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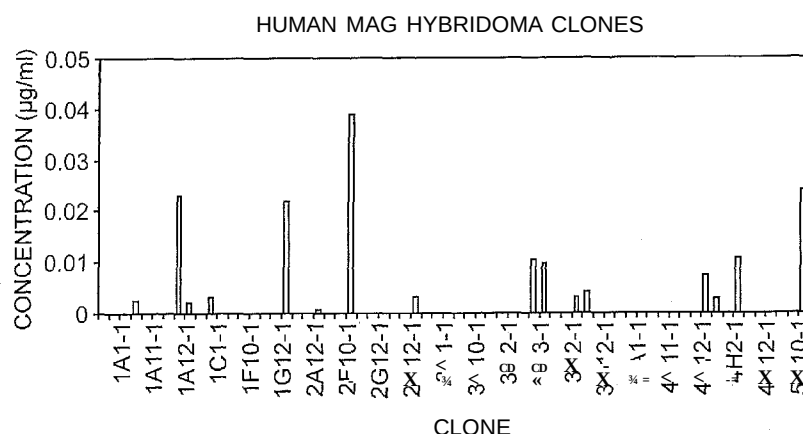
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(54) Title: METHOD FOR PRODUCING HUMAN MONOCLONAL IMMUNOGLOBULIN G ANTIBODIES



METHOD FOR PRODUCING HUMAN MONOCLONAL IMMUNOGLOBULIN G ANTIBODIES

Background of the Invention

[0001] Bone Marrow Liver Thymic mice (BLT mice) have been shown to develop a human immune system with high human T cell and other cell counts in virtually all of their tissues, including the gut and lungs, sites of important immune response to diseases (Melkus, et al. (2006) *Nat. Med.* 12:1316-22) . BLT mice are produced by non-lethally irradiating non-obese diabetic/severe combined immunodeficient crossed mice (nod/scid and nod/SCIDyc-/-) at 6 weeks with 2yG of radiation (Brainard, et al. (2009) *J. Virology* 83:7305-7321) . These irradiated mice pups have human fetal liver surgically implanted under the kidney capsule of both kidneys in association with the IV injection of CD34+ cells from human fetal liver. These mice have high levels of human CD45+ blood cells by 12 weeks after the transplant, wherein the CD45+ cells generally encompass roughly equal levels of B cells and T cells.

[0002] It has been shown that the antigen-specific T cell response cannot be elicited in mice transplanted with only CD34+ haematopoietic stem cells because the T cells fail to develop normally in such mice (Sato, et al. (2010) *PLoS One* 5:e13109) . Additionally, antigen-specific IgG+ human B cell clones have not been established in these animals because T cell help in this system is sub-optimal resulting in an absence of an antigen-specific T cell response (Becker, et al. (2010) *PLoS One* 5(10) :e13137) . A low frequency of IgG+ producing cells has been noted; however, it was concluded that antigen-specific IgG antibodies cannot be obtained with this model. Rather,

antigen- specific human monoclonal IgM antibodies were produced .

Summary of the Invention

[0003] The present invention a method for producing a human immunoglobulin G (IgG) antibody. The method of the invention involves the steps of (a) administering a prime dose of an antigen to a Bone Marrow Liver Thymic (BLT) mouse; (b) administering a first boost of the antigen at least three weeks after the immunization of (a) ; and (c) administering a second boost of the antigen at least three weeks after the first boost of (b) so that a human IgG is produced to the antigen. In certain embodiments, the method further includes the step of mixing spleen cells of the immunized and boosted BLT mouse with an immortal human cell line to produce a hybridoma .

Brief Description of the Drawings

[0004] Figure 1 shows generation of antigen-specific IgG antibodies in the sera of immunized BLT mice.

[0005] Figure 2 shows titers of MAG-1 hybridoma human IgG clones in 96 well plates, as determined by ELISA.

