate cancer cells; (m) a recombinant polypeptide of skin cancer cells; (n) a recombinant polypeptide of brain cancer cells; (o) a recombinant polypeptide of leukemia cells; (p) a recombinant profiling; (q) a recombinant polypeptide of bee sting allergy; (r) a recombinant polypeptide of nut allergy; (s) a recombinant polypeptide of pollen; (t) a recombinant polypeptide of house-dust; (u) a recombinant polypeptide of cat or cat hair allergy; (v) a recombinant protein of food allergies; (w) a recombinant protein of asthma; (x) a recombinant protein of *Chlamydia*; and (y) a fragment of any of the proteins set out in (a)-(x).

[0240] As will be clear to those skilled in the art, certain embodiments of the invention involve the use of recombinant nucleic acid technologies such as cloning, polymerase chain reaction, the purification of DNA and RNA, the expression of recombinant proteins in prokaryotic and eukaryotic cells, etc. Such methodologies are well known to those skilled in the art and may be conveniently found in published laboratory methods manuals (e.g., Sambrook, J. et al., eds., MOLECULAR CLONING, A LABORATORY MANUAL, 2nd. edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989); Ausubel, F. et al., eds., CURRENT PROTOCOLS IN MOLECULAR BIOLOGY, John H. Wiley & Sons, Inc. (1997)). Fundamental laboratory techniques for working with tissue culture cell lines (Celis, J., ed., CELL BIOLOGY, Academic Press, 2nd edition, (1998)) and antibody-based technologies (Harlow, E. and Lane, D., "Antibodies: A Laboratory Manual," Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y. (1988); Deutscher, M. P., "Guide to Protein Purification," *Meth. Enzymol.* 128, Academic Press San Diego (1990); Scopes, R. K., "Protein Purification Principles and Practice," 3rd ed., Springer-Verlag, New York (1994)) are also adequately described in the literature, all of which are incorporated herein by reference.

[0241] Preferred antigens used in the present invention can be synthesized or recombinantly expressed and coupled to the virus-like particle, or fused to the virus-like particle using recombinant DNA techniques. Exemplary procedures describing the attachment of antigens to virus-like particles are disclosed in WO 00/32227, in WO 01/85208 and in WO 02/056905, the disclosures of which are herewith incorporated by reference in its entirety.

[0242] The following examples are illustrative only and are not intended to limit the scope of the invention as defined by the appended claims. It will be apparent to those skilled in the art that various modifications and variations can be made in the methods of the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

[0243] All patents and publications referred to herein are expressly incorporated by reference in their entirety.

EXAMPLES

[0244] Enzymes and reagents used in the experiments that follow included: T4 DNA ligase obtained from New England Biolabs; Taq DNA Polymerase, QIAprep Spin Plasmid Kit, QIAGEN Plasmid Midi Kit, QiaExII Gel Extraction Kit, QIAquick PCR Purification Kit obtained from QIAGEN; QuickPrep Micro mRNA Purification Kit obtained from Pharmacia; SuperScript One-step RT PCR Kit, fetal calf serum (FCS), bacto-tryptone and yeast extract obtained from Gibco BRL; Oligonucleotides obtained from Microsynth (Switzerland); restriction endonucleases obtained from Boehringer Mannheim, New England Biolabs or MBI Fermentas; Pwo polymerase and dNTPs obtained from Boehringer Mannheim. HP-1 medium was obtained from Cell culture technologies (Glattbrugg, Switzerland). All standard chemicals were obtained from Fluka-Sigma-Aldrich, and all cell culture materials were obtained from TPP. DNA manipulations were carried out using standard techniques. DNA was prepared according to manufacturer instruction either from a 2 ml bacterial culture using the QIAprep Spin Plasmid Kit or from a 50 ml culture using the QIAGEN Plasmid Midi Kit. For restriction enzyme digestion, DNA was incubated at least 2 hours with the appropriate restriction enzyme at a concentration of 5-10 units (U) enzyme per mg DNA under manufacturer recommended conditions (buffer and temperature). Digests with more than one enzyme were performed simultaneously if reaction conditions were appropriate for all enzymes, otherwise consecutively. DNA fragments isolated for further manipulations were separated by electrophoresis in a 0.7 to 1.5% agarose gel, excised from the gel and purified with the QiaExII Gel Extraction Kit according to the instructions provided by the manufacturer. For ligation of DNA fragments, 100 to 200 pg of purified vector DNA were incubated overnight with a threefold molar excess of the insert fragment at 16°C. in the presence of 1 U T4 DNA ligase in the buffer provided by the manufacturer (total volume: 10-20 µl). An aliquot (0.1 to 0.5 µA) of the ligation reaction was used for transformation of *E. coli* XL1-Blue (Stratagene).

[0245] Transformation was done by electroporation using a Gene Pulser (BioRAD) and 0.1 cm Gene Pulser Cuvettes (BioRAD) at 200 Ohm, 25 µF, 1.7 kV. After electroporation, the cells were incubated with shaking for 1 h in 1 ml S.O.B. medium (Miller, 1972) before plating on selective S.O.B. agar.

Example 1

Construction of HBcAg1-185-Lys

[0246] Hepatitis core Antigen (HBcAg) 1-185 was modified as described in Example 24 of WO 02/056905. A part of the c/e1 epitope (residues 72 to 88) region (Proline 79 and Alanine 80) was genetically replaced by the peptide Gly-Gly-Lys-Gly-Gly (HBcAg1-185-Lys construct). The introduced Lysine residue contains a reactive amino group in its side chain that can be used for intermolecular chemical crosslinking of HBcAg particles with any antigen containing a free cysteine group. PCR methods and conventional cloning techniques were used to prepare the HBcAg1-185-Lys gene.

[0247] The Gly-Gly-Lys-Gly-Gly sequence was inserted by amplifying two separate fragments of the HBcAg gene from pEco63, as described in Example 24 of WO 02/056905,

and subsequently fusing the two fragments by PCR to assemble the full length gene. The following PCR primer combinations were used:

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fragment 1:
                                                    (SEQ ID NO: 96)
Primer 1: EcoRIHBcAg(s)
                                                    (SEQ ID NO: 97)
Primer 2: Lys-HBcAg(as)

fragment 2:
                                                    (SEQ ID NO: 98)
Primer 3: Lys-HBcAg(s)
Primer 4: HBcAgwtHindIII
                                                    (SEQ ID NO: 114)
CGCGTCCCAAGCTTCTAACATTGAGATTCCTCCGAGATTG

Assembly:
                                                    (SEQ ID NO: 99)
Primer 1: EcoRIHBcAg(s)
Primer 2: HBcAgwtHindIII

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[0248] The assembled full length gene was then digested with the EcoRI (GAATTC) and HindIII (AAGCTT) enzymes and cloned into the pKK vector (Pharmacia) cut at the same restriction sites.

Example 2

Fusion of a Peptide Epitope in the MIR Region of HBcAg

[0249] The residues 79 and 80 of HBcAg1-185 were substituted with the epitope CεH3 of sequence VNLTWSRASG (SEQ ID NO: 115). The CεH3 sequence stems from the sequence of the third constant domain of the heavy chain of human IgE. The epitope was inserted in the HBcAg1-185 sequence using an assembly PCR method. In the first PCR step, the HBcAg1-185 gene originating from ATCC clone pEco63 and amplified with primers HBcAg-wt EcoRI fwd and HBcAg-wt Hind III rev was used as template in two separate reactions to amplify two fragments containing sequence elements coding for the CεH3 sequence. These two fragments were then assembled in a second PCR step, in an assembly PCR reaction.

[0250] Primer combinations in the first PCR step: CεH3fwd with HBcAg-wt Hind III rev, and HBcAg-wt EcoRI fwd with CεH3rev. In the assembly PCR reaction, the two fragments isolated in the first PCR step were first assembled during 3 PCR cycles without outer primers, which were added afterwards to the reaction mixture for the next 25 cycles. Outer primers: HBcAg-wt EcoRI fwd and HBcAg-wt Hind III rev.

[0251] The PCR product was cloned in the pKK223.3 using the EcoRI and HindIII sites, for expression in *E. coli* (see Example 23 of WO 02/056905). The chimeric VLP was expressed in *E. coli* and purified as described in Example 23 of WO 02/056905. The elution volume at which the HBcAg1-185-CεH3 eluted from the gel filtration showed assembly of the fusion proteins to a chimeric VLP.

Primer sequences:

CeH3fwd:

5'GTT AAC TTG ACC TGG TCT CGT GCT TCT GGT GCA TCC AGG GAT CTA GTA GTC 3'; (SEQ ID NO: 116)
 V N L T W S R A S G A S R D L V V (SEQ ID NO: 117)

CeH3rev:

5'ACC AGA AGC ACG AGA CCA GGT CAA GTT AAC ATC TTC CAA ATT ATT ACC CAC 3' (SEQ ID NO: 118)
 D E L N N G V (SEQ ID NO: 119)

HBcAg-wt EcoRI fwd:

5'CCGgaattcATGGACATTGACCCTTATAAAG (SEQ ID NO: 96)

HBcAg-wt Hind III rev:

5'cgcgctcccAAGCTTctaacattgagattcccgagattg (SEQ ID NO: 114)

[0252] In the following Examples (Example 3 to Example 7) further two preferred embodiments of the first and/or second core particle of the first and/or second composition have been used, i.e., first, a strategically modified Hepatitis core Antigen (HBcAg), typically referred throughout this specification as HBcAg-lys-2cys-Mut (SEQ ID NO: 140), and, second, a virus-like particle of the RNA-phage Q β .

[0253] The modification of the strategically modified Hepatitis core Antigen (HBcAg) comprises, first, the introduction of a lysine residue within its c/e1 epitope (being residues 72 to 88 of SEQ ID NO:77), which is located in the tip region on the surface of the Hepatitis B virus capsid (HBcAg). A part of this region (Proline 79 and Alanine 80) was genetically replaced by the peptide Gly-Gly-Lys-Gly-Gly (SEQ ID NO: 138) leading to the "HBcAg-Lys construct" (SEQ ID NO: 78). The introduced Lysine residue contains a reactive amino group in its side chain that can be used for intermolecular chemical crosslinking of HBcAg particles with any antigen containing a free cysteine group as described herein. Second, cysteine residues at positions corresponding to 48 and 107 in SEQ ID NO:77 have been replaced by serine residues resulting in the HBcAg-lys-2cys-Mut (SEQ ID NO: 140). The experimental setup for the production of the HBcAg-lys-2cys-Mut is described in Examples 23, 24 and 31 of WO 02/056905.

