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(54) Title: HUMANIZATION OF ANTIBODIES

V_H-233

5' GAGGTGAAGCTGGTGGAGTCTGGAGGAGGCTTGGTACAGCCTGGGGGTTCTCTGAGTCTCTCCTGTGCAGCTTCTGGATTCCACC
TTCACCTGATTACTCCATGAAC TGGGTCCGCCAGCCTCCAGGGAAGGCACTTGAGTGGTTGGGT TTTATTAGAAACAAAGCTAATGA
TTACACAACAGAGTACAGTGCATCTGTGAAGGGT CGGTTACCATCTCCAGAGATAATCCCAAAGCATCCTCTATCTTCAAATGA
ATGCCCTGAGAGCTGAGGACAGTGCCACTTATTACTGTGTAAGA TACCCTAGGTATCATGCTATGGACTCC TGGGGTCAAGGAACC
TCAGTCACCGTCTCCTCA3' (SEQ ID NO. 1773)

EVKLIVESGGGLVQPGGSLSLSCAASGFTFT DYSMN WVRQPPGKALEWLGFIRNKANDYTTEYSASVKG RFTISRDNQSILYLQMN
ALRAEDSATYYCVR YPRYHAMDS WGQGTSTVTVSS (SEQ ID NO. 1775)

V_L-233

5' GATATTGTGCTAACTCAGTCTCCAGCCACCCTGTCTGTGACTCCAGGAGATAGCGTCAATCTTTCCTGC AGGGCCAGCCAAAGT
ATTAGCAACAACCTACAC TGGTATCAACAAAAATCACATGAGTCTCCAAGGCTTCTCATCAAG TATGTTTTCCAGTCCATCTCTGG
GATCCCCTCCAGGTTCAAGTGGCAGTGGATCAGGGACAGATTTCACTCTCAGTATCAACAGTGTGGAGACTGAAGATTTTGGAATGT
ATTTCTGT CAACAGAGTAACAGCTGGCCGCTCACG TTCGGTGCTGGGACCAAGCTGGAGCTGAAA3' (SEQ ID NO. 1774)

DIVLTQSPATLSVTPGDSVNLSC RASQISNNLH WYQKSHESPRLLIK YVFQSSIGIPSRFSGSGSGTDFTLINSVETEDFGMY
FCQQNSWPLTFGAGTKLELK (SEQ ID NO. 1776)

(57) Abrégé/Abstract:

The present invention relates to methods of reengineering or reshaping antibodies to reduce the immunogenicity of the antibodies, while maintaining the immunospecificity of the antibodies for an antigen. In particular, the present invention provides methods of producing antibodies immunospecific for an antigen by synthesizing a combinatorial library comprising complementarity determining regions (CDRs) from a donor antibody fused in frame to framework regions from a sub-bank of framework regions. The present invention also provides antibodies produced by the methods of the invention.



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(54) Title: HUMANIZATION OF ANTIBODIES

V_H-233

5' GAGGTGAAGCTGGTGGAGTCTGGAGGAGGCTTGGTACAGCCTGGGGGTTCTCTGAGTCTCTCCTGTGCAGCTTCTGGATTACCC
TTCACTGATTACTCCATGAACGTTGGTCCGCCAGCCTCCAGGGAAGGCACTTGAGTGGTTGGGTTTTATTAGAAACAAAGCTAATGA
TTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGGTTCACCATCTCCAGAGATAATTCCCAAAGCATCTCTATCTTCAAATGA
ATGCCCTGAGAGCTGAGGACAGTGCCACTTATTACTGTGTGAAGATACCCTAGGTATCATGCTATGGACTCCGTTGGGGTCAAGGAACC
TCAGTCACCGTCTCCTCA3' (SEQ ID NO. 1773)

EVKLIVESGGGLVQPGGSLSLSCAASGFTFTDYSMNWVRQPPGKALEWLGFI RNKANDYTTEYSASVKGRFTISRDNQSILYLQMN
ALRAEDSATYYCVRVPRYHAMDSWGQTSVTVSS (SEQ ID NO. 1775)

V_L-233

5' GATATTGTGCTAACTCAGTCTCCAGCCACCCCTGTCTGTGACTCCAGGAGATAGCGTCAATCTTTCTGCGAGGGCCAGCCAAAGT
ATTAGCAACAACCTACACGTTGGTATCAACAAAAATCACATGAGTCTCCAAGGCTTCTCATCAAGTATGTTTTCCAGTCCATCTCTGG
GATCCCTCCAGGTTCAAGTGGCAGTGGATCAGGGACAGATTTCACTCTCAGTATCAACAGTGTGGAGACTGAAGATTTTGAATGT
ATTTCTGTCAACAGAGTAACAGCTGGCCGCTCACGTTTCGGTGCTGGGACCAAGCTGGAGCTGAAA3' (SEQ ID NO. 1774)

DIVLTQSPATLSVTPGDSVNLSCRASQSISNNLHWYQQKSHESPRLLIKYVFQSISSGIPSRFSGSGSGTDFTLSINSVETEDFGMY
FCQQNSWPLTFGAGTKLELK (SEQ ID NO. 1776)

(57) **Abstract:** The present invention relates to methods of reengineering or reshaping antibodies to reduce the immunogenicity of the antibodies, while maintaining the immunospecificity of the antibodies for an antigen. In particular, the present invention provides methods of producing antibodies immunospecific for an antigen by synthesizing a combinatorial library comprising complementarity determining regions (CDRs) from a donor antibody fused in frame to framework regions from a sub-bank of framework regions. The present invention also provides antibodies produced by the methods of the invention.

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HUMANIZATION OF ANTIBODIES

FIELD OF THE INVENTION

5 The present invention relates to methods of reengineering or reshaping antibodies to reduce the immunogenicity of the antibodies, while maintaining the immunospecificity of the antibodies for an antigen. In particular, the present invention provides methods of producing antibodies immunospecific for an antigen by synthesizing a combinatorial library comprising complementarity determining regions (CDRs) from a
10 donor antibody fused in frame to framework regions from a sub-bank of framework regions. The present invention also provides antibodies produced by the methods of the invention.

1. BACKGROUND OF THE INVENTION

Antibodies play a vital role in our immune responses. They can inactivate viruses and bacterial toxins, and are essential in recruiting the complement system and
15 various types of white blood cells to kill invading microorganisms and large parasites. Antibodies are synthesized exclusively by B lymphocytes, and are produced in millions of forms, each with a different amino acid sequence and a different binding site for an antigen. Antibodies, collectively called immunoglobulins (Ig), are among the most abundant protein components in the blood. Alberts *et al.*, Molecular Biology of the Cell, 2nd ed., 1989,
20 Garland Publishing, Inc.

A typical antibody is a Y-shaped molecule with two identical heavy (H) chains (each containing about 440 amino acids) and two identical light (L) chains (each containing about 220 amino acids). The four chains are held together by a combination of noncovalent and covalent (disulfide) bonds. The proteolytic enzymes, such as papain and
25 pepsin, can split an antibody molecule into different characteristic fragments. Papain produces two separate and identical Fab fragments, each with one antigen-binding site, and one Fc fragment. Pepsin produces one F (ab')₂ fragment. Alberts *et al.*, Molecular Biology of the Cell, 2nd ed., 1989, Garland Publishing, Inc.

Both L and H chains have a variable sequence at their amino-terminal ends
30 but a constant sequence at their carboxyl-terminal ends. The L chains have a constant region about 110 amino acids long and a variable region of the same size. The H chains

also have a variable region about 110 amino acids long, but the constant region of the H chains is about 330 or 440 amino acid long, depending on the class of the H chain. Alberts *et al.*, Molecular Biology of the Cell, 2nd ed., 1989, Garland Publishing, Inc. at pp1019.

Only part of the variable region participates directly in the binding of antigen. Studies have shown that the variability in the variable regions of both L and H chains is for the most part restricted to three small hypervariable regions (also called complementarity-determining regions, or CDRs) in each chain. The remaining parts of the variable region, known as framework regions (FR), are relatively constant. Alberts *et al.*, Molecular Biology of the Cell, 2nd ed., 1989, Garland Publishing, Inc. at pp 1019 - 1020.

Natural immunoglobulins have been used in assays, diagnosis and, to a more limited extent, therapy. However, such uses, especially in therapy, have been hindered by the polyclonal nature of natural immunoglobulins. The advent of monoclonal antibodies of defined specificity increased the opportunities for therapeutic use. However, most monoclonal antibodies are produced following immunization of a rodent host animal with the target protein, and subsequent fusion of a rodent spleen cell producing the antibody of interest with a rodent myeloma cell. They are, therefore, essentially rodent proteins and as such are naturally immunogenic in humans, frequently giving rise to an undesirable immune response termed the HAMA (Human Anti-Mouse Antibody) response.