Detailed Description of the Invention

[0006] BLT mice are of use as an animal model for HIV AIDS research. It has been shown that T cells fail to develop normally in BLT mice, and antibodies produced by these mice are typically of the IgM class. Using a unique immunization process, BLT animals have now been shown to develop good titers of IgG isotype antibodies, and subsequent hybridoma formation with spleen cells from these animals. The immunization process includes a prime-boost regime, wherein a first boost injection is administered after at least 3

weeks, and a second boost is administered after at least 3 more weeks. Using BLT mice and the instant method, monoclonal human IgG antibodies for therapeutic and diagnostic usefulness can now be produced. In particular, such antibodies can be used as therapeutic targeting agents, agents for imaging and diagnosing tumors, agents for immunohistochemistry and western blot analysis, agents for confocal and electron microscopy, agents for FACS analyses, and agents for RIA, ELISA, and other assays.

[0007] Therefore, the present invention features a method for producing a human immunoglobulin G (IgG) antibody by (a) immunizing a Bone Marrow Liver Thymic (BLT) mouse with an antigen; (b) administering a first boost of the antigen at least three weeks after the immunization of (a); and (c) administering a second boost of the antigen at least three weeks after the first boost of (b) so that a human IgG is produced to the antigen.

[0008] BLT mice, i.e., Bone Marrow Liver Thymic mice, are known in the art and produced by surgically implanting thymic and liver organoids into non-obese diabetic (NOD)/SCID mice (which lack endogenous T and B cells) (Mekus, et al. (2006) *supra*).

[0009] An "antigen," as used herein, is a molecule capable of provoking an immune response. Antigens include but are not limited to peptides, polypeptides, cells, cell extracts, polysaccharides, polysaccharide conjugates, lipids, glycolipids and carbohydrates. Antigens may be given in a crude, purified or recombinant form and polypeptide/peptide antigens, including peptide mimics of polysaccharides, may also be encoded within nucleic acids. The term antigen broadly includes any type of molecule which is recognized by a host immune system as being foreign. Antigens include but are not limited to cancer

antigens, microbial antigens, cell-type specific antigens and any other molecule for which a specific antibody is desired .

[0010] A "cancer antigen" as used herein is a compound, such as a peptide, associated with a tumor or cancer cell surface and which is capable of provoking an immune response when expressed on the surface of an antigen presenting cell in the context of an MHC molecule. Cancer antigens can be prepared from cancer cells either by preparing crude extracts of cancer cells, for example, as described in Cohen, et al. (1994) *Cancer Research* 54:1055, by partially purifying the antigens, by recombinant technology, or by *de novo* synthesis of known antigens. Cancer antigens include antigens immunogenic portions of antigens. Such antigens can be isolated or prepared recombinantly or by any other means known in the art.

[0011] A "cell-type specific antigen" is an antigen that is expressed by a particular cell or group of cells. Examples of cell-type specific antigens include antigens only expressed by, e.g., epidermal cells, immune cells, liver cells, nerve cells, blood cells, etc.

[0012] A "microbial antigen" as used herein is an antigen of a microorganism and includes, but is not limited to, infectious virus, infectious bacteria, infectious parasites and infectious fungi. Such antigens include the intact microorganism as well as natural isolates and fragments or derivatives thereof and also synthetic 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. Most such antigens are used routinely in the art

and are well-known to those of ordinary skill in the art. Another example is a peptide mimic of a polysaccharide antigen .