[0254] The other preferred embodiment of the first and/or second core particle used within the examples is the virus-like particle, which comprises, or alternatively consists essentially of, or alternatively consists of recombinant proteins, or fragments thereof, of the RNA-bacteriophage Q β , wherein the recombinant proteins comprise, or alternatively consist essentially of, or alternatively consist of a mixture of coat proteins having amino acid sequences of SEQ ID NO:10 and of SEQ ID NO: 11. Typically and preferably, the indicated RNA-phage Q β was expressed in *E. coli* using the expression vector, pQ β 10, and purified as described in Cielens, I., et al. (2000) *FEBS Lett* 482: 261-264.

[0255] For the sake of simplicity the HBcAg-lys-2cys-Mut as well as the RNA-bacteriophage Q β are referred within the following examples as HBcAg and Q13.

Example 3

Staining of Specific B Cells in Mice Immunized with Q β or HBcAg Containing a Reactive Lys in the Immunodominant Region

[0256] Mice were immunized intravenously with 10 μ g Q β or HBcAg diluted in PBS and spleens were removed 21 days after immunization.

[0257] For detection of B cells expressing Q β - or HbcAg-specific surface Ig, single cells suspensions of splenocytes were incubated with Q β or HBcAg capsids (1 μ g/ml) followed by a polyclonal rabbit anti-Q β or anti-HBcAg antiserum and Cy5-conjugated donkey anti-rabbit IgG serum (Jackson Immuno Research Laboratories, West Grove, Pa.). Cells were stained with a mixture of FITC-conjugated antibodies (anti-IgD, clone 11-26; goat anti-IgM serum, Jackson Immuno Research Laboratories; anti CD4, clone GK1.5; anti CD8, clone 53-6.7; anti-CD11b, clone M1/70; anti-Gr-1, clone RB6-8C5) and PE-conjugated anti-CD19 (clone 1D3) to detect isotype-switched B cells (FIG. 1). Alternatively, Q β particles were labelled with the fluorochrome Alexa 488, using the Alexa Fluor 488 Protein Labeling Kit (Molecular Probes) according to the manufacturer's instructions. To detect isotype-switched B cells, single cells suspensions of splenocytes were then incubated with the labeled Q β , stained with biotinylated anti-IgD (eBioscience) and anti-IgM antibodies (Jackson Immuno Research) followed by streptavidin-Cy-Chrome, a mixture of Cy-Chrome-conjugated antibodies (anti-CD4, anti-CD8, anti-CD11b) and PE-conjugated anti-CD19 (FIG. 1).

[0258] After staining, cells were resuspended in 0.5 μ g/ml-propidium iodide for exclusion of dead cells. Staining was performed at 4° C. for 30 min in PBS containing 2% FCS and 0.05% NaN₃; Fc-receptors were blocked with anti-mouse CD16/32 (clone 2.4G2). Antibodies were purchased from BD Biosciences unless otherwise noted.

Example 4

Coupling of Peptide D2 to Q β Capsid and Hepatitis B Core

[0259] A solution of 125 μ M Q β capsid or hepatitis B core (HBcAg(1-149) with Lysin in tip) (in 20 mM Hepes, 150 mM NaCl pH 7.2) was reacted for 45 minutes with a 50-fold molar excess of SMPH (Pierce), diluted from a stock solution in DMSO, at 25° C. on a rocking shaker. The reaction solution was subsequently dialyzed twice for 2 hours against 1 L of 20 mM Hepes, 150 mM NaCl, pH 7.2 at 4° C. The dialyzed VLP-reaction mixture was then reacted with the D2 peptide from *Salmonella Typhi* for four hours at 25° C. on a rocking shaker (end concentrations: 125 μ M VLP, 1.25-2.5 mM D2 for high coupling density or 625 μ M D2 for low coupling

density). The reaction was dialyzed against 1L 20 mM Hepes, 150 mM NaCl, pH 7.2 at 4° C. (2×2 hours). Coupling products were analysed by SDS-PAGE (FIG. 3).

Example 5

Staining of Antigen-Specific B Cells Using Q β Containing an Antigen Coupled to a Reactive Lys in the Immunodominant Region

[0260] Mice were immunized intravenously with 10 μ g peptide D2 coupled to HBcAg (diluted in PBS) and spleens were removed 21 days after immunization.

[0261] For detection of B cells specific for the D2 peptide (*Salmonella Typhi*) (FIG. 4), single cells suspensions of splenocytes were incubated with D2 coupled to Q β capsids (1 μ g/ml) followed by a polyclonal rabbit anti-Q β antiserum and Cy5-conjugated donkey anti-rabbit IgG serum (Jackson Immuno Research Laboratories, West Grove, Pa.). Cells were stained with a mixture of FITC-conjugated antibodies (anti-IgD, clone 11-26; goat anti-IgM serum, Jackson Immuno Research Laboratories; anti CD4, clone GK1.5; anti CD8, clone 53-6.7; anti-CD11b, clone M1/70; anti-Gr-1, clone RB6-8C5) and PE-conjugated anti-CD19 (clone 1D3) to detect isotype-switched B cells. After staining cells were resuspended in 0.5 μ g/ml propidium iodide for exclusion of dead cells. Staining was performed at 4° C. for 30 min in PBS containing 2% FCS and 0.05% NaN₃; Fc-receptors were blocked with anti-mouse CD16/32 (clone 2.4G2). Antibodies were purchased from BD Biosciences unless otherwise noted.

Example 6

[0262] Staining of High Affinity B Cells Using Q β Exhibiting Few Antigens Coupled to it

[0263] Mice were immunized intravenously with 10 μ g peptide D2 coupled to HBcAg (diluted in PBS) and spleens were removed 21 days after immunization. For detection of high affinity B cells specific for the D2 peptide (*Salmonella Typhi*) (FIG. 4, upper middle panel), single cells suspensions of splenocytes were incubated with D2 coupled to Q β with

low efficiency (Q β -D2 concentration 1 μ g/ml) followed by a polyclonal rabbit anti-Q β antiserum and Cy5-conjugated donkey anti-rabbit IgG serum (Jackson Immuno Research Laboratories, West Grove, Pa.). Cells were stained with a mixture of FITC-conjugated antibodies (anti-IgD, clone 11-26; goat anti-IgM serum, Jackson Immuno Research Laboratories; anti CD4, clone GK1.5; anti CD8, clone 53-6.7; anti-CD11b, clone M1/70; anti-Gr-1, clone RB6-8C5) and PE-conjugated anti-CD19 (clone 1D3) to detect isotype-switched B cells. After staining cells were resuspended in 0.5 μ g/ml propidium iodide for exclusion of dead cells. Staining was performed at 4° C. for 30 min in PBS containing 2% FCS and 0.05% NaN₃; Fc-receptors were blocked with anti-mouse CD16/32 (clone 2.4G2). Antibodies were purchased from BD Biosciences unless otherwise noted.

Example 7

Single Cell Sorting of Specific B Cells Upon Staining with Q β

[0264] Single B cells specific for Q β stained as in example 3, were sorted as described in "Current protocols in immunology, John Wiley & sons Inc., Coligan J. et. al.; Volume 1, Chapter 5 (5.0.1-5.8.23); 2002" using a FACSVantage (Becton Dickinson) into 96-well plates containing 6.10⁵ rat thymocytes/well in 200 μ l RPMI medium supplemented with 7.5% FCS, 1 ng/ml IL-6 (R&D Systems) and 25 μ g/ml LPS (Sigma-Aldrich). Cells were grown 8 days at 37° C. and 5% CO₂. Specific antibody production was detected by ELISA, which was performed according to standard protocols. In brief, 10 μ g Q β in coating buffer (0.1 M NaHCO₃, pH 9.6) was coated onto ELISA plates (Nunc Immuno Maxisorb) at 4° C. overnight. After a blocking step, supernatants from B cell cultures were added to the plates and incubated for 4 hours at 37° C. Specific antibody bound to the plate was detected using HRPO-conjugated anti IgG antibody (Sigma-Aldrich). Plates were developed with OPD substrate buffer (0.5 mg/ml OPD, 0.01% H₂O₂, 0.066 M Na₂HPO₄, 0.038 M citric acid, pH 5.0; 100 μ l each well) and plates were read in an ELISA reader at 450 nm.

SEQUENCE LISTING

<160> NUMBER OF SEQ ID NOS: 85

<210> SEQ ID NO 1

<211> LENGTH: 132

<212> TYPE: PRT

<213> ORGANISM: Bacteriophage Q beta

<400> SEQUENCE: 1

Ala Lys Leu Glu Thr Val Thr Leu Gly Asn Ile Gly Lys Asp Gly Lys
1 5 10 15

Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly Val
20 25 30

Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg Val
35 40 45

Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys Val
50 55 60

Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser Cys

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65              70              75              80
Asp Pro Ser Val Thr Arg Gln Ala Tyr Ala Asp Val Thr Phe Ser Phe
      85              90              95

Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu Leu
      100              105              110

Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln Leu
      115              120              125

Asn Pro Ala Tyr
      130

<210> SEQ ID NO 2
<211> LENGTH: 329
<212> TYPE: PRT
<213> ORGANISM: Bacteriophage Q beta