Many groups have devised techniques to decrease the immunogenicity of therapeutic antibodies. Traditionally, a human template is selected by the degree of homology to the donor antibody, *i.e.*, the most homologous human antibody to the non-human antibody in the variable region is used as the template for humanization. The rationale is that the framework sequences serve to hold the CDRs in their correct spatial orientation for interaction with an antigen, and that framework residues can sometimes even participate in antigen binding. Thus, if the selected human framework sequences are most similar to the sequences of the donor frameworks, it will maximize the likelihood that affinity will be retained in the humanized antibody. Winter (EP No. 0239400), for instance, proposed generating a humanized antibody by site-directed mutagenesis using long oligonucleotides in order to graft three complementarity determining regions (CDR1, CDR2 and CDR3) from each of the heavy and light chain variable regions. Although this approach has been shown to work, it limits the possibility of selecting the best human template supporting the donor CDRs.

Although a humanized antibody is less immunogenic than its natural or chimeric counterpart in a human, many groups find that a CDR grafted humanized antibody

may demonstrate a significantly decreased binding affinity (*e.g.*, Riechmann *et al.*, 1988, Nature 332:323-327). For instance, Reichmann and colleagues found that transfer of the CDR regions alone was not sufficient to provide satisfactory antigen binding activity in the CDR-grafted product, and that it was also necessary to convert a serine residue at position
5 27 of the human sequence to the corresponding rat phenylalanine residue. These results indicated that changes to residues of the human sequence outside the CDR regions may be necessary to obtain effective antigen binding activity. Even so, the binding affinity was still significantly less than that of the original monoclonal antibody.

For example, Queen *et al* (U.S. Patent No. 5,530,101) described the
10 preparation of a humanized antibody that binds to the interleukin-2 receptor, by combining the CDRs of a murine monoclonal (anti-Tac MAb) with human immunoglobulin framework and constant regions. The human framework regions were chosen to maximize homology with the anti-Tac MAb sequence. In addition, computer modeling was used to identify framework amino acid residues which were likely to interact with the CDRs or antigen, and
15 mouse amino acids were used at these positions in the humanized antibody. The humanized anti-Tac antibody obtained was reported to have an affinity for the interleukin-2 receptor (p55) of $3 \times 10^9 \text{ M}^{-1}$, which was still only about one-third of that of the murine MAb.

Other groups identified further positions within the framework of the variable regions (*i.e.*, outside the CDRs and structural loops of the variable regions) at which the
20 amino acid identities of the residues may contribute to obtaining CDR-grafted products with satisfactory binding affinity. See, *e.g.*, U.S. Patent Nos. 6,054,297 and 5,929,212. Still, it is impossible to know beforehand how effective a particular CDR grafting arrangement will be for any given antibody of interest.

Leung (U.S. Patent Application Publication No. US 2003/0040606) describes
25 a framework patching approach, in which the variable region of the immunoglobulin is compartmentalized into FR1, CDR1, FR2, CDR2, FR3, CDR3 and FR4, and the individual FR sequence is selected by the best homology between the non-human antibody and the human antibody template. This approach, however, is labor intensive, and the optimal framework regions may not be easily identified.

30 As more therapeutic antibodies are being developed and are holding more promising results, it is important to be able to reduce or eliminate the body's immune response elicited by the administered antibody. Thus, new approaches allowing efficient and rapid engineering of antibodies to be human-like, and/or allowing a reduction in labor to humanize an antibody provide great benefits and medical value.

Citation or discussion of a reference herein shall not be construed as an admission that such is prior art to the present invention.

2. SUMMARY OF THE INVENTION

The invention is based, in part, on the synthesis of framework region sub-banks for the variable heavy chain framework regions and the variable light chain framework regions of antibodies and on the synthesis of combinatorial libraries of antibodies comprising a variable heavy chain region and/or a variable light chain region with the variable chain region(s) produced by fusing together in frame complementarity determining regions (CDRs) derived from a donor antibody and framework regions derived from framework region sub-banks. The synthesis of framework region sub-banks allows for the fast, less labor intensive production of combinatorial libraries of antibodies (with or without constant regions) which can be readily screened for their immunospecificity for an antigen of interest, as well as their immunogenicity in an organism of interest. The library approach described in the invention allows for efficient selection and identification of acceptor frameworks (*e.g.*, human frameworks). In addition to the synthesis of framework region sub-banks, sub-banks of CDRs can be generated and randomly fused in frame with framework regions from framework region sub-banks to produce combinatorial libraries of antibodies (with or without constant regions) that can be screened for their immunospecificity for an antigen of interest, as well as their immunogenicity in an organism of interest. The combinatorial library methodology of the invention is exemplified herein for the production of humanized antibodies for use in human beings. However, the combinatorial library methodology of the invention can readily be applied to the production of antibodies for use in any organism of interest.

The present invention provides for a framework region sub-bank for each framework region of the variable light chain and variable heavy chain. Accordingly, the invention provides a framework region sub-bank for variable light chain framework region 1, variable light chain framework region 2, variable light chain framework region 3, and variable light chain framework region 4 for each species of interest and for each definition of a CDR (*e.g.*, Kabat and Chothia). The invention also provides a framework region sub-bank for variable heavy chain framework region 1, variable heavy chain framework region 2, variable heavy chain framework region 3, and variable heavy chain framework region 4 for each species of interest and for each definition of a CDR (*e.g.*, Kabat and Chothia). The framework region sub-banks may comprise framework regions from germline framework sequences and/or framework regions from functional antibody sequences. The framework

region sub-banks may comprise framework regions from germline framework sequences and/or framework regions from functional antibody sequences into which one or more mutations have been introduced. The framework region sub-banks can be readily used to synthesize a combinatorial library of antibodies which can be screened for their immunospecificity for an antigen of interest, as well as their immunogenicity in an organism of interest.

The present invention provides for a CDR sub-bank for each CDR of the variable light chain and variable heavy chain. Accordingly, the invention provides a CDR region sub-bank for variable light chain CDR1, variable light chain CDR2, and variable light CDR3 for each species of interest and for each definition of a CDR (*e.g.*, Kabat and Chothia). The invention also provides a CDR sub-bank for variable heavy chain CDR1, variable heavy CDR2, and variable heavy chain CDR3 for each species of interest and for each definition of a CDR (*e.g.*, Kabat and Chothia). The CDR sub-banks may comprise CDRs that have been identified as part of an antibody that immunospecifically to an antigen of interest. The CDR sub-banks can be readily used to synthesize a combinatorial library of antibodies which can be screened for their immunospecificity for an antigen of interest, as well as their immunogenicity in an organism of interest.

The present invention provides a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region and/or a nucleotide sequence encoding a light chain variable region with the variable region(s) produced by fusing together CDRs 1-3 derived from a donor antibody in frame with framework regions 1-4 from framework region sub-banks. In some embodiments, one or more of the CDRs derived from the donor antibody heavy and/or light chain variable region(s) contain(s) one or more mutations relative to the nucleic acid sequence encoding the corresponding CDR in the donor antibody. The present invention also provides a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region and/or a nucleotide sequence encoding a light chain variable region with the variable region(s) produced by fusing together CDRs 1-3 derived from CDR sub-banks (preferably, sub-banks of CDRs that immunospecifically bind to an antigen of interest) in frame with framework regions 1-4 from framework region sub-banks.

In one embodiment, the present invention provides a nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said first nucleotide sequence encoding the heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy

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chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). In accordance with this embodiment, the nucleic acid sequence may further comprise a second nucleotide sequence encoding a donor light chain variable region (preferably, a non-human donor light chain variable region). Alternatively, in accordance with this embodiment, the nucleic acid sequence may further comprise a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said second nucleotide sequence encoding the light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, sub-bank of human light chain framework regions).

25 In another embodiment, the present invention provides a nucleic acid sequence comprising a first nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said first nucleotide sequence encoding the light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank

of light chain framework regions (preferably, a sub-bank of human light chain framework regions). In accordance with this embodiment, the nucleic acid sequence may further comprise a second nucleotide sequence encoding a donor heavy chain variable region (preferably, a non-human donor heavy chain variable region).

5 In another embodiment, the present invention provides a nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said first nucleotide acid sequence encoding the heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a
10 heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies
15 (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). In accordance with this embodiment, the nucleic acid may further comprise a second nucleotide sequence encoding a donor light chain variable region (preferably, a non-human donor light chain variable region). Alternatively, in accordance
20 with this embodiment, the nucleic acid sequence may further comprise a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said second nucleotide sequence encoding the light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence
25 encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) or at
30 least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human antibodies) and at least one light chain framework region is from a sub-bank of human light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a nucleic acid sequence comprising a first nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said first nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions). In accordance with this embodiment, the nucleic acid sequence may further comprise a second nucleotide sequence encoding a donor heavy chain variable region (preferably, a non-human heavy chain variable region). Alternatively, in accordance with this embodiment, the nucleic acid sequence may further comprise a second nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said second nucleotide sequence encoding the heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions).