[0013] Examples of infectious virus that have been found in humans include, but are not limited to, Retroviridae (*e.g.*, human immunodeficiency viruses, such as HIV-1 (also referred to as HTLV-III, LAV or HTLV-III/LAV, or HIV-III) and other isolates, such as HIV-LP; Picornaviridae (*e.g.*, polio viruses, hepatitis A virus, enteroviruses, human Coxsackie viruses, rhinoviruses, echoviruses); Calciviridae (*e.g.*, strains that cause gastroenteritis); Togaviridae (*e.g.*, equine encephalitis viruses, rubella viruses); Flaviridae (*e.g.*, dengue viruses, encephalitis viruses, yellow fever viruses); Coronaviridae (*e.g.*, coronaviruses); Rhabdoviridae (*e.g.*, vesicular stomatitis viruses, rabies viruses); Coronaviridae (*e.g.*, coronaviruses); Rhabdoviridae (*e.g.*, vesicular stomatitis viruses, rabies viruses); Filoviridae (*e.g.*, ebola viruses); Paramyxoviridae (*e.g.*, parainfluenza viruses, mumps virus, measles virus, respiratory syncytial virus); Orthomyxoviridae (*e.g.*, influenza viruses); Bunyaviridae (*e.g.*, Hantaan viruses, bunya viruses, phleboviruses and Nairo viruses); Arenaviridae (hemorrhagic fever viruses); Reoviridae (*e.g.*, reoviruses, orbiviruses and rotaviruses); Birnaviridae; Hepadnaviridae (Hepatitis B virus); Parvoviridae (parvoviruses); Papovaviridae (papilloma viruses, polyoma viruses); Adenoviridae (most adenoviruses); Herpesviridae (herpes simplex virus 1 and 2, varicella zoster virus, cytomegalovirus, herpes virus); Poxviridae (variola viruses, vaccinia viruses, pox viruses); and Iridoviridae (*e.g.*, African swine fever virus); and unclassified viruses (*e.g.*, the etiological agents of Spongiform encephalopathies, the agent of delta

hepatitis (thought to be a defective satellite of hepatitis B virus), the agents of non-A, non-B hepatitis (class 1=internally transmitted; class 2=parenterally transmitted {i.e., Hepatitis c}); Norwalk and related viruses, and astroviruses).

[0014] Gram negative and gram positive bacteria, or components thereof, also serve as antigens. Such gram positive bacteria include, but are not limited to *Pasteurella* species, *Staphylococci* species, and *Streptococcus* species. Gram negative bacteria include, but are not limited to, *Escherichia coli*, *Pseudomonas* species, and *Salmonella* species. Specific examples of infectious bacteria include, but are not limited to, *Helicobacter pylori*, *Borelia burgdorferi*, *Legionella pneumophila*, *Mycobacteria* spp. (e.g., *M. tuberculosis*, *M. avium*, *M. intracellulare*, *M. kansaii*, *M. gordonae*), *Staphylococcus aureus*, *Neisseria gonorrhoeae*, *Neisseria meningitidis*, *Listeria monocytogenes*, *Streptococcus pyogenes* (Group A *Streptococcus*), *Streptococcus agalactiae* (Group B *Streptococcus*), *Streptococcus* (viridans group), *Streptococcus faecalis*, *Streptococcus bovis*, *Streptococcus* (anaerobic spp.), *Streptococcus pneumoniae*, pathogenic *Campylobacter* sp., *Enterococcus* sp., *Haemophilus influenzae*, *Bacillus anthracis*, *Corynebacterium diphtheriae*, *Corynebacterium* sp., *Erysipelothrix rhusiopathiae*, *Clostridium perfringens*, *Clostridium tetani*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*, *Pasteurella multocida*, *Bacteroides* sp., *Fusobacterium nucleatum*, *Streptobacillus moniliformis*, *Treponema pallidum*, *Treponema pertenue*, *Leptospira*, *Rickettsia*, and *Actinomyces israelii*.

[0015] Examples of infectious fungi include *Cryptococcus neoformans*, *Histoplasma capsulatum*, *Coccidioides immitis*,

Blastomyces dermatitidis, *Chlamydia trachomatis*, and *Candida albicans*,

[0016] Examples of infectious parasites include *Plasmodium* such as *Plasmodium falciparum*, *Plasmodium malariae*, *Plasmodium ovate*, and *Plasmodium vivax*. Other infectious organisms (i.e., protists) include *Toxoplasma gondii*.

[0017] Other medically relevant microorganisms have been described extensively in the literature, e.g., see C. G. Thomas (1983) *Medical Microbiology*, Bailliere Tindall, Great Britain.

[0018] As discussed above, antigens include cancer cells, infectious microbes such as virus, bacteria, parasites and fungi, and components thereof, e.g., isolated or substantially purified proteins, polysaccharides, etc., isolated from the microbe. The term "substantially purified" as used herein refers to an antigen, which is substantially free of other proteins, lipids, carbohydrates or other materials with which it is naturally associated. One skilled in the art can purify antigens using standard techniques routinely used in the art. For example, a substantially pure protein antigen will often yield a single major band on a non-reducing polyacrylamide gel. In the case of partially glycosylated polypeptides or those that have several start codons, there may be several bands on a non-reducing polyacrylamide gel, but these will form a distinctive pattern for that polypeptide.