<400> SEQUENCE: 2

Met Ala Lys Leu Glu Thr Val Thr Leu Gly Asn Ile Gly Lys Asp Gly
1      5      10      15
Lys Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly
      20      25      30
Val Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg
      35      40      45
Val Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys
      50      55      60
Val Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser
65      70      75      80
Cys Asp Pro Ser Val Thr Arg Gln Ala Tyr Ala Asp Val Thr Phe Ser
      85      90      95
Phe Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu
      100      105      110
Leu Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln
      115      120      125
Leu Asn Pro Ala Tyr Trp Thr Leu Leu Ile Ala Gly Gly Gly Ser Gly
      130      135      140
Ser Lys Pro Asp Pro Val Ile Pro Asp Pro Pro Ile Asp Pro Pro Pro
145      150      155      160
Gly Thr Gly Lys Tyr Thr Cys Pro Phe Ala Ile Trp Ser Leu Glu Glu
      165      170      175
Val Tyr Glu Pro Pro Thr Lys Asn Arg Pro Trp Pro Ile Tyr Asn Ala
      180      185      190
Val Glu Leu Gln Pro Arg Glu Phe Asp Val Ala Leu Lys Asp Leu Leu
      195      200      205
Gly Asn Thr Lys Trp Arg Asp Trp Asp Ser Arg Leu Ser Tyr Thr Thr
      210      215      220
Phe Arg Gly Cys Arg Gly Asn Gly Tyr Ile Asp Leu Asp Ala Thr Tyr
225      230      235      240
Leu Ala Thr Asp Gln Ala Met Arg Asp Gln Lys Tyr Asp Ile Arg Glu
      245      250      255
Gly Lys Lys Pro Gly Ala Phe Gly Asn Ile Glu Arg Phe Ile Tyr Leu
      260      265      270
Lys Ser Ile Asn Ala Tyr Cys Ser Leu Ser Asp Ile Ala Ala Tyr His
      275      280      285

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Ala Asp Gly Val Ile Val Gly Phe Trp Arg Asp Pro Ser Ser Gly Gly
290 295 300

Ala Ile Pro Phe Asp Phe Thr Lys Phe Asp Lys Thr Lys Cys Pro Ile
305 310 315 320

Gln Ala Val Ile Val Val Pro Arg Ala
325

<210> SEQ ID NO 3
<211> LENGTH: 130
<212> TYPE: PRT
<213> ORGANISM: Bacteriophage fr

<400> SEQUENCE: 3

Met Ala Ser Asn Phe Glu Glu Phe Val Leu Val Asp Asn Gly Gly Thr
1 5 10 15

Gly Asp Val Lys Val Ala Pro Ser Asn Phe Ala Asn Gly Val Ala Glu
20 25 30

Trp Ile Ser Ser Asn Ser Arg Ser Gln Ala Tyr Lys Val Thr Cys Ser
35 40 45

Val Arg Gln Ser Ser Ala Asn Asn Arg Lys Tyr Thr Val Lys Val Glu
50 55 60

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

Ala Ala Trp Arg Ser Tyr Met Asn Met Glu Leu Thr Ile Pro Val Phe
85 90 95

Ala Thr Asn Asp Asp Cys Ala Leu Ile Val Lys Ala Leu Gln Gly Thr
100 105 110

Phe Lys Thr Gly Asn Pro Ile Ala Thr Ala Ile Ala Ala Asn Ser Gly
115 120 125

Ile Tyr
130

<210> SEQ ID NO 4
<211> LENGTH: 130
<212> TYPE: PRT
<213> ORGANISM: Bacteriophage GA

<400> SEQUENCE: 4

Met Ala Thr Leu Arg Ser Phe Val Leu Val Asp Asn Gly Gly Thr Gly
1 5 10 15

Asn Val Thr Val Val Pro Val Ser Asn Ala Asn Gly Val Ala Glu Trp
20 25 30

Leu Ser Asn Asn Ser Arg Ser Gln Ala Tyr Arg Val Thr Ala Ser Tyr
35 40 45

Arg Ala Ser Gly Ala Asp Lys Arg Lys Tyr Ala Ile Lys Leu Glu Val
50 55 60

Pro Lys Ile Val Thr Gln Val Val Asn Gly Val Glu Leu Pro Gly Ser
65 70 75 80

Ala Trp Lys Ala Tyr Ala Ser Ile Asp Leu Thr Ile Pro Ile Phe Ala
85 90 95

Ala Thr Asp Asp Val Thr Val Ile Ser Lys Ser Leu Ala Gly Leu Phe
100 105 110

Lys Val Gly Asn Pro Ile Ala Glu Ala Ile Ser Ser Gln Ser Gly Phe
115 120 125

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 Tyr Ala
130

<210> SEQ ID NO 5
 <211> LENGTH: 128
 <212> TYPE: PRT
 <213> ORGANISM: Bacteriophage PP7

<400> SEQUENCE: 5

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Met Ser Lys Thr Ile Val Leu Ser Val Gly Glu Ala Thr Arg Thr Leu
1           5           10           15
Thr Glu Ile Gln Ser Thr Ala Asp Arg Gln Ile Phe Glu Glu Lys Val
           20           25           30
Gly Pro Leu Val Gly Arg Leu Arg Leu Thr Ala Ser Leu Arg Gln Asn
           35           40           45
Gly Ala Lys Thr Ala Tyr Arg Val Asn Leu Lys Leu Asp Gln Ala Asp
           50           55           60
Val Val Asp Cys Ser Thr Ser Val Cys Gly Glu Leu Pro Lys Val Arg
65           70           75           80
Tyr Thr Gln Val Trp Ser His Asp Val Thr Ile Val Ala Asn Ser Thr
           85           90           95
Glu Ala Ser Arg Lys Ser Leu Tyr Asp Leu Thr Lys Ser Leu Val Ala
           100          105          110
Thr Ser Gln Val Glu Asp Leu Val Val Asn Leu Val Pro Leu Gly Arg
           115          120          125

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<210> SEQ ID NO 6
 <211> LENGTH: 132
 <212> TYPE: PRT
 <213> ORGANISM: Bacteriophage Q-beta

<400> SEQUENCE: 6

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Ala Lys Leu Glu Thr Val Thr Leu Gly Asn Ile Gly Arg Asp Gly Lys
1           5           10           15
Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly Val
           20           25           30
Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg Val
           35           40           45
Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys Val
           50           55           60
Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser Cys
65           70           75           80
Asp Pro Ser Val Thr Arg Gln Lys Tyr Ala Asp Val Thr Phe Ser Phe
           85           90           95
Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu Leu
           100          105          110
Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln Leu
           115          120          125
Asn Pro Ala Tyr
           130

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<210> SEQ ID NO 7
 <211> LENGTH: 132
 <212> TYPE: PRT
 <213> ORGANISM: Bacteriophage Q-beta

-continued

<400> SEQUENCE: 7

Ala Lys Leu Glu Thr Val Thr Leu Gly Lys Ile Gly Lys Asp Gly Lys
 1 5 10 15
 Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly Val
 20 25 30
 Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg Val
 35 40 45
 Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys Val
 50 55 60
 Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser Cys
 65 70 75 80
 Asp Pro Ser Val Thr Arg Gln Lys Tyr Ala Asp Val Thr Phe Ser Phe
 85 90 95
 Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu Leu
 100 105 110
 Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln Leu
 115 120 125
 Asn Pro Ala Tyr
 130

<210> SEQ ID NO 8

<211> LENGTH: 132

<212> TYPE: PRT

<213> ORGANISM: Bacteriophage Q-beta

<400> SEQUENCE: 8

Ala Arg Leu Glu Thr Val Thr Leu Gly Asn Ile Gly Arg Asp Gly Lys
 1 5 10 15
 Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly Val
 20 25 30
 Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg Val
 35 40 45
 Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys Val
 50 55 60
 Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser Cys
 65 70 75 80
 Asp Pro Ser Val Thr Arg Gln Lys Tyr Ala Asp Val Thr Phe Ser Phe
 85 90 95
 Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu Leu
 100 105 110
 Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln Leu
 115 120 125
 Asn Pro Ala Tyr
 130

<210> SEQ ID NO 9

<211> LENGTH: 132

<212> TYPE: PRT

<213> ORGANISM: Bacteriophage Q-beta

<400> SEQUENCE: 9

Ala Lys Leu Glu Thr Val Thr Leu Gly Asn Ile Gly Lys Asp Gly Arg
 1 5 10 15
 Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly Val

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                20                25                30
Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg Val
      35                40                45
Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys Val
      50                55                60
Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser Cys
      65                70                75                80
Asp Pro Ser Val Thr Arg Gln Lys Tyr Ala Asp Val Thr Phe Ser Phe
      85                90                95
Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu Leu
      100                105                110
Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln Leu
      115                120                125
Asn Pro Ala Tyr
      130

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<210> SEQ ID NO 10
<211> LENGTH: 132
<212> TYPE: PRT
<213> ORGANISM: Bacteriophage Q-beta

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<400> SEQUENCE: 10

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Ala Arg Leu Glu Thr Val Thr Leu Gly Asn Ile Gly Lys Asp Gly Arg
  1      5      10      15
Gln Thr Leu Val Leu Asn Pro Arg Gly Val Asn Pro Thr Asn Gly Val
      20      25      30
Ala Ser Leu Ser Gln Ala Gly Ala Val Pro Ala Leu Glu Lys Arg Val
      35      40      45
Thr Val Ser Val Ser Gln Pro Ser Arg Asn Arg Lys Asn Tyr Lys Val
      50      55      60
Gln Val Lys Ile Gln Asn Pro Thr Ala Cys Thr Ala Asn Gly Ser Cys
      65      70      75      80
Asp Pro Ser Val Thr Arg Gln Lys Tyr Ala Asp Val Thr Phe Ser Phe
      85      90      95
Thr Gln Tyr Ser Thr Asp Glu Glu Arg Ala Phe Val Arg Thr Glu Leu
      100      105      110
Ala Ala Leu Leu Ala Ser Pro Leu Leu Ile Asp Ala Ile Asp Gln Leu
      115      120      125
Asn Pro Ala Tyr
      130

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<210> SEQ ID NO 11
<211> LENGTH: 185
<212> TYPE: PRT
<213> ORGANISM: Hepatitis B virus

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<400> SEQUENCE: 11

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Met Asp Ile Asp Pro Tyr Lys Glu Phe Gly Ala Thr Val Glu Leu Leu
  1      5      10      15
Ser Phe Leu Pro Ser Asp Phe Phe Pro Ser Val Arg Asp Leu Leu Asp
      20      25      30
Thr Ala Ser Ala Leu Tyr Arg Glu Ala Leu Glu Ser Pro Glu His Cys
      35      40      45
Ser Pro His His Thr Ala Leu Arg Gln Ala Ile Leu Cys Trp Gly Glu