The present invention also provides cells comprising, containing or engineered to express the nucleic acid sequences described herein. In one embodiment, the present invention provides a cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid

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sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). In accordance with this embodiment, the cell may further comprise a second nucleic acid sequence comprising a second nucleotide sequence encoding a light chain variable region (preferably, a humanized or human light chain variable region).

In another embodiment, the present invention provides a cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region) synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions). In accordance with this embodiment, the cell may further comprise a second nucleic acid sequence comprising a second nucleotide sequence encoding a heavy chain variable region (preferably, a human or humanized heavy chain variable region).

In another embodiment, the present invention provides a cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) and a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a heavy chain

variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs of the heavy chain variable region are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), the CDRs of the light chain variable region are derived from a donor light chain variable region (preferably, a non-human donor light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions), and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). In accordance with this embodiment, the cell may further comprise a second nucleic acid sequence comprising a second nucleotide

sequence encoding a light chain variable region (preferably, a humanized or human light chain variable region).

5 In another embodiment, the present invention provides a cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions). In accordance with this embodiment, the cell may further comprise a second nucleic acid sequence comprising a second nucleotide sequence encoding a heavy chain variable region (preferably, a humanized or human heavy chain variable region).

20 In another embodiment, the present invention provides a cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) and a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence

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encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions), and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) and a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions), and at least one light chain framework region is

from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) and a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), the light chain variable region CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions), and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a cell containing nucleic acid sequences encoding an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said cell produced by the process comprising: (a) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said first nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework

region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); and (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework region (preferably, a sub-bank of human light chain framework region).

The present invention provides a cell containing nucleic acid sequences encoding an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said cell produced by the process comprising: (a) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a heavy chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); and (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a light chain

variable region (preferably, a humanized light chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework region (preferably, a sub-bank of human light chain framework region).

The present invention provides a cell containing nucleic acid sequences encoding an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said cell produced by the process comprising: (a) introducing into a cell a nucleic acid sequence comprising a nucleotide acid sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); and (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain

framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a cell containing nucleic acid sequences encoding an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said cell produced by the process comprising: (a) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); and (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a method of producing a heavy chain variable region (preferably, a humanized heavy chain variable region), said method comprising expressing the nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) in a cell described herein. The present invention provides a method of producing a light chain variable region (preferably, a humanized light chain variable region), said method comprising expressing the nucleotide sequence

encoding a light chain variable region (preferably, a humanized light chain variable region) in a cell described herein. The present invention also provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising expressing the nucleic acid sequence(s) encoding the humanized antibody contained in the cell described herein.

In one embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of heavy chain framework regions; (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a variable light chain variable region (preferably, a humanized or human variable light chain variable region); and (d) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the humanized or human light chain variable region). In accordance with this embodiment, the method may further comprise a step (e) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of heavy chain framework regions; (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy

chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is
5 from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a variable light chain variable region
10 (preferably, a humanized or human variable light chain variable region); and (d) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the humanized or human light chain variable region). In accordance with this embodiment, the method may further comprise a step (e) comprising screening for an antibody (preferably, a
15 humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence
20 encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework
25 region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions);
30 (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a variable heavy chain variable region (preferably, a humanized or human variable heavy chain variable region); and (d) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the
35 humanized or human light chain variable region). In accordance with this embodiment, the

method may further comprise a step (e) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions); (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a variable heavy chain variable region (preferably, a humanized or human variable heavy chain variable region); and (d) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the humanized or human light chain variable region). In accordance with this embodiment, the method may further comprise a step (e) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid

sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions); (e) introducing the nucleic acid sequences into a cell; and (f) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the humanized light chain variable region (preferably, the humanized light chain variable region). In accordance with this embodiment, the method may further comprise a step (g) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human antibodies) and at least one

heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably a humanized light chain variable region), said nucleotide sequence
5 produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain
10 framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions; (e) introducing the nucleic acid sequences into a cell; and (f) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the humanized light chain variable region). In accordance with this embodiment, the method may further comprise a step (g) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to
20 an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human
25 donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said nucleotide sequence produced by fusing together a nucleic acid
30 sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a
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light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR
5 is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions); (e) introducing the nucleic acid sequences into a cell; and (f) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized
10 heavy chain variable region) and the light chain variable region (preferably, the humanized light chain variable region). In accordance with this embodiment, the method may further comprise a step (g) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of
15 producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said nucleotide sequence
20 produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy
25 chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions); (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable
30 region (preferably, a humanized light chain variable region), said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid
35 sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain

framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions); (e) introducing the
5 nucleic acid sequences into a cell; and (f) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the humanized light chain variable region). In accordance with this embodiment, the method may further comprise a step (g) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds
10 to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a
15 nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding
20 heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light
25 chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived
30 from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), the light chain variable region CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions)
35 and at least one light chain framework region is from a sub-bank of light chain framework

regions (preferably, a sub-bank of human light chain framework regions); (d) introducing the nucleic acid sequence into a cell; and (e) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the light chain variable region (preferably, the humanized light chain variable region). In accordance with this embodiment, the method may further comprise a step (f) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

The present invention provides a method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions; (d) introducing the nucleic acid sequence into a cell; and (e) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region. In accordance with this embodiment, the method may further comprise a step (f) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

The present invention provides a method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions; (d) introducing the nucleic acid sequence into a cell; and (e) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region. In accordance with this embodiment, the method may further comprise a step (f) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

In another embodiment, the present invention provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising: (a) generating sub-banks of light chain framework regions; (b) generating sub-banks of heavy chain framework regions; (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region), said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid

sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a light chain variable region (preferably, a humanized light chain variable region), said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions); (d) introducing the nucleic acid sequence into a cell; and (e) expressing the nucleotide sequences encoding the heavy chain variable region (preferably, the humanized heavy chain variable region) and the humanized light chain variable region (preferably, the humanized light chain variable region). In accordance with this embodiment, the method may further comprise a step (f) comprising screening for an antibody (preferably, a humanized antibody) that immunospecifically binds to the antigen.

The present invention provides antibodies produced by the methods described herein. In a preferred embodiment, the invention provides humanized antibodies produced by the methods described herein. The present invention also provides a composition comprising an antibody produced by the methods described herein and a carrier, diluent or excipient. In a preferred embodiment, the invention provides a composition comprising a humanized antibody produced by the methods described herein and a carrier, diluent or excipient. Preferably, the compositions of the invention are pharmaceutical compositions in a form for its intended use.

The present invention provides a plurality of nucleic acid sequences comprising nucleotide sequences encoding heavy chain variable regions (preferably,

humanized heavy chain variable regions), said nucleotide sequences encoding the heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-humanized donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). The present invention also provides a plurality of nucleic acid sequences comprising nucleotide sequences encoding heavy chain variable regions (preferably, humanized heavy chain variable regions), said nucleotide sequences encoding the heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions).

The present invention provides a plurality of nucleic acid sequences comprising nucleotide sequences encoding light chain variable regions (preferably, humanized light chain variable regions), said nucleotide sequences encoding the light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions). The present

invention also provides a plurality of nucleic acid sequences comprising nucleotide sequences encoding light chain variable regions (preferably, humanized light chain variable regions), said nucleotide sequences encoding the light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions (preferably, humanized heavy chain variable regions), said first set of nucleotide sequences encoding the heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide encoding light chain variable regions (preferably, humanized light chain variable regions), said second set of nucleotide sequences encoding the light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), the light chain variable region CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions)

and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions (preferably, humanized heavy chain variable regions), said first set of nucleotide sequences encoding the heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide encoding light chain variable regions (preferably, humanized light chain variable regions), said second set of nucleotide sequences encoding the light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), the light chain variable region CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions (preferably, humanized heavy chain variable regions), said first set of nucleotide sequences encoding the heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3,

and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide encoding light chain variable regions (preferably, humanized light chain variable regions), said second set of nucleotide sequences encoding the light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain

5 framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived
10 from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at
15 least one light chain framework region is from a sub-bank of light chain framework regions (preferably, human light chain framework regions).

The present invention provides a plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions (preferably, humanized heavy chain variable regions), said first set of nucleotide sequences
20 encoding the heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3,
25 and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide encoding light chain variable regions (preferably, humanized light chain variable regions), said second set of nucleotide sequences encoding the light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid
30 sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-
35 human antibodies), at least one light chain variable region CDR is from a sub-bank of light

chain CDRs derived from donor antibodies (preferably, non-human antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions)and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

The present invention provides a population of cells comprising the nucleic acid sequences described herein. In one embodiment, the present invention provides a population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of heavy chain variable regions (preferably, humanized heavy chain variable regions), said cells produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). In accordance with this embodiment, the cells may further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized or human light chain variable region).