[0019] In some embodiments, the antigen is linked to a carrier. The term "linked," as used herein interchangeably with the term "coupled," refers to proximately associated, e.g., the antigen and the carrier are in close spatial proximity. In some embodiments, the linkage is a covalent linkage. In other embodiments, the linkage is a non-covalent linkage. In some embodiments, the antigen is

linked directly to the carrier. In other embodiments, the antigen is linked indirectly, e.g., via a linker molecule.

[0020] Examples of suitable carriers include large, slowly metabolized macromolecules such as proteins; polysaccharides such as SEPHAROSE, agarose, cellulose, cellulose beads and the like; polymeric amino acids such as polyglutamic acid, polylysine, and the like; amino acid copolymers; inactivated virus particles; inactivated bacterial toxins such as toxoid from diphtheria, tetanus, cholera, leukotoxin molecules; liposomes; inactivated bacteria; dendritic cells; and the like. Suitable carriers are well-known in the art, and include, e.g., thyroglobulin, albumins such as human serum albumin, VP6 polypeptides of rotaviruses, influenza virus hemagglutinin, influenza virus nucleoprotein, hepatitis B virus core protein, hepatitis B virus surface antigen, purified protein derivative (PPD) of tuberculin from *Mycobacterium tuberculosis*, inactivated *Pseudomonas aeruginosa* exotoxin A (toxin A), Keyhole Limpet Hemocyanin (KLH), filamentous hemagglutinin (FHA) of *Bordetella pertussis*, T helper cell (Th) epitopes of tetanus toxoid (TT) and Bacillus Calmette-Guerin (BCG) cell wall, recombinant 10 kDa, 19 kDa and 30-32 kDa proteins from *M. leprae* or from *M. tuberculosis*, or any combination of these proteins; and the like. See, e.g., U.S. Patent No. 6,447,778 for a discussion of carriers, and for methods of conjugating peptides to carriers. Examples of methods by which a subject antigen is conjugated with a carrier include disulfide linkages through a C-terminal peptide cysteine linkage, coupling with glutaraldehyde solution for two hours, coupling with tyrosine, or coupling with water soluble carbodiimide.

[0021] The antigen of the invention can be administered as is or in combination with an adjuvant to enhance the immune

response to the antigen. Adjuvants can be added directly to the antigen composition or can be administered separately, either concurrently with or shortly after, administration of the antigen. Such adjuvants include, but are not limited to, aluminum salts (alum), such as aluminum hydroxide, aluminum phosphate, aluminum sulfate, etc.; oil-in-water emulsion formulations (with or without other specific immunostimulating agents such as muramyl peptides; saponin adjuvants, such as STIMULON (Cambridge Bioscience, Worcester, MA) may be used or particles generated therefrom such as ISCOMs (immunostimulating complexes); Complete Freund's Adjuvant (CFA) and Incomplete Freund's Adjuvant (IFA); cytokines, such as interleukins (IL-1, IL-2, etc.), macrophage colony stimulating factor (M-CSF), tumor necrosis factor (TNF), etc.; detoxified mutants of a bacterial ADP-ribosylating toxin such as a cholera toxin (CT), a pertussis toxin (PT), or an E. coli heat-labile toxin (LT), particularly LT-K63 (where lysine is substituted for the wild-type amino acid at position 63) LT-R72 (where arginine is substituted for the wild-type amino acid at position 72), CT-S109 (where serine is substituted for the wild-type amino acid at position 109), and PT-K9/G129 (where lysine is substituted for the wild-type amino acid at position 9 and glycine substituted at position 129); and the like.

[0022] As indicated, antigen-specific IgG antibodies are produced by BLT mice using a prime-boost regimen, which includes one priming immunization, followed by two secondary or boosting immunizations at three- to four-week intervals. Alternatively stated, the BLT mouse is given a priming immunization with an antigen of interest; three or more weeks after the priming immunization, the mouse is given a boosting immunization with the antigen of interest;

and three or more weeks later (i.e., six to eight weeks after the priming boost), the mouse is given a second boosting immunization with the antigen of interest.