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50              55              60
Leu Met Thr Leu Ala Thr Trp Val Gly Asn Asn Leu Glu Asp Pro Ala
65              70              75              80
Ser Arg Asp Leu Val Val Asn Tyr Val Asn Thr Asn Met Gly Leu Lys
85              90
Ile Arg Gln Leu Leu Trp Phe His Ile Ser Cys Leu Thr Phe Gly Arg
100             105
Glu Thr Val Leu Glu Tyr Leu Val Ser Phe Gly Val Trp Ile Arg Thr
115             120             125
Pro Pro Ala Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser Thr Leu Pro
130             135             140
Glu Thr Thr Val Val Arg Arg Arg Asp Arg Gly Arg Ser Pro Arg Arg
145             150             155             160
Arg Thr Pro Ser Pro Arg Arg Arg Arg Ser Gln Ser Pro Arg Arg Arg
165             170             175
Arg Ser Gln Ser Arg Glu Ser Gln Cys
180             185

<210> SEQ ID NO 12
<211> LENGTH: 212
<212> TYPE: PRT
<213> ORGANISM: Hepatitis B virus

<400> SEQUENCE: 12
Met Gln Leu Phe His Leu Cys Leu Ile Ile Ser Cys Ser Cys Pro Thr
1              5              10              15
Val Gln Ala Ser Lys Leu Cys Leu Gly Trp Leu Trp Gly Met Asp Ile
20             25             30
Asp Pro Tyr Lys Glu Phe Gly Ala Thr Val Glu Leu Leu Ser Phe Leu
35             40             45
Pro Ser Asp Phe Phe Pro Ser Val Arg Asp Leu Leu Asp Thr Ala Ser
50             55             60
Ala Leu Tyr Arg Glu Ala Leu Glu Ser Pro Glu His Cys Ser Pro His
65             70             75             80
His Thr Ala Leu Arg Gln Ala Ile Leu Cys Trp Gly Asp Leu Met Asn
85             90             95
Leu Ala Thr Trp Val Gly Gly Asn Leu Glu Asp Pro Val Ser Arg Asp
100            105            110
Leu Val Val Gly Tyr Val Asn Thr Thr Val Gly Leu Lys Phe Arg Gln
115            120            125
Leu Leu Trp Phe His Ile Ser Cys Leu Thr Phe Gly Arg Glu Thr Val
130            135            140
Ile Glu Tyr Leu Val Ser Phe Gly Val Trp Ile Arg Thr Pro Pro Ala
145            150            155            160
Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser Thr Leu Pro Glu Thr Thr
165            170            175
Val Val Arg Arg Arg Gly Arg Ser Pro Arg Arg Arg Thr Pro Ser Pro
180            185            190
Arg Arg Arg Arg Ser Gln Ser Pro Arg Arg Arg Arg Ser Gln Ser Arg
195            200            205
Glu Ser Gln Cys
210

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<210> SEQ ID NO 13
<211> LENGTH: 188
<212> TYPE: PRT
<213> ORGANISM: Hepatitis B virus

<400> SEQUENCE: 13

Met Asp Ile Asp Pro Tyr Lys Glu Phe Gly Ser Ser Tyr Gln Leu Leu
1          5          10          15

Asn Phe Leu Pro Leu Asp Phe Phe Pro Asp Leu Asn Ala Leu Val Asp
20          25          30

Thr Ala Thr Ala Leu Tyr Glu Glu Glu Leu Thr Gly Arg Glu His Cys
35          40          45

Ser Pro His His Thr Ala Ile Arg Gln Ala Leu Val Cys Trp Asp Glu
50          55          60

Leu Thr Lys Leu Ile Ala Trp Met Ser Ser Asn Ile Thr Ser Glu Gln
65          70          75          80

Val Arg Thr Ile Ile Val Asn His Val Asn Asp Thr Trp Gly Leu Lys
85          90          95

Val Arg Gln Ser Leu Trp Phe His Leu Ser Cys Leu Thr Phe Gly Gln
100         105         110

His Thr Val Gln Glu Phe Leu Val Ser Phe Gly Val Trp Ile Arg Thr
115         120         125

Pro Ala Pro Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser Thr Leu Pro
130         135         140

Glu His Thr Val Ile Arg Arg Arg Gly Gly Ala Arg Ala Ser Arg Ser
145         150         155         160

Pro Arg Arg Arg Thr Pro Ser Pro Arg Arg Arg Ser Gln Ser Pro
165         170         175

Arg Arg Arg Arg Ser Gln Ser Pro Ser Thr Asn Cys
180         185

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<210> SEQ ID NO 14
<211> LENGTH: 185
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: Hepatitis B virus variant

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<400> SEQUENCE: 14

Met Asp Ile Asp Pro Tyr Lys Glu Phe Gly Ala Thr Val Glu Leu Leu
1          5          10          15

Ser Phe Leu Pro Ser Asp Phe Phe Pro Ser Val Arg Asp Leu Leu Asp
20          25          30

Thr Ala Ser Ala Leu Tyr Arg Glu Ala Leu Glu Ser Pro Glu His Cys
35          40          45

Ser Pro His His Thr Ala Leu Arg Gln Ala Ile Leu Cys Trp Gly Glu
50          55          60

Leu Met Thr Leu Ala Thr Trp Val Gly Asn Asn Leu Glu Asp Pro Ala
65          70          75          80

Ser Arg Asp Leu Val Val Asn Tyr Val Asn Thr Asn Met Gly Leu Lys
85          90          95

Ile Arg Gln Leu Leu Trp Phe His Ile Ser Cys Leu Thr Phe Gly Arg
100         105         110

Glu Thr Val Leu Glu Tyr Leu Val Ser Phe Gly Val Trp Ile Arg Thr

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115	120	125
Pro Pro Ala Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser Thr Leu Pro		
130	135	140
Glu Thr Thr Val Val Arg Arg Arg Asp Arg Gly Arg Ser Pro Arg Arg		
145	150	155
Arg Thr Pro Ser Pro Arg Arg Arg Arg Ser Gln Ser Pro Arg Arg Arg		
165	170	175
Arg Ser Gln Ser Arg Glu Ser Gln Cys		
180	185	

<210> SEQ ID NO 15
 <211> LENGTH: 152
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: HBcAg variant

<400> SEQUENCE: 15

Met Asp Ile Asp Pro Tyr Lys Glu Phe Gly Ala Thr Val Glu Leu Leu	
1	5 10 15
Ser Phe Leu Pro Ser Asp Phe Phe Pro Ser Val Arg Asp Leu Leu Asp	
20	25 30
Thr Ala Ala Ala Leu Tyr Arg Asp Ala Leu Glu Ser Pro Glu His Cys	
35	40 45
Ser Pro His His Thr Ala Leu Arg Gln Ala Ile Leu Cys Trp Gly Asp	
50	55 60
Leu Met Thr Leu Ala Thr Trp Val Gly Thr Asn Leu Glu Asp Gly Gly	
65	70 75 80
Lys Gly Gly Ser Arg Asp Leu Val Val Ser Tyr Val Asn Thr Asn Val	
85	90 95
Gly Leu Lys Phe Arg Gln Leu Leu Trp Phe His Ile Ser Cys Leu Thr	
100	105 110
Phe Gly Arg Glu Thr Val Leu Glu Tyr Leu Val Ser Phe Gly Val Trp	
115	120 125
Ile Arg Thr Pro Pro Ala Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser	
130	135 140
Thr Leu Pro Glu Thr Thr Val Val	
145	150

<210> SEQ ID NO 16
 <211> LENGTH: 3635
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Plasmid, pAP283-58, encoding RNA phage AP205 coat protein

<400> SEQUENCE: 16

cgagctcgcc cctggcttat cgaaattaat acgactcact atagggagac cggaattcga	60
gctcgcccg ggatcctcta gaattttctg cgcaccatc cgggtggcg cccaaagtga	120
ggaaaatcac atggcaaata agccaatgca accgatcaca tctacagcaa ataaaattgt	180
gtggtcggat ccaactcgtt tatcaactac attttcagca agtctgttac gccaacgtgt	240
taaagttggt atagccgaac tgaataatgt ttcaggtaa tatgtatctg tttataagcg	300
tcctgcacct aaaccggaag gttgtgcaga tgctgtgtc attatgccga atgaaaacca	360