In another embodiment, the present invention provides a population of cells comprising nucleic acid sequences comprising nucleotide acid sequences encoding a plurality of heavy chain variable regions (preferably, humanized heavy chain variable regions), said cells produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain

CDRs derived from donor antibodies (preferably, non-human donor antibodies) and at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions). In accordance with this embodiment, the cells may further comprise a nucleic acid sequence comprising a
5 nucleotide sequence encoding a light chain variable region (preferably, a humanized or human light chain variable region).

In another embodiment, the present invention provides a population of cells comprising nucleic sequences comprising nucleotide sequences encoding a plurality of light chain variable regions (preferably, humanized light chain variable regions), said cells
10 produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid
15 sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-
20 bank of human light chain framework regions). In accordance with this embodiment, the cells may further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized or human light chain variable region).

In another embodiment, the present invention provides a population of cells
25 comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of light chain variable regions (preferably, humanized light chain variable regions), said cells produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain
30 framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor

antibodies (preferably, non-human donor antibodies) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions). In accordance with this embodiment, the cells may further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region (preferably, a humanized or human light chain variable region).

In another embodiment, the present invention provides a population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of heavy chain variable regions (preferably, humanized heavy chain variable regions) and a plurality of light chain variable regions (preferably, humanized light chain variable regions), said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), the light chain variable region CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of heavy chain variable regions (preferably, humanized heavy chain variable regions) and a

plurality of light chain variable regions (preferably, humanized light chain variable regions), said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), the light chain variable region CDRs are derived from a donor antibody light chain variable region (preferably, a non-human donor antibody light chain variable region), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of heavy chain variable regions (preferably, humanized heavy chain variable regions) and a plurality of light chain variable regions (preferably, humanized light chain variable regions), said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding

light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region (preferably, a non-human donor antibody heavy chain variable region), at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

In another embodiment, the present invention provides a population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of heavy chain variable regions (preferably, humanized heavy chain variable regions) and a plurality of light chain variable regions (preferably, humanized light chain variable regions), said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies (preferably, non-human donor antibodies), at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies (preferably,

non-human donor antibodies), at least one heavy chain framework region is from a sub-bank of heavy chain framework regions (preferably, a sub-bank of human heavy chain framework regions) and at least one light chain framework region is from a sub-bank of light chain framework regions (preferably, a sub-bank of human light chain framework regions).

5 The present invention provides a method of identifying an antibody that immunospecifically binds to an antigen, said method comprising expressing the nucleic acid sequences in the cells as described herein and screening for an antibody that has an affinity of at least $1 \times 10^6 \text{ M}^{-1}$, at least $1 \times 10^7 \text{ M}^{-1}$, at least $1 \times 10^8 \text{ M}^{-1}$, at least $1 \times 10^9 \text{ M}^{-1}$, at least $1 \times 10^{10} \text{ M}^{-1}$ or above for said antigen. In a preferred embodiment, the invention provides a
10 method of identifying a humanized antibody that immunospecifically to an antigen, said method comprising expressing the nucleic acid sequences in the cells as described herein and screening for a humanized antibody that has an affinity of at least $1 \times 10^6 \text{ M}^{-1}$, at least $1 \times 10^7 \text{ M}^{-1}$, at least $1 \times 10^8 \text{ M}^{-1}$, at least $1 \times 10^9 \text{ M}^{-1}$, at least $1 \times 10^{10} \text{ M}^{-1}$ or above for said antigen. The present invention provides an antibody identified by the methods described
15 herein. In a preferred embodiment, the invention provides a humanized antibody identified by the methods described herein.

 In accordance with the present invention, the antibodies generated as described herein (*e.g.*, a humanized antibody) comprise a light chain variable region and/or a heavy chain variable region. In some embodiments, the antibodies generated as described
20 herein further comprise a constant region(s).

 The present invention provides antibodies (preferably, humanized antibodies) generated in accordance with the invention conjugated or fused to a moiety (*e.g.*, a therapeutic agent or drug). The present invention also provides compositions, preferably pharmaceutical compositions, comprising an antibody generated and/or identified in
25 accordance with the present invention and a carrier, diluent or excipient. In certain preferred embodiments, the present invention provides compositions, preferably pharmaceutical compositions, comprising a humanized antibody as described herein and a carrier, diluent or excipient. The present invention also provides compositions, preferably pharmaceutical compositions, comprising an antibody generated and/or identified in
30 accordance with the present invention conjugated or fused to a moiety (*e.g.*, a therapeutic agent or drug), and a carrier, diluent or excipient. In certain preferred embodiments, the present invention provides compositions comprising a humanized antibody (or fragment thereof) conjugated or fused to a moiety (*e.g.*, a therapeutic agent or drug), and a carrier, diluent or excipient. The present invention further provides uses of an antibody generated

and/or identified in accordance with the present invention (*e.g.*, a humanized antibody) alone or in combination with other therapies to prevent, treat, manage or ameliorate a disorder or a symptom thereof.

5 The pharmaceutical compositions of the invention may be used for the prevention, management, treatment or amelioration of a disease or one or more symptoms thereof. Preferably, the pharmaceutical compositions of the invention are sterile and in suitable form for a particular method of administration to a subject with a disease.

10 The invention further provides methods of detecting, diagnosing and/or monitoring the progression of a disorder utilizing one or more antibodies (preferably, one or more humanized antibodies) generated and/or identified in accordance with the methods of the invention.

The invention provides kits comprising sub-banks of antibody framework regions of a species of interest. The invention also provides kits comprising sub-banks of CDRs of a species of interest. The invention also provides kits comprising combinatorial sub-libraries of nucleic acids, wherein the nucleic acids comprise nucleotide sequences that contain one framework region (*e.g.*, FR1) fused in frame to one corresponding CDR (*e.g.*, CDR1). The invention further provides kits comprising combinatorial libraries of nucleic acids, wherein the nucleic acids comprise nucleotide sequences that contain the framework regions and CDRs of the variable heavy chain region or variable light chain region fused in frame (*e.g.*, FR1+CDR1+FR2+CDR2+FR3+CDR3+FR4).

In some preferred embodiments, the invention provides kits comprising sub-banks of human immunoglobulin framework regions, sub-banks of CDRs, combinatorial sub-libraries, and/or combinatorial libraries. In one embodiment, the invention provides a kit comprising a framework region sub-bank for variable light chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Kabat system. In another embodiment, the invention provides a kit comprising a framework region sub-bank for variable light chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Chothia system. In another embodiment, the invention provides a kit comprising a framework region sub-bank for variable heavy chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Kabat system. In another embodiment, the invention provides a kit comprising a framework region sub-bank for variable heavy chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Chothia system. In yet another embodiment, the invention

provides a kit comprising sub-banks of both the variable light chain and the variable heavy chain framework regions.

The invention also provides a pharmaceutical pack or kit comprising one or more containers filled with a humanized antibody of the invention. The pharmaceutical
 5 pack or kit may further comprises one or more other prophylactic or therapeutic agents useful for the prevention, treatment, management or amelioration of a particular disease or a symptom thereof. The invention also provides a pharmaceutical pack or kit comprising one or more containers filled with one or more of the ingredients of the pharmaceutical compositions of the invention. Optionally associated with such container(s) can be a notice
 10 in the form prescribed by a governmental agency regulating the manufacture, use or sale of pharmaceuticals or biological products, which notice reflects approval by the agency of manufacture, use or sale for human administration.

The present invention also provides articles of manufacture.

2.1 Terminology

15 As used herein, the terms “acceptor” and “acceptor antibody” refer to the antibody or nucleic acid sequence providing or encoding at least 80%, at least 85%, at least 90%, or at least 95% amino acid sequences of one or more of the framework regions. In some embodiments, the term “acceptor” refers to the antibody or nucleic acid sequence providing or encoding the constant region(s). In a specific embodiment, the term “acceptor”
 20 refers to a human antibody or nucleic acid sequence that provides or encodes at least 80%, preferably, at least 85%, at least 90%, or at least 95% amino acid sequences of one or more of the framework regions. An acceptor framework region and/or acceptor constant region(s) may be, *e.g.*, derived or obtained from a germline antibody gene, a mature antibody gene, a functional antibody (*e.g.*, antibodies well-known in the art, antibodies in development, or
 25 antibodies commercially available).