[0023] Preparation of hybridomas expressing the antibody to the antigen of interest also embraced by the present invention. The term "hybridoma" is art recognized and is understood by those of ordinary skill in the art to refer to a cell produced by the fusion of an antibody-producing cell and an immortal cell. Such a hybrid cell is capable of producing a continuous supply of antibody. Hybridomas can be prepared by conventional methods. In general, such methods include harvesting spleen cells from immunized BLT mice and fusing the spleen cells with an immortal human cell line, such as with a myeloma cell line (e.g., Wi-12-729hf2 lymphoblastoid cells; Heitzmann, et al. (1986) *Mol. Biol. Med.* 3:339-50), using the well-known processes of Kohler and Milstein ((1975) *Nature* 256:495-497) and Harlow and Lane ((1988) *Antibodies: A Laboratory Manual* (Cold Spring Harbor Laboratory, New York)). The resulting hybrid cells are then cloned in the conventional manner, e.g., using limiting dilution, and the resulting clones, which produce the desired monoclonal antibodies, cultured. The so obtained hybridomas are chemically selected by plating the cells in a selection medium containing hypoxanthine, aminopterin and thymidine (HAT). Hybridomas are subsequently screened for the ability to produce monoclonal antibodies against the antigen of interest. Hybridomas producing antibodies of interest are cloned, expanded and stored frozen for future production.

[0024] Antibodies produced by the instant method provide a means of directly making human monoclonal antibodies for therapeutic (e.g., treating cancers and other disease states), diagnostic, prognostic and analytical use.

Conventionally, it has been necessary to go from mouse antibodies to chimeric then humanized antibodies. Using the instant method, the time to produce a humanized antibody (including a human antibody) is dramatically shortened.

[0025] The invention is described in greater detail by the following non-limiting examples.

Example 1: Protocol for IgG Production in BLT Mice

[0026] *Immunization.* Antigenic peptides {e.g., VQLAGAPEPFEPAPDAY (SEQ ID NO:1), MSIYSDKSIH-NH₂ (SEQ ID NO:2), YQANKRHGSW-NH₂ (SEQ ID NO:3), YLEGGCSRG-NH₂ (SEQ ID NO:4)) or other small molecules are coupled to bovine thyroglobulin using glutaraldehyde as the coupling agent. However, antigens of 10 kDa or larger could be used without coupling to a larger molecule. The complex in solution (1 mg/ml antigen in 0.05 M sodium phosphate, pH 7.5) is mixed with Freund's complete adjuvant and human BLT mice are immunized (-50 µg antigen) through multiple (3-4) subcutaneous injections along the back after shaving the area. After 3-4 weeks, a boost injection of antigen-thyroglobulin complex, mixed 1:1 with incomplete Freund's adjuvant, is given s.c. (-25 µg antigen). Subsequently, a second boost identical to the first boost is given subcutaneously 3 weeks later. Four to seven days after the second boost, the animal is sacrificed and the spleen removed. Plasma is harvested through orbital bleed (at day 21-28, 42-49) and on the day the animal was sacrificed. The plasma is screened for the presence of human IgG antigen-specific antibodies by ELISA assays (Figure 1). For these assays, 96-well plates are coated with antigen coupled to bovine albumen, a range of plasma dilutions are added and incubated at 4°C overnight. Plates are thoroughly washed with assay buffer (PBS with 0.05% TWEEN 20), blocked with

albumen for 3 hours and enzyme (Horse Radish Peroxidase) - conjugated antibodies (goat anti-human IgG H-L specific antibodies) are added at a dilution of 1:5000. Following an incubation of 4 hours at ambient temperature, plates are washed (x4) and dilute H_2O_2 and AMPLEX UltraRed Reagent substrate solution (Invitrogen Molecular Probes) is added. Developing fluorescence (excitation 530 nm; emission 590 nm) is measured on a Synergy HT plate scanner. Reference standard is a human chimera of a mouse monoclonal antibody (e.g., MAG-1 chimera, Woomera Therapeutics), with albumen-coupled antigen for this antibody coating reference plates.