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atccattcgc acagtgattt cagggtcagc cgaaaacttg gctacctaa aagcagaatg	420
ggaaaactcac aaacgtaacg ttgacacact cttcgcgagc ggcaacgccg gtttggttt	480
ccttgaccct actgcggcta tcgtatcgtc tgatactact gottaagctt gtattctata	540
gtgtcaccta aatcgatgtg gtatgatata taaggttatg tattaatgtg agccgcgttc	600
taacgacaat atgtacaagc ctaattgtgt agcatctggc ttactgaagc agaccctatc	660
atctctctcg taaactgccc tcagagtcgg tttggttggc cgaaccttct gagtttctgg	720
taacgcgctt ccgacccccg gaaatggtca ccgaaccaat cagcagggtc atcgctagcc	780
agatcctcta cgcgggacgc atcgtggccc gcataccccc cgcacaggt gcggttctg	840
gcgctatat cgcgcacatc accgatgggg aagatcgggc tcgccacttc gggctcatga	900
gcgcttgttt cggcgtgggt atggtggcag gccccgtggc cgggggactg ttgggcgcca	960
tctccttgca tgcaccatcc cttgcggcgg cgggtctcaa cggcctcaac ctactactgg	1020
gctgcttccct aatgcaggag tcgcataagg gagagcgtcg atatggtgca ctctcagtac	1080
aatctgctct gatgccgat agttaagcca actccgctat cgctacgtga ctgggtcatg	1140
gctgcgcccc gacaccgcc aacaccgct gacgcgccct gacgggcttg tctgctccc	1200
gcataccgctt acagacaagc tgtgaccgct tccgggagct gcatagtgca gaggttttca	1260
ccgctcatc cgaaacgcgc gaggcagctt gaagacgaaa gggcctcgtg ataccgctat	1320
ttttataggt taatgtcatg ataataatgg tttcttagac gtcaggtggc acttttcggg	1380
gaaatgtgcg cggaaacctt atttgtttat ttttctaat acattcaaat atgtatccgc	1440
tcatagagaca ataacctgta taaatgcttc aataatattg aaaaaggaag agtatgagta	1500
ttcaacatth cegtgtcgc cttattccct tttttgcggc attttgctt cctgtttttg	1560
ctcaccaga aacgctggtg aaagtaaaag atgctgaaga tcagttgggt gcacgagtg	1620
gttacatgca actggatctc aacagcggta agatccttga gagttttcgc ccgaagaac	1680
gttttccaat gatgagcaat tttaaagtcc tgctatgtgg cgcggtatta tcccgtattg	1740
acgcggggca agagcaactc ggtcgcgca tacactatc tcagaatgac ttggttgagt	1800
actcaccagt cacagaaaag catcttacgg atggcatgac agtaagagaa ttatgcagt	1860
ctgcataaac catgagtgat aacctgccc ccaacttact tctgacaacg atcggaggac	1920
cgaaggagct aaccgctttt ttgcacaaca tgggggatca tgtaactcgc cttgatcgtt	1980
gggaaccgga gctgaatgaa gccataccaa acgacgagcg tgacaccacg atgcctgtag	2040
caatggcaac aacgttgccc aaactattaa ctggcgaact acttactcta gcttcccggc	2100
aacaattaat agactggatg gaggcggata aagttgcagg accacttctg cgtcggccc	2160
ttccggctgg ctggtttatt gctgataaat ctggagccgg tgagcgtggg tctcgcggt	2220
tcattgcagc actggggcca gatggttaagc cctcccgtat cgtagttatc tacacgacgg	2280
ggagtcaggg aactatgat gaacgaaata gacagatcgc tgagataggt gctcactga	2340
ttaagcattg gtaactgtca gaccaagttt actcatatat actttagatt gatttaaaac	2400
ttcattttta atttaaaagg atctaggtga agatcctttt tgataatctc atgacaaaa	2460
tcccttaacg tgagttttct ttccactgag cgtcagaccc cgtagaaaag atcaaaggat	2520
cttcttgaga tctttttttt ctgcgctgaa tctgctgctt gcaaacaaaa aaaccaccg	2580
taccagcggg ggtttgtttg ccgatcaag agctaccaac tctttttccg aaggtaactg	2640

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gcttcagcag agcgcagata ccaataactg tccttctagt gtagccgtag ttaggccacc 2700
acttcaagaa ctctgtagca ccgcctacat acctcgctct gctaatcctg ttaccagtgg 2760
ctgctgccag tggcgataag tcgtgtctta ccgggttgga ctcaagacga tagttaccgg 2820
ataaggcgca gcggtcgggc tgaacggggg gttcgtgcac acagcccagc ttggagcgaa 2880
cgacctacac cgaactgaga tacctacagc gcgagcattg agaaagcgcc acgcttcccg 2940
aaggagaaaa ggcggacagg tatccggtaa gcggcagggt cggaacagga gagcgcacga 3000
gggagcttcc agggggaaac gcctgggtatc tttatagtc tgctgggttt cggcacctct 3060
gacttgagcg tcgatttttg tgatgctgt caggggggag gagcctatgg aaaaacgcca 3120
gcaacgcggc ctttttacgg ttctggcct tttgctggcc tttgctcac atgttctttc 3180
ctgcgttatc cctgattct gtggataacc gtattaccgc ctttgagtga gctgataccg 3240
ctgcgcgag ccgaacgacc gagegcagcg agtcagtgag cgaggaagcg gaagagcgcc 3300
caatacgcga accgcctctc ccgcgcggtt ggccgattca ttaatgcagc tgtggtgtca 3360
tggtcggtga tcgccagggt gccgacgcgc atctcgactg catggtgcac caatgcttct 3420
ggcgtcaggg agccatcgga agctgtggta tggccgtgca ggtcgtaaat cactgcataa 3480
ttcgtgtcgc tcaaggcgca ctcccgttct ggataatggt ttttgccgag acatcataac 3540
ggttctggca aatattctga aatgagctgt tgacaattaa tcatcgaact agttaactag 3600
tacgcaagtt cacgtaaaaa gggatcgcg gaatt 3635
    
```

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<210> SEQ ID NO 17
<211> LENGTH: 35
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: vector pQb185
    
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<400> SEQUENCE: 17

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tctagattaa cccaacgcgt aggagtcagg ccatg 35
    
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```

<210> SEQ ID NO 18
<211> LENGTH: 131
<212> TYPE: PRT
<213> ORGANISM: Bacteriophage AP205
    
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<400> SEQUENCE: 18

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Met Ala Asn Lys Pro Met Gln Pro Ile Thr Ser Thr Ala Asn Lys Ile
1 5 10 15
Val Trp Ser Asp Pro Thr Arg Leu Ser Thr Thr Phe Ser Ala Ser Leu
20 25 30
Leu Arg Gln Arg Val Lys Val Gly Ile Ala Glu Leu Asn Asn Val Ser
35 40 45
Gly Gln Tyr Val Ser Val Tyr Lys Arg Pro Ala Pro Lys Pro Glu Gly
50 55 60
Cys Ala Asp Ala Cys Val Ile Met Pro Asn Glu Asn Gln Ser Ile Arg
65 70 75 80
Thr Val Ile Ser Gly Ser Ala Glu Asn Leu Ala Thr Leu Lys Ala Glu
85 90 95
Trp Glu Thr His Lys Arg Asn Val Asp Thr Leu Phe Ala Ser Gly Asn
100 105 110
    
```

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Ala Gly Leu Gly Phe Leu Asp Pro Thr Ala Ala Ile Val Ser Ser Asp
 115 120 125

Thr Thr Ala
 130

<210> SEQ ID NO 19
 <211> LENGTH: 131
 <212> TYPE: PRT
 <213> ORGANISM: Bacteriophage AP205

<400> SEQUENCE: 19

Met Ala Asn Lys Thr Met Gln Pro Ile Thr Ser Thr Ala Asn Lys Ile
 1 5 10 15

Val Trp Ser Asp Pro Thr Arg Leu Ser Thr Thr Phe Ser Ala Ser Leu
 20 25 30

Leu Arg Gln Arg Val Lys Val Gly Ile Ala Glu Leu Asn Asn Val Ser
 35 40 45

Gly Gln Tyr Val Ser Val Tyr Lys Arg Pro Ala Pro Lys Pro Glu Gly
 50 55 60

Cys Ala Asp Ala Cys Val Ile Met Pro Asn Glu Asn Gln Ser Ile Arg
 65 70 75 80

Thr Val Ile Ser Gly Ser Ala Glu Asn Leu Ala Thr Leu Lys Ala Glu
 85 90 95

Trp Glu Thr His Lys Arg Asn Val Asp Thr Leu Phe Ala Ser Gly Asn
 100 105 110

Ala Gly Leu Gly Phe Leu Asp Pro Thr Ala Ala Ile Val Ser Ser Asp
 115 120 125

Thr Thr Ala
 130

<210> SEQ ID NO 20
 <211> LENGTH: 3613
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Plasmid, pAP281-32, encoding RNA phage AP205 coat protein

<400> SEQUENCE: 20

cgagctcgcc cctggcttat cgaaattaat acgactcact atagggagac cggaattcga 60
 gctcgcccgg ggatcctcta gattaaccca acgcgtagga gtcaggccat ggcaaataag 120
 acaatgcaac cgatcacatc tacagcaaat aaaattgtgt ggtcggatcc aactcgttta 180
 tcaactacat tttcagcaag tctgttacgc caacgtgtta aagttggat agccgaactg 240
 aataatgttt caggtcaata tgtatctgtt tataagcgtc ctgcacctaa accggaaggt 300
 tgtgcagatg cctgtgtcat tatgccgaat gaaaaccaat ccattcgcac agtgatttca 360
 gggtcagccg aaaacttggc taccttaaaa gcagaatggg aaactcacia acgtaacggt 420
 gacacactct tcgcgagcgg caacgcgggt ttgggtttcc ttgaccctac tgcggtatc 480
 gtatcgtctg atactactgc ttaagcttgt attctatagt gtcacctaaa tcgtatgtgt 540
 atgatacata aggttatgta ttaattgtag ccgcgttcta acgacaatat gtacaagcct 600
 aattgtgtag catctggctt actgaagcag accctatcat ctctctcgta aactgcgctc 660
 agagtcggtt tggttggacg aaccttctga gtttctggta acgcccgtcc gcaccccgga 720
 aatggtcacc gaaccaatca gcagggatc cgctagccag atcctctacg ccggacgcat 780