As used herein, the terms “antibody” and “antibodies” refer to monoclonal antibodies, multispecific antibodies, human antibodies, humanized antibodies, camelised antibodies, chimeric antibodies, single-chain Fvs (scFv), single chain antibodies, single domain antibodies, Fab fragments, F(ab) fragments, disulfide-linked Fvs (sdFv), anti-
 30 idiotypic (anti-Id) antibodies, and epitope-binding fragments of any of the above. In particular, antibodies include immunoglobulin molecules and immunologically active fragments of immunoglobulin molecules, *i.e.*, molecules that contain an antigen binding site. Immunoglobulin molecules can be of any type (*e.g.*, IgG, IgE, IgM, IgD, IgA and IgY), class (*e.g.*, IgG₁, IgG₂, IgG₃, IgG₄, IgA₁ and IgA₂) or subclass.

A typical antibody contains two heavy chains paired with two light chains. A full-length heavy chain is about 50 kD in size (approximately 446 amino acids in length), and is encoded by a heavy chain variable region gene (about 116 amino acids) and a constant region gene. There are different constant region genes encoding heavy chain constant region of different isotypes such as alpha, gamma (IgG1, IgG2, IgG3, IgG4), delta, epsilon, and mu sequences. A full-length light chain is about 25 Kd in size (approximately 214 amino acids in length), and is encoded by a light chain variable region gene (about 110 amino acids) and a kappa or lambda constant region gene. The variable regions of the light and/or heavy chain are responsible for binding to an antigen, and the constant regions are responsible for the effector functions typical of an antibody.

As used herein, the term "CDR" refers to the complement determining region within antibody variable sequences. There are three CDRs in each of the variable regions of the heavy chain and the light chain, which are designated CDR1, CDR2 and CDR3, for each of the variable regions. The exact boundaries of these CDRs have been defined differently according to different systems. The system described by Kabat (Kabat *et al.*, Sequences of Proteins of Immunological Interest (National Institutes of Health, Bethesda, MD (1987) and (1991)) not only provides an unambiguous residue numbering system applicable to any variable region of an antibody, but also provides precise residue boundaries defining the three CDRs. These CDRs may be referred to as Kabat CDRs. Chothia and coworkers (Chothia & Lesk, J. Mol. Biol. 196:901-917 (1987) and Chothia *et al.*, Nature 342:877-883 (1989)) found that certain sub-portions within Kabat CDRs adopt nearly identical peptide backbone conformations, despite having great diversity at the level of amino acid sequence. These sub-portions were designated as L1, L2 and L3 or H1, H2 and H3 where the "L" and the "H" designates the light chain and the heavy chains regions, respectively. These regions may be referred to as Chothia CDRs, which have boundaries that overlap with Kabat CDRs. Other boundaries defining CDRs overlapping with the Kabat CDRs have been described by Padlan (FASEB J. 9:133-139 (1995)) and MacCallum (J Mol Biol 262(5):732-45 (1996)). Still other CDR boundary definitions may not strictly follow one of the above systems, but will nonetheless overlap with the Kabat CDRs, although they may be shortened or lengthened in light of prediction or experimental findings that particular residues or groups of residues or even entire CDRs do not significantly impact antigen binding. The methods used herein may utilize CDRs defined according to any of these systems, although preferred embodiments use Kabat or Chothia defined CDRs.

As used herein, the term "derivative" in the context of proteinaceous agent (*e.g.*, proteins, polypeptides, and peptides, such as antibodies) refers to a proteinaceous agent that comprises an amino acid sequence which has been altered by the introduction of amino acid residue substitutions, deletions, and/or additions. The term "derivative" as used
5 herein also refers to a proteinaceous agent which has been modified, *i.e.*, by the covalent attachment of any type of molecule to the proteinaceous agent. For example, but not by way of limitation, an antibody may be modified, *e.g.*, by glycosylation, acetylation, pegylation, phosphorylation, amidation, derivatization by known protecting/blocking groups, proteolytic cleavage, linkage to a cellular ligand or other protein, etc. A derivative of a proteinaceous
10 agent may be produced by chemical modifications using techniques known to those of skill in the art, including, but not limited to specific chemical cleavage, acetylation, formylation, metabolic synthesis of tunicamycin, etc. Further, a derivative of a proteinaceous agent may contain one or more non-classical amino acids. A derivative of a proteinaceous agent possesses a similar or identical function as the proteinaceous agent from which it was
15 derived.

As used herein, the terms "disorder" and "disease" are used interchangeably for a condition in a subject.

As used herein, the term "donor antibody" refers to an antibody providing one or more CDRs. In a preferred embodiment, the donor antibody is an antibody from a
20 species different from the antibody from which the framework regions are derived. In the context of a humanized antibody, the term "donor antibody" refers to a non-human antibody providing one or more CDRs.

As used herein, the term "effective amount" refers to the amount of a therapy which is sufficient to reduce or ameliorate the severity and/or duration of a disorder or one
25 or more symptoms thereof, prevent the advancement of a disorder, cause regression of a disorder, prevent the recurrence, development, onset or progression of one or more symptoms associated with a disorder, detect a disorder, or enhance or improve the prophylactic or therapeutic effect(s) of another therapy (*e.g.*, prophylactic or therapeutic agent).

30 As used herein, the term "epitopes" refers to fragments of a polypeptide or protein having antigenic or immunogenic activity in an animal, preferably in a mammal, and most preferably in a human. An epitope having immunogenic activity is a fragment of a polypeptide or protein that elicits an antibody response in an animal. An epitope having antigenic activity is a fragment of a polypeptide or protein to which an antibody

immunospecifically binds as determined by any method well-known to one of skill in the art, for example by immunoassays. Antigenic epitopes need not necessarily be immunogenic.

As used herein, the term "fusion protein" refers to a polypeptide or protein (including, but not limited to an antibody) that comprises an amino acid sequence of a first protein or polypeptide or functional fragment, analog or derivative thereof, and an amino acid sequence of a heterologous protein, polypeptide, or peptide (*i.e.*, a second protein or polypeptide or fragment, analog or derivative thereof different than the first protein or fragment, analog or derivative thereof). In one embodiment, a fusion protein comprises a prophylactic or therapeutic agent fused to a heterologous protein, polypeptide or peptide. In accordance with this embodiment, the heterologous protein, polypeptide or peptide may or may not be a different type of prophylactic or therapeutic agent. For example, two different proteins, polypeptides or peptides with immunomodulatory activity may be fused together to form a fusion protein. In a preferred embodiment, fusion proteins retain or have improved activity relative to the activity of the original protein, polypeptide or peptide prior to being fused to a heterologous protein, polypeptide, or peptide.

As used herein, the term "fragment" refers to a peptide or polypeptide (including, but not limited to an antibody) comprising an amino acid sequence of at least 5 contiguous amino acid residues, at least 10 contiguous amino acid residues, at least 15 contiguous amino acid residues, at least 20 contiguous amino acid residues, at least 25 contiguous amino acid residues, at least 40 contiguous amino acid residues, at least 50 contiguous amino acid residues, at least 60 contiguous amino residues, at least 70 contiguous amino acid residues, at least contiguous 80 amino acid residues, at least contiguous 90 amino acid residues, at least contiguous 100 amino acid residues, at least contiguous 125 amino acid residues, at least 150 contiguous amino acid residues, at least contiguous 175 amino acid residues, at least contiguous 200 amino acid residues, or at least contiguous 250 amino acid residues of the amino acid sequence of another polypeptide or protein. In a specific embodiment, a fragment of a protein or polypeptide retains at least one function of the protein or polypeptide.

As used herein, the term "functional fragment" refers to a peptide or polypeptide (including, but not limited to an antibody) comprising an amino acid sequence of at least 5 contiguous amino acid residues, at least 10 contiguous amino acid residues, at least 15 contiguous amino acid residues, at least 20 contiguous amino acid residues, at least 25 contiguous amino acid residues, at least 40 contiguous amino acid residues, at least 50

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contiguous amino acid residues, at least 60 contiguous amino residues, at least 70
contiguous amino acid residues, at least contiguous 80 amino acid residues, at least
contiguous 90 amino acid residues, at least contiguous 100 amino acid residues, at least
contiguous 125 amino acid residues, at least 150 contiguous amino acid residues, at least
5 contiguous 175 amino acid residues, at least contiguous 200 amino acid residues, or at least
contiguous 250 amino acid residues of the amino acid sequence of second, different
polypeptide or protein, wherein said polypeptide or protein retains at least one function of
the second, different polypeptide or protein. In a specific embodiment, a fragment of a
polypeptide or protein retains at least two, three, four, or five functions of the protein or
10 polypeptide. Preferably, a fragment of an antibody that immunospecifically binds to a
particular antigen retains the ability to immunospecifically bind to the antigen.