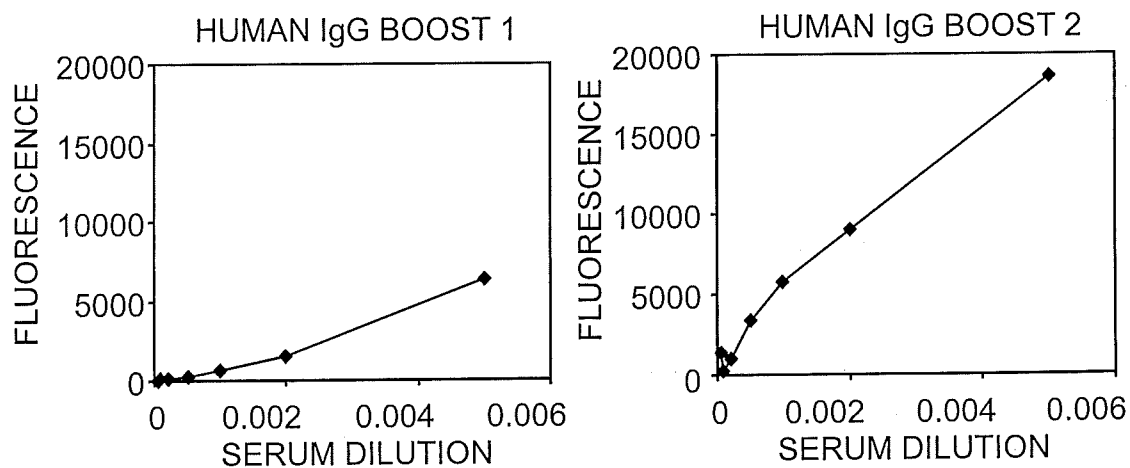
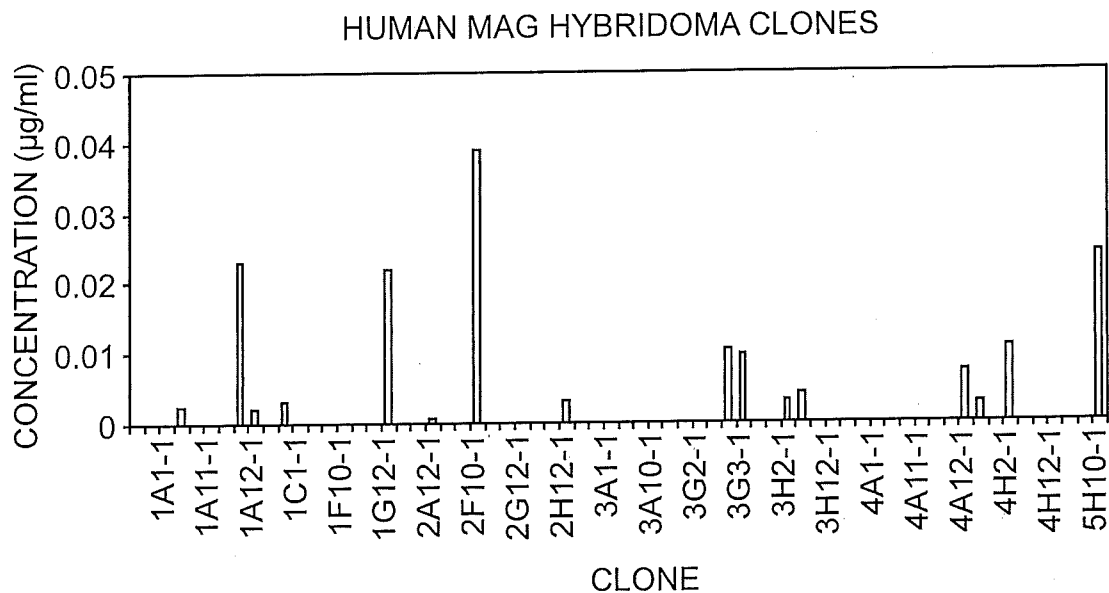
[0027] *Generation of Hybridomas*. Spleen cells are teased out of the spleen of immunized animals with curved forceps into serum-free DMEM/F-12 medium, and red blood cells removed by lysis. The remaining washed white cells are mixed with a similar number (ratio generally 5 spleen cells: 3 tumor cells) of human Wi-l2-729hf2 lymphoblastoid cells (Heitzmann, et al. (1986) *supra*) in serum-free DMEM/F-12 medium. The mixed cells are pelleted and cells fused by stirring in a 1.0 ml solution of 50% PEG 1500 in 75 mM HEPES (Roche). Hybridized cells are washed free of PEG and reconstituted in 30-60 ml of DMEM/F-12 Medium containing 10-20% bovine calf serum.