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cgtggcgggc atcaccggcg ccacaggtgc ggttgetggc gctatatacg cggacatcac	840
cgatggggaa gatcgggctc gccacttcgg gctcatgagc gcttgtttcg gcgtgggtat	900
ggtggcaggc cccgtggccg ggggactggt gggcgccatc tccttgcatg caccattcct	960
tgcgggcgcg gtgctcaacg gcctcaacct actactgggc tgcttcctaa tgcaggagtc	1020
gcataagggg gagcgtcgat atggtgcaact ctcaagtaca tctgctctga tgccgcatag	1080
ttaagccaac tccgctatcg ctacgtgact gggatcatggc tgcgccccga caccgcgcaa	1140
caccgcgtga cgcgcctga cgggcttgct tgctcccggc atccgcttac agacaagctg	1200
tgaccgtctc cgggagctgc atgtgtcaga ggttttcacc gtcacaccg aaacgcgcga	1260
ggcagcttga agacgaaagg gcctcgtgat acgcctatct ttataggtta atgtcatgat	1320
aataatggtt tcttagacgt cagggtggcgc ttttcgggga aatgtgcgcg gaaccctat	1380
ttgtttatct tctcaaatc attcaaatat gtatccgctc atgagacaat aaccctgata	1440
aatgcttcaa taatattgaa aaaggaagag tatgagtatt caacatttcc gtgtcgccct	1500
tattcccttt tttgcggcat tttgccttcc tgtttttgct caccagaaa cgctggtgaa	1560
agtaaaagat gctgaagatc agttgggtgc acgagtgggt tacatcgaac tggatctcaa	1620
cagcggtaag atccttgaga gttttcgccc cgaagaacgt tttccaatga tgagcacttt	1680
taaagtctcg ctatgtggcg cggatattatc ccgtattgac gccgggcaag agcaactcgg	1740
tcgccgcata cactatttcc agaatgactt ggttgagtac tcaccagtca cagaaaagca	1800
tcttacggat ggcgatgacg taagagaatt atgcagtgct gccataacca tgagtataaa	1860
cactgcggcc aacttacttc tgacaacgat cggaggaccg aaggagctaa ccgctttttt	1920
gcacaacatg ggggatcatg taactcgcct tgatcgttgg gaaccggagc tgaatgaagc	1980
cataccaaac gacgagcgtg acaccacgat gcctgtagca atggcaacaa cgttgcgcaa	2040
actattaact ggcgaactc ttactctagc ttcccggcaa caattaatag actggatgga	2100
ggcggataaa gttgcaggac cacttctgcg ctccggcctt ccggctggct ggtttattgc	2160
tgataaatct ggagccggty agcgtgggtc tcgcggtatc attgcagcac tggggccaga	2220
tggtaaagcc tcccgtatcg tagttatcta cagcagggg agtcaggcaa ctatggatga	2280
acgaaataga cagatcgctg agataggtgc ctcaactgatt aagcattggt aactgtcaga	2340
ccaagtctac tcatatatac tttagattga tttaaaactt catttttaat ttaaaaggat	2400
ctaggtgaag atcctttttg ataattctcat gacaaaaatc cottaactg agttttctgt	2460
ccactgagcg tcagaccccg tagaaaagat caaaggatct tcttgagatc cttttttct	2520
gcgcgtaatc tgctgcttgc aaacaaaaaa accaccgcta ccagcgggtg tttgtttgc	2580
ggatcaagag ctaccaactc tttttccgaa ggtaactggc ttcagcagag cgcagatacc	2640
aaatactgct cttctagtgt agccgtagtt aggccaccac ttcaagaact ctgtagcacc	2700
gcctacatac ctgcctctgc taatcctggt accagtggct gctgccagtg gcgataagtc	2760
gtgtcttacc gggttgact caagacgata gttaccggat aaggcgcagc ggtcgggctg	2820
aacggggggt tcgtgcacac agcccagctt ggagcgaacg acctacaccg aactgagata	2880
cctacagcgc gagcattgag aaagcggcgc gcttcccga gggagaaagg cggacaggtg	2940
tccggtaagc ggcagggtcg gaacaggaga gcgcacgagc gagcttccag ggggaaacgc	3000
ctggtatctt tatagtcctg tcgggttttcg ccacctctga cttgagcgtc gatttttctg	3060

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atgctcgca gggggcgga gcctatggaa aaacgccagc aacggggcct ttttacggtt 3120
cctggccttt tgctggcctt ttgtccacat gttctttcct ggttatccc ctgattctgt 3180
ggataaccgt attaccgctt ttgagtgagc tgataccgct cgccgcagcc gaacgaccga 3240
gcgcagcgag tcagtgagcg aggaagcgga agagcgcca atacgcaaac cgctctccc 3300
cgcgcttgg cggattcatt aatgcagctg tgggtgcatg gtcggtgatc gccaggggtg 3360
cgacgecat ctgactgca tggtgacca atgcttctgg cgtaggcag ccatecggaag 3420
ctgtggtatg gccgtgcagg tcgtaaata ctgcataatt cgtgtcgtc aaggcgact 3480
cccgttctgg ataatgtttt ttgcgccgac atcataacgg ttctggcaaa tattctgaaa 3540
tgagctgttg acaattaatc atcgaactag ttaactagta cgcaagttca cgtaaaaagg 3600
gtatcgcgga att 3613

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<210> SEQ ID NO 21
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: N terminal glycine serine linkers
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (1)..(1)
<223> OTHER INFORMATION: Glycine can be repeated from zero to five times
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (3)..(3)
<223> OTHER INFORMATION: Glycine can be repeated from zero to ten times
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (4)..(4)
<223> OTHER INFORMATION: Serine can be repeated from zero to two times
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (5)..(9)
<223> OTHER INFORMATION: These residues can be repeated from zero to
three times as a group

<400> SEQUENCE: 21

Gly Cys Gly Ser Gly Gly Gly Ser
1 5

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<210> SEQ ID NO 22
<211> LENGTH: 10
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: C terminal glycine serine linkers
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (1)..(1)
<223> OTHER INFORMATION: Glycine can be repeated from zero to ten times
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (2)..(2)
<223> OTHER INFORMATION: Serine can be repeated from zero to two times
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (3)..(7)
<223> OTHER INFORMATION: These residues can be repeated from zero to
three times as a group
<220> FEATURE:
<221> NAME/KEY: REPEAT
<222> LOCATION: (8)..(8)
<223> OTHER INFORMATION: Glycine can be repeated from zero to eight
times

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-continued

<220> FEATURE:
 <221> NAME/KEY: REPEAT
 <222> LOCATION: (10)..(10)
 <223> OTHER INFORMATION: Glycine can be repeated from zero to five times

<400> SEQUENCE: 22

Gly Ser Gly Gly Gly Gly Ser Gly Cys Gly
 1 5 10

<210> SEQ ID NO 23
 <211> LENGTH: 5
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: Glycine serine linker

<400> SEQUENCE: 23

Gly Gly Gly Gly Ser
 1 5

<210> SEQ ID NO 24
 <211> LENGTH: 10
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: N-terminal gammal

<400> SEQUENCE: 24

Cys Gly Asp Lys Thr His Thr Ser Pro Pro
 1 5 10

<210> SEQ ID NO 25
 <211> LENGTH: 10
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: C terminal gamma 1

<400> SEQUENCE: 25

Asp Lys Thr His Thr Ser Pro Pro Cys Gly
 1 5 10

<210> SEQ ID NO 26
 <211> LENGTH: 17
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: N terminal gamma 3

<400> SEQUENCE: 26

Cys Gly Gly Pro Lys Pro Ser Thr Pro Pro Gly Ser Ser Gly Gly Ala
 1 5 10 15

Pro

<210> SEQ ID NO 27
 <211> LENGTH: 18
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: C terminal gamma 3

<400> SEQUENCE: 27

Pro Lys Pro Ser Thr Pro Pro Gly Ser Ser Gly Gly Ala Pro Gly Gly
 1 5 10 15

-continued

Cys Gly

<210> SEQ ID NO 28
<211> LENGTH: 6
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: N terminal glycine linker

<400> SEQUENCE: 28

Gly Cys Gly Gly Gly Gly
1 5

<210> SEQ ID NO 29
<211> LENGTH: 6
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: C terminal glycine linker

<400> SEQUENCE: 29

Gly Gly Gly Gly Cys Gly
1 5

<210> SEQ ID NO 30
<211> LENGTH: 6
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: C terminal glycine-lysine linker

<400> SEQUENCE: 30

Gly Gly Lys Lys Gly Cys
1 5

<210> SEQ ID NO 31
<211> LENGTH: 6
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: N terminal glycine lysine linker

<400> SEQUENCE: 31

Cys Gly Lys Lys Gly Gly
1 5

<210> SEQ ID NO 32
<211> LENGTH: 4
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: C terminal linker

<400> SEQUENCE: 32

Gly Gly Cys Gly
1

<210> SEQ ID NO 33
<211> LENGTH: 31
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: oligonucleotide primer

-continued

<400> SEQUENCE: 33
 ccggaattca tggacattga cccttataaa g 31

<210> SEQ ID NO 34
 <211> LENGTH: 51
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: oligonucleotide primer

<400> SEQUENCE: 34
 cctagagcca cctttgccac catcttctaa attagtaccc acccaggtag c 51

<210> SEQ ID NO 35
 <211> LENGTH: 48
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: oligonucleotide primer

<400> SEQUENCE: 35
 gaagatggtg gcaaaggtgg ctctagggac ctagtagtca gttatgtc 48

<210> SEQ ID NO 36
 <211> LENGTH: 38
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: oligonucleotide primer

<400> SEQUENCE: 36
 cgcgtcccaa gcttctaaca ttgagattcc cgagattg 38

<210> SEQ ID NO 37
 <211> LENGTH: 10
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: epitope CepsilonH3

<400> SEQUENCE: 37
 Val Asn Leu Thr Trp Ser Arg Ala Ser Gly
 1 5 10

<210> SEQ ID NO 38
 <211> LENGTH: 51
 <212> TYPE: DNA
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: oligonucleotide primer
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(51)

<400> SEQUENCE: 38
 gtt aac ttg acc tgg tct cgt gct tct ggt gca tcc agg gat cta gta 48
 Val Asn Leu Thr Trp Ser Arg Ala Ser Gly Ala Ser Arg Asp Leu Val
 1 5 10 15

gtc 51
 Val

<210> SEQ ID NO 39
 <211> LENGTH: 17

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<210> SEQ ID NO 45
<211> LENGTH: 10
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 45

Leu Leu Asp Gly Thr Ala Thr Leu Arg Leu
1 5 10

<210> SEQ ID NO 46
<211> LENGTH: 10
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 46

Val Leu Tyr Arg Tyr Gly Ser Phe Ser Val
1 5 10

<210> SEQ ID NO 47
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 47

Ala Ala Gly Ile Gly Ile Leu Thr Val
1 5

<210> SEQ ID NO 48
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 48

Ile Leu Thr Val Ile Leu Gly Val Leu
1 5

<210> SEQ ID NO 49
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 49

Met Leu Leu Ala Val Leu Tyr Cys Leu
1 5

<210> SEQ ID NO 50
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 50

Tyr Met Asp Gly Thr Met Ser Gln Val
1 5

<210> SEQ ID NO 51
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 51

Val Leu Pro Asp Val Phe Ile Arg Cys
1 5

-continued

<210> SEQ ID NO 52
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 52

Phe Leu Trp Gly Pro Arg Ala Leu Val
1 5

<210> SEQ ID NO 53
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 53

Tyr Leu Ser Gly Ala Asn Leu Asn Leu
1 5

<210> SEQ ID NO 54
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 54

Arg Met Pro Glu Ala Ala Pro Pro Val
1 5

<210> SEQ ID NO 55
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 55

Ser Thr Pro Pro Pro Gly Thr Arg Val
1 5

<210> SEQ ID NO 56
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 56

Leu Leu Gly Arg Asn Ser Phe Glu Val
1 5

<210> SEQ ID NO 57
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 57

Lys Ile Phe Gly Ser Leu Ala Phe Leu
1 5

<210> SEQ ID NO 58
<211> LENGTH: 9
<212> TYPE: PRT
<213> ORGANISM: Homo sapiens

<400> SEQUENCE: 58

Ile Ile Ser Ala Val Val Gly Ile Leu

-continued

1 5

<210> SEQ ID NO 59
 <211> LENGTH: 8
 <212> TYPE: PRT
 <213> ORGANISM: Homo sapiens