As used herein, the term "framework" or "framework sequence" refers to the
remaining sequences of a variable region minus the CDRs. Because the exact definition of a
CDR sequence can be determined by different systems, the meaning of a framework
15 sequence is subject to correspondingly different interpretations. The six CDRs (CDR1, 2,
and 3 of light chain and CDR1, 2, and 3 of heavy chain) also divide the framework regions
on the light chain and the heavy chain into four sub-regions (FR1, FR2, FR3 and FR4) on
each chain, in which CDR1 is positioned between FR1 and FR2, CDR2 between FR2 and
FR3, and CDR3 between FR3 and FR4. Without specifying the particular sub-regions as
20 FR1, FR2, FR3 or FR4, a framework region, as referred by others, represents the combined
FR's within the variable region of a single, naturally occurring immunoglobulin chain. As
used herein, a FR represents one of the four sub-regions, and FRs represents two or more of
the four sub-regions constituting a framework region. As an example, Table 1-4 list the
germline sequences of FR1, 2, 3, and 4 of kappa light chain, respectively. Table 5-7 list the
25 germline sequences of FR1, 2, and 3 of heavy chain according to the Kabat definition,
respectively. Table 8-10 list the germline sequences of FR 1, 2 and 3 of heavy chain
according to the Chothia definition, respectively. Table 11 lists the germline sequence of
FR4 of the heavy chain.

Tables 1-65

30 The SEQ ID Number for each sequence described in tables 1-65 is indicated
in the first column of each table.

Table 1. FR1 of Light Chains

1 GATGTTGTGATGACTCAGTCTCCACTCTCCCTGCCCGTCACCCTTGGACAGCCGGCCTCCATCTCCTGC
2 GATGTTGTGATGACTCAGTCTCCACTCTCCCTGCCCGTCACCCTTGGACAGCCGGCCTCCATCTCCTGC

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3 GATATTGTGATGACCCAGACTCCACTCTCTCTGTCCGTCACCCCTGGACAGCCGGCCTCCATCTCCTGC
 4 GATATTGTGATGACTCAGTCTCCACTCTCCCTGCCCCGTCACCCCTGGAGAGCCGGCCTCCATCTCCTGC
 5 GATATTGTGATGACCCAGACTCCACTCTCTCTGTCCGTCACCCCTGGACAGCCGGCCTCCATCTCCTGC
 6 GATATTGTGATGACCCAGACTCCACTCTCCTCACCTGTCACCCCTGGACAGCCGGCCTCCATCTCCTGC
 5 7 GATATTGTGATGACTCAGTCTCCACTCTCCCTGCCCCGTCACCCCTGGAGAGCCGGCCTCCATCTCCTGC
 8 GAGATTGTGATGACCCAGACTCCACTCTCCTTGTCTATCACCCCTGGAGAGCAGGCCTCCATCTCCTGC
 9 GATATTGTGATGACCCAGACTCCACTCTCCTCGCCTGTCACCCCTGGACAGCCGGCCTCCATCTCCTTC
 10 GAAATTGTGCTGACTCAGTCTCCAGACTTTCAGTCTGTGACTCCAAAGGAGAAAGTCACCATCACCTGC
 11 GATGTTGTGATGACACAGTCTCCAGCTTTCCTCTCTGTGACTCCAGGGGAGAAAGTCACCATCACCTGC
 10 12 GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 13 GAAATTGTGCTGACTCAGTCTCCAGACTTTCAGTCTGTGACTCCAAAGGAGAAAGTCACCATCACCTGC
 14 GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 15 GAAACGACACTCACGCAGTCTCCAGCATTTCATGTCAGCGACTCCAGGAGACAAAGTCAACATCTCCTGC
 16 GACATCCAGATGACCCAGTCTCCATCCTCACTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGT
 15 17 GCCATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 18 GACATCCAGATGACCCAGTCTCCTTCCACCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 19 AACATCCAGATGACCCAGTCTCCATCTGCCATGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGT
 20 GACATCCAGATGACCCAGTCTCCATCCTCACTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGT
 21 GAAATAGTGATGATGCAGTCTCCAGCCACCCTGTCTGTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 20 22 GCCATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 23 GACATCCAGATGACCCAGTCTCCATCTTCTGTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGT
 24 GAAATAGTGATGACGCAGTCTCCAGCCACCCTGTCTGTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 25 GAAATTGTGTTGACACAGTCTCCAGCCACCCTGTCTTTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 26 GACATCCAGATGATCCAGTCTCCATCTTTCCTGTCTGCATCTGTAGGAGACAGAGTCAGTATCATTTGC
 25 27 GCCATCCGGATGACCCAGTCTCCATTCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 28 GTCATCTGGATGACCCAGTCTCCATCCTTACTCTCTGCATCTACAGGAGACAGAGTCACCATCAGTTGT
 29 GCCATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 30 GACATCCAGATGACCCAGTCTCCATCTTCCGTTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGT
 31 GAAATTGTGTTGACACAGTCTCCAGCCACCCTGTCTTTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 30 32 GACATCCAGTTGACCCAGTCTCCATCCTTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 33 GCCATCCGGATGACCCAGTCTCCATCCTCATTCTCTGCATCTACAGGAGACAGAGTCACCATCACTTGT
 34 GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 35 GACATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 36 GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 35 37 GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 38 GACATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 39 GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGC
 40 GAAATTGTAATGACACAGTCTCCACCCACCCTGTCTTTGTCTCCAGGGGAAAGAGTCACCCCTCTCCTGC
 41 GAAATTGTAATGACACAGTCTCCAGCCACCCTGTCTTTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 40 42 GAAATTGTGTTGACGCAGTCTCCAGCCACCCTGTCTTTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 43 GAAATTGTGTTGACGCAGTCTCCAGGCACCCTGTCTTTGTCTCCAGGGGAAAGAGCCACCCTCTCCTGC
 44 GACATCGTGATGACCCAGTCTCCAGACTCCCTGGCTGTGTCTCTGGGCGAGAGGGCCACCATCAACTGC
 45 GATATTGTGATGACCCAGACTCCACTCTCCCTGCCCCGTCACCCCTGGAGAGCCGGCCTCCATCTCCTGC
 46 GATATTGTGATGACCCAGACTCCACTCTCCCTGCCCCGTCACCCCTGGAGAGCCGGCCTCCATCTCCTGC

Table 2. FR2 of Light Chains

	47	TGGTTTCAGCAGAGGCCAGGCCAATCTCCAAGGCGCCTAATTTAT
	48	TGGTTTCAGCAGAGGCCAGGCCAATCTCCAAGGCGCCTAATTTAT
5	49	TGGTACCTGCAGAAGCCAGGCCAGTCTCCACAGCTCCTGATCTAT
	50	TGGTACCTGCAGAAGCCAGGGCAGTCTCCACAGCTCCTGATCTAT
	51	TGGTACCTGCAGAAGCCAGGCCAGCCTCCACAGCTCCTGATCTAT
	52	TGGCTTCAGCAGAGGCCAGGCCAGCCTCCAAGACTCCTAATTTAT
	53	TGGTACCTGCAGAAGCCAGGGCAGTCTCCACAGCTCCTGATCTAT
10	54	TGGTTTCTGCAGAAAGCCAGGCCAGTCTCCACACTCCTGATCTAT
	55	TGGCTTCAGCAGAGGCCAGGCCAGCCTCCAAGACTCCTAATTTAT
	56	TGGTACCAGCAGAAACCAGATCAGTCTCCAAAGCTCCTCATCAAG
	57	TGGTACCAGCAGAAACCAGATCAAGCCCCAAAGCTCCTCATCAAG
	58	TGGTATCAGCAGAAACCAGGGAAAGTTCCTAAGCTCCTGATCTAT
15	59	TGGTACCAGCAGAAACCAGATCAGTCTCCAAAGCTCCTCATCAAG
	60	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCGCCTGATCTAT
	61	TGGTACCAACAGAAACCAGGAGAAGCTGCTATTTTCATTATTCAA
	62	TGGTTTCAGCAGAAACCAGGGAAAGCCCCTAAGTCCCTGATCTAT
	63	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
20	64	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
	65	TGGTTTCAGCAGAAACCAGGGAAAGTCCCTAAGCACCTGATCTAT
	66	TGGTATCAGCAGAAACCAGAGAAAGCCCCTAAGTCCCTGATCTAT
	67	TGGTACCAGCAGAAACCTGGCCAGGCTCCCAGGCTCCTCATCTAT
	68	TGGTATCAGCAGAAACCAGGGAAAGCTCCTAAGCTCCTGATCTAT
25	69	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
	70	TGGTACCAGCAGAAACCTGGCCAGGCTCCCAGGCTCCTCATCTAT
	71	TGGTACCAGCAGAAACCTGGCCAGGCTCCCAGGCTCCTCATCTAT
	72	TGGTATCTGCAGAAACCAGGGAAATCCCCTAAGCTCTTCCTCTAT
	73	TGGTATCAGCAAAAACCAGCAAAAGCCCCTAAGCTCTTCATCTAT
30	74	TGGTATCAGCAAAAACCAGGGAAAGCCCCTGAGCTCCTGATCTAT
	75	TGGTATCAGCAGAAACCAGGGAAAGCTCCTAAGCTCCTGATCTAT
	76	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
	77	TGGTACCAACAGAAACCTGGCCAGGCTCCCAGGCTCCTCATCTAT
	78	TGGTATCAGCAAAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
35	79	TGGTATCAGCAAAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
	80	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
	81	TGGTATCGGCAGAAACCAGGGAAAGTTCCTAAGCTCCTGATCTAT
	82	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAC
	83	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAT
40	84	TGGTATCGGCAGAAACCAGGGAAAGTTCCTAAGCTCCTGATCTAT
	85	TGGTATCAGCAGAAACCAGGGAAAGCCCCTAAGCTCCTGATCTAC
	86	TGGTATCAGCAGAAACCTGGCCAGGCGCCAGGCTCCTCATCTAT
	87	TGGTACCAGCAGAAACCTGGGCAGGCTCCCAGGCTCCTCATCTAT