[0028] Aliquots (100 μ l) of cell suspensions are added to cells of 96-well plates and left for three days, after which cells are placed in lxHAT supplement-containing medium and then lxHT supplement-containing medium to remove any non-spleen hybridomas and non-hybridized lymphoblastoid cells. Clones are generated by serial dilution of the cells and screened for the expression of human antigen-specific IgG antibodies using an ELISA (Figure 2).

What is claimed is:

1. A method for producing a human immunoglobulin G (IgG) antibody comprising
 - (a) administering a prime dose of an antigen to a Bone Marrow Liver Thymic (BLT) mouse;
 - (b) administering a first boost of the antigen at least three weeks after the immunization of (a) ; and
 - (c) administering a second boost of the antigen at least three weeks after the first boost of (b) so that a human IgG is produced to the antigen.
2. The method of claim 1, further comprising mixing spleen cells of the immunized and boosted BLT mouse with an immortal human cell line to produce a hybridoma.
3. A method of using an antibody produced by the method of claim 1 for therapy, diagnosis, or prognosis of human health or disease states.

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*FIG. 1**FIG. 2*

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/66531

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - C12P 21/00 (2013.01)

USPC - 800/6

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC: 800/6

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 800/6
(keyword limited; terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase; Google; PubMed

Search terms: BLT, bone marrow thymus, mice, mouse, IgG, antibody, immunization, second, boost, three weeks, hybridoma

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	TONOMURA et al. "Antigen-specific human T-cell responses and T cell-dependent production of human antibodies in a humanized mouse model" Blood; 15 April 2008; Vol. 111, No. 8; pages 4293-4296; abstract; pg 4293, para 2-3; pg 4295, para 1; pg 4295, Ref. 10; Fig. 2D.	1-3
Y	US 6,593,197 B1 (ERLANGER et al.) 15 July 2003 (15.07.2003) col 2, ln 13-37; col 15, ln 46-51; col 16, ln 12-16, ln 54-55	1-3
A	BRAINARD et al. "Induction of robust cellular and humoral virus-specific adaptive immune responses in human immunodeficiency virus-infected humanized BLT mice: J. Virol.; July 2009; Vol. 83, No. 14; pages 7305-7321 .	1-3
A	BECKER et al. "Generation of human antigen-specific monoclonal IgM antibodies using vaccinated "human immune system" mice" PLoS One; 4 October 2010; Vol. 5, No. 10; article e13137, pages 1-10.	1-3
A	BERGES et al. "The utility of the new generation of humanized mice to study HIV-1 infection: transmission, prevention, pathogenesis, and treatment" Retrovirology; 11 August 2011; Vol. 8, No. 65; pages 1-19.	1-3
A	DENTON et al. "Humanized mouse models of HIV infection" AIDS Rev.; July-September 2011; Vol. 13, No. 3; pages 135-148.	1-3
A	US 2011/0142870 A1 (YUSIBOV et al.) 16 June 2011 (16.06.2011) entire document	1-3

☒ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

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Date of mailing of the international search report

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Name and mailing address of the ISA/US

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Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/66531

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
L	Melkus et al. "Humanized mice mount specific adaptive and innate immune responses to EBV and TSST-1" Nat. Med.; published online 22 October 2006; Vol. 12; pg. 1316-1322. Entire Document. Provided to support citations from Tonomura, above.	1-3