<400> SEQUENCE: 59

Thr Leu Gly Ile Val Cys Pro Ile
 1 5

<210> SEQ ID NO 60
 <211> LENGTH: 5
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: HBcAg peptide

<400> SEQUENCE: 60

Gly Gly Lys Gly Gly
 1 5

<210> SEQ ID NO 61
 <211> LENGTH: 185
 <212> TYPE: PRT
 <213> ORGANISM: Artificial Sequence
 <220> FEATURE:
 <223> OTHER INFORMATION: HBcAg variant

<400> SEQUENCE: 61

Met Asp Ile Asp Pro Tyr Lys Glu Phe Gly Ala Thr Val Glu Leu Leu
 1 5 10 15

Ser Phe Leu Pro Ser Asp Phe Phe Pro Ser Val Arg Asp Leu Leu Asp
 20 25 30

Thr Ala Ser Ala Leu Tyr Arg Glu Ala Leu Glu Ser Pro Glu His Ser
 35 40 45

Ser Pro His His Thr Ala Leu Arg Gln Ala Ile Leu Cys Trp Gly Glu
 50 55 60

Leu Met Thr Leu Ala Thr Trp Val Gly Asn Asn Leu Glu Asp Pro Ala
 65 70 75 80

Ser Arg Asp Leu Val Val Asn Tyr Val Asn Thr Asn Met Gly Leu Lys
 85 90 95

Ile Arg Gln Leu Leu Trp Phe His Ile Ser Ser Leu Thr Phe Gly Arg
 100 105 110

Glu Thr Val Leu Glu Tyr Leu Val Ser Phe Gly Val Trp Ile Arg Thr
 115 120 125

Pro Pro Ala Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser Thr Leu Pro
 130 135 140

Glu Thr Thr Val Val Arg Arg Arg Asp Arg Gly Arg Ser Pro Arg Arg
 145 150 155 160

Arg Thr Pro Ser Pro Arg Arg Arg Arg Ser Gln Ser Pro Arg Arg Arg
 165 170 175

Arg Ser Gln Ser Arg Glu Ser Gln Cys
 180 185

<210> SEQ ID NO 62
 <211> LENGTH: 152
 <212> TYPE: PRT

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<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: HBcAg

<400> SEQUENCE: 62

Met Asp Ile Asp Pro Tyr Lys Glu Phe Gly Ala Thr Val Glu Leu Leu
1           5           10           15

Ser Phe Leu Pro Ser Asp Phe Phe Pro Ser Val Arg Asp Leu Leu Asp
          20           25           30

Thr Ala Ala Ala Leu Tyr Arg Asp Ala Leu Glu Ser Pro Glu His Ser
      35           40           45

Ser Pro His His Thr Ala Leu Arg Gln Ala Ile Leu Cys Trp Gly Asp
      50           55           60

Leu Met Thr Leu Ala Thr Trp Val Gly Thr Asn Leu Glu Asp Gly Gly
65           70           75           80

Lys Gly Gly Ser Arg Asp Leu Val Val Ser Tyr Val Asn Thr Asn Val
          85           90           95

Gly Leu Lys Phe Arg Gln Leu Leu Trp Phe His Ile Ser Ser Leu Thr
          100          105          110

Phe Gly Arg Glu Thr Val Leu Glu Tyr Leu Val Ser Phe Gly Val Trp
      115           120           125

Ile Arg Thr Pro Pro Ala Tyr Arg Pro Pro Asn Ala Pro Ile Leu Ser
      130           135           140

Thr Leu Pro Glu Thr Thr Val Val
145           150

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<210> SEQ ID NO 63
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: HB1 primer
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (3)..(3)
<223> OTHER INFORMATION: k is g or t
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (6)..(6)
<223> OTHER INFORMATION: r is a or g
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (7)..(7)
<223> OTHER INFORMATION: m is a or c

<400> SEQUENCE: 63

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gakgtrmagc ttcaggagtc

20

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<210> SEQ ID NO 64
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: HB2 primer
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (6)..(6)
<223> OTHER INFORMATION: b is g or c or t
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (12)..(12)
<223> OTHER INFORMATION: b is g or c or t

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<400> SEQUENCE: 64
gaggtbcagc tbcagcagtc 20

<210> SEQ ID NO 65
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: HB3 primer
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (16)..(16)
<223> OTHER INFORMATION: s is c or g
<220> FEATURE:
<221> NAME/KEY: misc_feature
<222> LOCATION: (18)..(18)
<223> OTHER INFORMATION: s is c or g

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<223> OTHER INFORMATION: r is a or g

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What is claimed is:

1. A method for selecting at least one antigen-specific B cell from a mixture of cells, said method comprising:

- (a) providing a mixture of cells comprising B cells;
- (b) providing a first composition comprising:
 - (i) a first core particle with at least one first attachment site; and
 - (ii) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of:

- (1) an attachment site not naturally occurring with said antigen or antigenic determinant; and
- (2) an attachment site naturally occurring with said antigen or antigenic determinant;

wherein said second attachment site is capable of association to said first attachment site; and wherein said antigen or antigenic determinant and said first core particle interact through said association to form an ordered and repetitive antigen array;

- (c) contacting said mixture of cells with said first composition;
- (d) labeling said first composition with a first labeling compound;
- (e) labeling said B cells in said mixture of cells with a second labeling compound; and
- (f) selecting at least one B cell which is positive for said first and said second labeling compound.

2. The method of claim 1, wherein said first core particle is selected from the group consisting of:

- (a) a virus;
- (b) a virus-like particle;
- (c) a bacteriophage;
- (d) a bacterial pilus;
- (e) a viral capsid particle;
- (f) a virus-like particle of a RNA-phage; and
- (g) a recombinant form of (a), (b), (c), (d), (e), or (f).

3. The method of claim 1, wherein said first core particle is a virus-like particle.

4. The method of claim 3, wherein said at least one antigen or antigenic determinant is bound to said virus-like particle.

5. The method of claim 3, wherein said virus-like particle comprises recombinant proteins, or fragments thereof, selected from the group consisting of:

- (a) recombinant proteins of Hepatitis B virus;
- (b) recombinant proteins of measles virus;
- (c) recombinant proteins of Sindbis virus;
- (d) recombinant proteins of Rotavirus;
- (e) recombinant proteins of Foot-and-Mouth-Disease virus;
- (f) recombinant proteins of Retrovirus;
- (g) recombinant proteins of Norwalk virus;
- (h) recombinant proteins of Alphavirus;
- (i) recombinant proteins of human Papilloma virus;
- (j) recombinant proteins of Polyoma virus;
- (k) recombinant proteins of bacteriophages;
- (l) recombinant proteins of RNA-phages;
- (m) recombinant proteins of Ty;
- (n) recombinant proteins of Q β -phage;
- (o) recombinant proteins of GA-phage;
- (p) recombinant proteins of fr-phage;
- (q) fragments of any of the recombinant proteins from (a) to (p); and

- (r) variants of any of the recombinant proteins from (a) to (q).

6. The method of claim 3, wherein said virus-like particle is Hepatitis B virus core antigen.

7. The method of claim 3, wherein said virus-like particle comprises recombinant proteins, or fragments thereof, of a RNA-phage.

8. The method of claim 7, wherein said RNA-phage is selected from the group consisting of:

- (a) bacteriophage Q β ;
- (b) bacteriophage R17;
- (c) bacteriophage fr;
- (d) bacteriophage GA;
- (e) bacteriophage SP;
- (f) bacteriophage MS2;
- (g) bacteriophage M11;
- (h) bacteriophage MX1;
- (i) bacteriophage NL95;
- (j) bacteriophage f2;
- (k) bacteriophage PP7; and
- (l) bacteriophage AP205.

9. The method of claim 3, wherein said virus-like particle comprises recombinant proteins, or fragments thereof, of RNA-phage Q β .

10. The method of claim 1, wherein said second attachment site of said first composition is capable of association to said first attachment site through at least one covalent bond.

11. The method of claim 10, wherein said covalent bond is a non-peptide bond.

12. The method of claim 1, wherein said antigen or antigenic determinant is selected from the group consisting of:

- (a) polypeptides;
- (b) carbohydrates;
- (c) steroid hormones;
- (d) organic molecules;
- (e) viruses;
- (f) bacteria;
- (g) parasites;
- (h) prions;
- (i) tumors;
- (j) self-molecules;
- (k) non-peptide hapten molecules; and
- (l) allergens.

13. The method of claim 1, wherein said antigen or antigenic determinant is attached to said first core particle at high density.

14. The method of claim 1, wherein said antigen or antigenic determinant is attached to said first core particle at low density.

15. The method of claim 1, further comprising the step of isolating said at least one antigen-specific B cell which is positive for said first and said second labeling compound.

16. The method of claim 1, further comprising verifying specific antibody production of said selected at least one B cell.

17. The method of claim 16, wherein said verifying specific antibody production of said selected at least one antigen-specific B cell is effected by ELISA.

18. The method of claim 1, wherein said selecting at least one B cell which is positive for said first and said second labeling compound is effected by using a first device capable of detecting said first labeling compound and a second device capable of detecting said second labeling compound.

19. The method of claim 1, wherein said first labeling compound is a first fluorochrome.

20. The method of claim 1, wherein said second labeling compound is a second fluorochrome.

21. The method of claim 18, wherein said first labeling compound is a first fluorochrome and said second labeling compound is a second fluorochrome, said first fluorochrome yielding a color different from said second fluorochrome upon activation, and wherein said first device capable of detecting said first labeling compound and said second device capable of detecting said second labeling compound is a fluorescence activated cell sorting apparatus (FACS).