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88 TGGTACCAGCAGAAACCTGGCCTGGCGCCCAGGCTCCTCATCTAT
 89 TGGTACCAGCAGAAACCTGGCCAGGCTCCCAGGCTCCTCATCTAT
 90 TGGTACCAGCAGAAACCAGGACAGCCTCCTAAGCTGCTCATTAC
 91 TGGTACCTGCAGAAGCCAGGGCAGTCTCCACAGCTCCTGATCTAT
 5 92 TGGTACCTGCAGAAGCCAGGGCAGTCTCCACAGCTCCTGATCTAT

Table 3. FR3 of Light Chains

10	93 GGGGTCCCAGACAGATTCAGCGGCAGTGGGTCAGGCACTGATTTACACTGAAAATCAGCAGGGTGGAGGC TGAGGATGTTGGGGTTTATTACTGC
	94 GGGGTCCCAGACAGATTCAGCGGCAGTGGGTCAGGCACTGATTTACACTGAAAATCAGCAGGGTGGAGGC TGAGGATGTTGGGGTTTATTACTGC
15	95 GGAGTGCCAGATAGGTTTCAGTGGCAGCGGGTCAGGGACAGATTTACACTGAAAATCAGCCGGGTGGAGGC TGAGGATGTTGGGGTTTATTACTGA
	96 GGGGTCCCTGACAGGTTTCAGTGGCAGTGGATCAGGCACAGATTTTACACTGAAAATCAGCAGAGTGGAGGC TGAGGATGTTGGGGTTTATTACTGC
20	97 GGAGTGCCAGATAGGTTTCAGTGGCAGCGGGTCAGGGACAGATTTACACTGAAAATCAGCCGGGTGGAGGC TGAGGATGTTGGGGTTTATTACTGC
	98 GGGGTCCCAGACAGATTCAGTGGCAGTGGGGCAGGGACAGATTTACACTGAAAATCAGCAGGGTGGGAAGC
25	TGAGGATGTCGGGGTTTATTACTGC
	99 GGGGTCCCTGACAGGTTTCAGTGGCAGTGGATCAGGCACAGATTTTACACTGAAAATCAGCAGAGTGGAGGC TGAGGATGTTGGGGTTTATTACTGC
30	100 GGAGTGCCAGATAGGTTTCAGTGGCAGCGGGTCAGGGACAGATTTACACTGAAAATCAGCCGGGTGGAGGC TGAGGATTTTGGAGTTTATTACTGC
	101 GGGGTCCCAGACAGATTCAGTGGCAGTGGGGCAGGGACAGATTTACACTGAAAATCAGCAGGGTGGGAAGC TGAGGATGTCGGGGTTTATTACTGC
35	102 GGGGTCCCCTCGAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTACCCCTCACCATCAATAGCCTGGAAGCT GAAGATGCTGCAACGTATTACTGT
	103 GGGGTCCCCTCGAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTACCTTTACCATCAGTAGCCTGGAAGCT GAAGATGCTGCAACATATTACTGT
40	104 GGGGTCCCATCTCGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT GAAGATGTTGCAACTTATTACTGT
	105 GGGGTCCCCTCGAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTACCCCTCACCATCAATAGCCTGGAAGCT GAAGATGCTGCAACGTATTACTGT
45	106 GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAATTCCTCTCACAATCAGCAGCCTGCAGCCT GAAGATTTTGCAACTTATTACTGT
	107 GGAATCCCACCTCGATTCAGTGGCAGCGGGTATGGAACAGATTTTACCCTCACAATTAATAACATAGAATCT GAGGATGCTGCATATTACTTCTGT
50	108 GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT GAAGATTTTGCAACTTATTACTGC
55	

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109
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGCACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGT

5 110
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAATTCCTCTCACCATCAGCAGCCTGCAGCCT
GATGATTTTGCAACTTATTACTGC

111
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAATTCCTCTCACAATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGT

10 112
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGC

113
GGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGAGTTCACTCTCACCATCAGCAGCCTGCAGTCT
15 GAAGATTTTGCACTTTATTACTGT

114
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGT

115
20 GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACTATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTACTATTGT

116
GGTATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGAGTTCACTCTCACCATCAGCAGCCTGCAGTCT
GAAGATTTTGCACTTTATTACTGT

25 117
GGCATCCCAGCCAGGTTTCAGTGGCAGTGGGCCTGGGACAGACTTCACTCTCACCATCAGCAGCCTAGAGCCT
GAAGATTTTGCACTTTATTACTGT

118
GGGGTCTCATCGAGGTTTCAGTGGCAGGGGATCTGGGACGGATTTCACTCTCACCATCATCAGCCTGAAGCCT
30 GAAGATTTTGCACTTATTACTGT

119
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACGGATTACCTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGT

120
35 GGGGTCCCATCAAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGTTGCCTGCAGTCT
GAAGATTTTGCAACTTATTACTGT

121
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGT

40 122
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTACTATTGT

123
GGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAGCAGCCTAGAGCCT
45 GAAGATTTTGCACTTTATTACTGT

124
GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAATTCCTCTCACAATCAGCAGCCTGCAGCCT
GAAGATTTTGCAACTTATTACTGT

125
50 GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCTGCCTGCAGTCT
GAAGATTTTGCAACTTATTACTGT

126
GGGGTCCCATCAAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAGCAGTCTGCAACCT
GAAGATTTTGCAACTTACTACTGT

55 127
GGAGTCCCATCTCGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACTATCAGCAGCCTGCAGCCT
GAAGATGTTGCAACTTATTACGGT

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128
GGGGTCCCATCAAGGTTTCAGTGGGAAGTGGATCTGGGACAGATTTTACTTTCACCATCAGCAGCCTGCAGCCT
GAAGATATTGCAACATATTACTGT

129
5 GGGGTCCCATCAAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTTACTCTCACCATCAGCAGTCTGCAACCT
GAAGATTTTGCAACTTACTACTGT

130
GGAGTCCCATCTCGGTTTCAGTGGCAGTGGATCTGGGACAGATTTTACTCTCACTATCAGCAGCCTGCAGCCT
GAAGATGTTGCAACTTATTACGGT

10 131
GGGGTCCCATCAAGGTTTCAGTGGGAAGTGGATCTGGGACAGATTTTACTTTCACCATCAGCAGCCTGCAGCCT
GAAGATATTGCAACATATTACTGT

132
15 AGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAAGTTTATTACTGT

133
GGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAGCAGCCTGCAGCCT
GAAGATTTTGCAAGTTTATTACTGT

134
20 GGCATCCCAGACAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAGCAGACTGGAGCCT
GAAGATTTTGCAAGTGTATTACTGT

135
GGCATCCCAGACAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAGCAGACTGGAGCCT
GAAGATTTTGCAAGTGTATTACTGT

25 136
GGGGTCCCTGACCGATTTCAGTGGCAGCGGGTCTGGGACAGATTTTCACTCTCACCATCAGCAGCCTGCAGGCT
GAAGATGTGGCAGTTTATTACTGT

137
30 GGAGTCCCAGACAGGTTTCAGTGGCAGTGGGTTCAGGCACTGATTTTCACTGAAAATCAGCAGGGTGGAGGC
TGAGGATGTTGGAGTTTATTACTGC

138
GGAGTCCCAGACAGGTTTCAGTGGCAGTGGGTTCAGGCACTGATTTTCACTGAAAATCAGCAGGGTGGAGGC
TGAGGATGTTGGAGTTTATTACTGC

35 Table 4. FR4 of Light Chains

139 TTCGGCCAAGGGACCAAGGTGGAAATCAAA
140 TTTGGCCAGGGGACCAAGCTGGAGATCAAA
141 TTCGGCCCTGGGACCAAGTGGATATCAAA
142 TTCGGCGGAGGGACCAAGGTGGAGATCAAA
40 143 TTCGGCCAAGGGACACGACTGGAGATTAAA