22. The method of claim 1, wherein said labeling of said first composition is effected prior to contacting said mixture of cells with said first composition.

23. The method of claim 1, wherein said labeling of said first composition is effected after contacting said mixture of cells with said first composition.

24. The method of claim 23, wherein said labeling is effected with at least one antibody probe, wherein said probe comprises an antibody which is specific for said first composition, said antibody being conjugated with said first labeling compound.

25. The method of claim 24, wherein said first labeling compound is a first fluorochrome.

26. The method of claim 25, wherein said second labeling compound is a second fluorochrome, said first fluorochrome yielding a color different from said second fluorochrome upon activation, and wherein said selecting at least one B cell which is positive for said first and said second labeling compound is effected by using a first device capable of detecting said first labeling compound and a second device capable of detecting said second labeling compound, and wherein said first device capable of detecting said first labeling compound and said second device capable of detecting said second labeling compound is a fluorescence activated cell sorting apparatus (FACS).

27. The method of claim 24, wherein said antibody is specific for said first core particle of said first composition.

28. The method of claim 23, wherein said labeling is effected with at least one first antibody probe, wherein said first probe comprises a first antibody which is specific for said first composition, and at least one second antibody probe, wherein said second probe comprises a second antibody which is specific for said first antibody, said second antibody being conjugated with said first labeling compound.

29. The method of claim 28, wherein said first labeling compound is a first fluorochrome.

30. The method of claim 29, wherein said second labeling compound is a second fluorochrome, said first fluorochrome yielding a color different from said second fluorochrome upon activation, and wherein said selecting at least one B cell which is positive for said first and said second labeling compound is effected by using a first device capable of detecting said first labeling compound and a second device capable of detecting said second labeling compound, and wherein said first device capable of detecting said first labeling compound and said second device capable of detecting said second labeling compound is a fluorescence activated cell sorting apparatus (FACS).

31. The method of claim 28, wherein said first antibody is specific for said first core particle of said first composition.

32. The method of claim 1, wherein said labeling of said B cells is effected with a first set of at least one first targeting

molecule, wherein said first targeting molecule is specific for at least one B cell marker, and wherein said first targeting molecule is labeled with said second labeling compound.

33. The method of claim 32, wherein said second labeling compound is a second fluorochrome.

34. The method of claim 33, wherein said first labeling compound is a first fluorochrome, said first fluorochrome yielding a color different from said second fluorochrome upon activation, and wherein said selecting at least one B cell which is positive for said first and said second labeling compound is effected by using a first device capable of detecting said first labeling compound and a second device capable of detecting said second labeling compound, and wherein said first device capable of detecting said first labeling compound and said second device capable of detecting said second labeling compound is a fluorescence activated cell sorting apparatus (FACS).

35. The method of claim 32, wherein said first targeting molecule is $F(ab')_2$ specific for IgG.

36. The method of claim 32, wherein said B cell marker is selected from the group consisting of molecules expressed by B cells, such as:

- (a) the surface IgG,
- (b) kappa and lambda chains,
- (c) CD19,
- (d) Ia,
- (e) Fc receptors,
- (f) B220,
- (g) CD20,
- (h) CD21,
- (i) CD22,
- (j) CD23,
- (k) CD79, or
- (l) CD81.

37. The method of claim 1, further comprising labeling said mixture with a second set of at least one second additional targeting molecule, wherein said at least one second targeting molecule is specific for at least one marker unique for cells other than isotype-switched B cells, and wherein said at least one second targeting molecule is labeled with a third labeling compound.

38. The method of claim 37, wherein said third labeling compound is a third fluorochrome.

39. The method of claim 37, wherein said first labeling compound is a first fluorochrome, said second labeling compound is a second fluorochrome, and said third labeling compound is a third fluorochrome, said first, second, and third fluorochromes yielding different colors upon activation.

40. The method of claim 37, wherein said at least one marker unique for cells other than switched B cells is selected from the group consisting of at least one of IgD, IgM, CD3, CD4, CD8, CD11b, or Gr-1.

41. The method of claim 1 further comprising an additional step of adding a dead cell marker to said mixture of cells.

42. The method of claim 1, wherein said mixture of cells is a mixture of splenocytes.

43. The method of claim 1, wherein said mixture of cells is a mixture of peripheral blood cells.

44. The method of claim 1, wherein said mixture of cells is a mixture of splenocytes from immunized animals, said animals being immunized with a second composition comprising:

- (a) a second core particle with at least one first attachment site; and

- (b) at least one antigen or antigenic determinant with at least one second attachment site, wherein said second attachment site being selected from the group consisting of:
- (i) an attachment site not naturally occurring with said antigen or antigenic determinant; and
 - (ii) an attachment site naturally occurring with said antigen or antigenic determinant,
- wherein said second attachment site is capable of association to said first attachment site; and
- wherein said antigen or antigenic determinant and said second core particle interact through said association to form an ordered and repetitive antigen array.
- 45.** The method of claim **44**, wherein said second core particle is different from said first core particle.
- 46.** The method of claim **44**, wherein said second core particle is selected from the group consisting of:
- (a) a virus;
 - (b) a virus-like particle;
 - (c) a bacteriophage;
 - (d) a bacterial pilus;
 - (e) a viral capsid particle;
 - (f) a virus-like particle of a RNA-phage; and
 - (g) a recombinant form of (a), (b), (c), (d), (e), or (f).
- 47.** The method of claim **44**, wherein said second core particle is a virus-like particle.
- 48.** The method of claim **47**, wherein said at least one antigen or antigenic determinant is bound to said virus-like particle.
- 49.** The method of claim **47**, wherein said virus-like particle comprises recombinant proteins, or fragments thereof, selected from the group consisting of:
- (a) recombinant proteins of Hepatitis B virus;
 - (a) recombinant proteins of measles virus;
 - (b) recombinant proteins of Sindbis virus;
 - (c) recombinant proteins of Rotavirus;
 - (d) recombinant proteins of Foot-and-Mouth-Disease virus;
 - (e) recombinant proteins of Retrovirus;
 - (f) recombinant proteins of Norwalk virus;
 - (g) recombinant proteins of Alphavirus;
 - (h) recombinant proteins of human Papilloma virus;
 - (i) recombinant proteins of Polyoma virus;
 - (j) recombinant proteins of bacteriophages;
 - (k) recombinant proteins of RNA-phages;
 - (l) recombinant proteins of Ty;
 - (m) recombinant proteins of Q β -phage;
 - (n) recombinant proteins of GA-phage;
 - (o) recombinant proteins of fr-phage;
 - (p) fragments of any of the recombinant proteins from (a) to (p); and
 - (q) variants of any of the recombinant proteins from (a) to (q).
- 50.** The method of claim **47**, wherein said virus-like particle is Hepatitis B virus core antigen.
- 51.** The method of claim **47**, wherein said virus-like particle comprises recombinant proteins, or fragments thereof, of a RNA-phage.
- 52.** The method of claim **51**, wherein said RNA-phage is selected from the group consisting of:
- (a) bacteriophage Q β ;
 - (b) bacteriophage R17;
 - (c) bacteriophage fr;
 - (d) bacteriophage GA;
 - (e) bacteriophage SP;
 - (f) bacteriophage MS2;
 - (g) bacteriophage M11;
 - (h) bacteriophage MX1;
 - (i) bacteriophage NL95;
 - (j) bacteriophage f2;
 - (k) bacteriophage PP7; and
 - (l) bacteriophage AP205.
- 53.** The method of claim **47**, wherein said virus-like particle comprises recombinant proteins, or fragments thereof, of RNA-phage Q β .
- 54.** The method of claim **44**, wherein said second attachment site of said second composition is capable of association to said first attachment site through at least one covalent bond.
- 55.** The method of claim **44**, wherein said covalent bond is a non-peptide bond.
- 56.** The method of claim **44**, wherein said antigen or antigenic determinant is selected from the group consisting of:
- (a) polypeptides;
 - (b) carbohydrates;
 - (c) steroid hormones;
 - (d) organic molecules;
 - (e) viruses;
 - (f) bacteria;
 - (g) parasites;
 - (h) prions;
 - (i) tumors;
 - (j) self-molecules;
 - (k) non-peptide hapten molecules; and
 - (l) allergens.
- 57.** The method of claim **44**, wherein said antigen or antigenic determinant of said second composition is the same as said antigen or antigenic determinant of said first composition.
- 58.** An antigen-specific B cell selected by the method of claim **1**.
- 59.** A method for generating monoclonal antibodies comprising the steps of providing at least one antigen-specific B cell selected by the method of claim **1** and fusing said at least one antigen-specific B cell with a myeloma cell line.
- 60.** A method for generating monoclonal antibodies comprising the steps providing at least one antigen-specific B cell selected by the method of claim **44** and fusing said at least one antigen-specific B cell with a myeloma cell line.
- 61.** A method for generating monoclonal antibodies or antibody fragments comprising the steps of isolating at least one genetic element encoding the immunoglobulin or parts of the immunoglobulin expressed by said at least one antigen-specific B cell selected by the method of claim **1** and expressing said genetic element.
- 62.** The method of claim **61**, wherein said genetic element is expressed as a fusion molecule.

专利名称(译)	具有特异性的B细胞的选择：制备和使用方法		
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申请号	US12/573617	申请日	2009-10-05
[标]申请(专利权)人(译)	赛托斯生物技术公司		
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IPC分类号	C12Q1/70 G01N33/53 C12N5/0781 C12P21/00 C07K16/00 G01N27/447 G01N33/50 G01N33/543 G01N33/566 G01N33/569 G01N33/58		
CPC分类号	G01N27/447 G01N33/5052 G01N33/58 G01N33/56972 G01N33/54313		
优先权	PCT/EP2004/005208 2004-05-14 WO 60/470443 2003-05-15 US		
外部链接	Espacenet USPTO		

摘要(译)

本发明涉及分子生物学，病毒学，免疫学和医学领域。本发明提供了使用包含有序和重复抗原或抗原决定簇阵列的组合物的方法，用于可视化和选择对抗原特异的B细胞。这些B细胞可用于生产用于治疗，诊断或研究目的的单克隆抗体。