Table 5. FR1 of Heavy Chains (Kabat definition)

144
45 CAGGTTTCAGCTGGTGCAGTCTGGAGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGCT
TCTGGTTACACCTTTACC

145
CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGC
TTCTGGATACACCTTACC

146
50 CAGGTCCAGCTGGTACAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGTT
TCCGGATACACCCTCACT

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147
CAGGTTGAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTTTCCTGCAAGGCT
TCTGGATACACCTTCACT

5 148
CAGATGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGACTGGGTCCTCAGTGAAGGTTTCCTGCAAGGCT
TCCGGATACACCTTCACC

149
CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTTTCCTGCAAGGC
ATCTGGATACACCTTCACC

10 150
CAAATGCAGCTGGTGCAGTCTGGGCCTGAGGTGAAGAAGCCTGGGACCTCAGTGAAGGTCTCCTGCAAGGCT
TCTGGATTACCTTTACT

151
CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGTCCTCGGTGAAGGTCTCCTGCAAGGCT

15 TCTGGAGGCACCTTCAGC

152
CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGC
TTCTGGATACACCTTCACC

153
CAGGTCACCTTGAAGGAGTCTGGTCCTGTGCTGGTGA AACCACAGAGACCCTCACGCTGACCTGCACCGTC
TCTGGGTTCTCACTCAGC

20 154
CAGATCACCTTGAAGGAGTCTGGTCCTACGCTGGTGA AACCACACAGACCCTCACGCTGACCTGCACCTTC
TCTGGGTTCTCACTCAGC

25 155
CAGGTCACCTTGAGGGAGTCTGGTCCTGCGCTGGTGA AACCACACAGACCCTCACACTGACCTGCACCTTC
TCTGGGTTCTCACTCAGC

156
CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCAAGCCTGGAGGGTCCCTGAGACTCTCCTGTGCAGCC

30 TCTGGATTACCTTCAGT

157
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTACCTTCAGT

158
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTAAAGCCTGGGGGGTCCCTTAGACTCTCCTGTGCAGCC

35 TCTGGATTCACTTTCAGT

159
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTACCTTCAGT

40 160
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGTGTGGTACGGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTACCTTTGAT

161
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCCTGGTCAAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC

45 TCTGGATTACCTTCAGT

162
GAGGTGCAGCTGTTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTACCTTTAGC

163
CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCCCTGAGACTCTCCTGTGCAGCC

50 TCTGGATTACCTTCAGT

164
CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCCCTGAGACTCTCCTGTGCAGCG
TCTGGATTACCTTCAGT

55 165
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGATCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTACCTTCAGT

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166
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTAGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCGTCAGT

5 167
GAAGTGCAGCTGGTGGAGTCTGGGGGAGTCGTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCTTTGAT

168
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCTTCAGT

10 169
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCAGGGCGGTCCCTGAGACTCTCCTGTACAGCT
TCTGGATTCACCTTTGGT

170
GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
15 TCTGGGTTACCGTCAGT

171
GAGGTGCAGCTGGTGGAGTCTGGGGAAGGCTTGGTCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCTTCAGT

172
GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
20 TCTGGGTTACCGTCAGT

173
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCTTTAGT

25 174
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGAGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCTTCAGT

175
GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTGGTCCAGCCTGGGGGGTCCCTGAAACTCTCCTGTGCAGCC
30 TCTGGGTTACCTTCAGT

176
GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTAGTTCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCTGGATTCACCTTCAGT

177
GAAGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGCAGGTCCCTGAGACTCTCCTGTGCAGCC
35 TCTGGATTCACCTTTGAT

178
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGACACCCTGTCCCTCACCTGCGCTGTC
TCTGGTTACTCCATCAGC

40 179
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCACAGACCCTGTCCCTCACCTGTACTGTC
TCTGGTGGCTCCATCAGC

180
CAGGTGCAGCTACAGCAGTGGGGCGCAGGACTGTTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCGCTGTC
45 TATGGTGGGTCCTTCAGT

181
CAGCTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
TCTGGTGGCTCCATCAGC

182
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
50 TCTGGTGGCTCCATCAGT

183
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
TCTGGTGGCTCCATCAGT

55 184
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
TCTGGTGGCTCCGTCAGC

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185

GAGGTGCAGCTGGTGCAGTCTGGAGCAGAGGTGAAAAAGCCCGGGGAGTCTCTGAAGATCTCCTGTAAGGG
TTCTGGATACAGCTTTACC

186

5 CAGGTACAGCTGCAGCAGTCAGGTCCAGGACTGGTGAAGCCCTCGCAGACCCTCTCACTCACCTGTGCCATC
TCCGGGGACAGTGTCTCT

187

CAGGTGCAGCTGGTGCAGTCTGGCCATGAGGTGAAGCAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGCT
TCTGGTTACAGTTTCACC

10

Table 6. FR2 of Heavy Chains (Kabat definition)

188 TGGGTGCGACAGGCCCCTGGACAAGGGCTTGAGTGGATGGGA

189 TGGGTGCGACAGGCCCCTGGACAAGGGCTTGAGTGGATGGGA

190 TGGGTGCGACAGGCTCCTGGAAAAGGGCTTGAGTGGATGGGA

15 191 TGGGTGCGCCAGGCCCCCGGACAAAGGCTTGAGTGGATGGGA

192 TGGGTGCGACAGGCCCCCGGACAAGCGCTTGAGTGGATGGGA

193 TGGGTGCGACAGGCCCCTGGACAAGGGCTTGAGTGGATGGGA

194 TGGGTGCGACAGGCTCGTGGACAACGCCTTGAGTGGATAGGA

195 TGGGTGCGACAGGCCCCTGGACAAGGGCTTGAGTGGATGGGA

20 196 TGGGTGCGACAGGCCACTGGACAAGGGCTTGAGTGGATGGGA

197 TGGATCCGTCAGCCCCCAGGGAAGGCCCTGGAGTGGCTTGCA

198 TGGATCCGTCAGCCCCCAGGAAAGGCCCTGGAGTGGCTTGCA

199 TGGATCCGTCAGCCCCCAGGGAAGGCCCTGGAGTGGCTTGCA

200 TGGATCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTTTCA

25 201 TGGGTCCGCCAAGCTACAGGAAAAGGTCTGGAGTGGGTCTCA

202 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTTGGC

203 TGGGCCCCGCAAGGCTCCAGGAAAGGGGCTGGAGTGGGTATCG

204 TGGGTCCGCCAAGCTCCAGGGAAGGGGCTGGAGTGGGTCTCT

205 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCA

30 206 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCA

207 TGGGTCCGCCAGGCTCCAGGCAAGGGGCTGGAGTGGGTGGCA

208 TGGGTCCGCCAGGCTCCAGGCAAGGGGCTGGAGTGGGTGGCA

209 TGGGTCCATCAGGCTCCAGGAAAGGGGCTGGAGTGGGTATCG

210 TGGATCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCA

35 211 TGGGTCCGTCAAGCTCCGGGGAAGGGTCTGGAGTGGGTCTCT

212 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTTTCA

213 TGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTAGGT

214 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCA

215 TGGGTCCGCCAGGCTCCAGGGAAGGGACTGGAATATGTTTCA

40 216 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCA

217 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTGGCC

218 TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTGGC

219 TGGGTCCGCCAGGCTTCCGGGAAAGGGCTGGAGTGGGTGGC

220 TGGGTCCGCCAAGCTCCAGGGAAGGGGCTGGTGTGGGTCTCA

45 221 TGGGTCCGGCAAGCTCCAGGGAAGGGCCTGGAGTGGGTCTCA

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222 TGGATCCGGCAGCCCCCAGGGAAGGGACTGGAGTGGATTGGG
 223 TGGATCCGCCAGCACCCAGGGAAGGGCCTGGAGTGGATTGGG
 224 TGGATCCGCCAGCCCCCAGGGAAGGGGCTGGAGTGGATTGGG
 225 TGGATCCGCCAGCCCCCAGGGAAGGGGCTGGAGTGGATTGGG
 5 226 TGGATCCGGCAGCCCGCCGGGAAGGGACTGGAGTGGATTGGG
 227 TGGATCCGGCAGCCCCCAGGGAAGGGACTGGAGTGGATTGGG
 228 TGGATCCGGCAGCCCCCAGGGAAGGGACTGGAGTGGATTGGG
 229 TGGGTGCGCCAGATGCCCGGGAAAGGCCTGGAGTGGATGGGG
 230 TGGATCAGGCAGTCCCCATCGAGAGGCCTTGAGTGGCTGGGA
 10 231 TGGGTGCCACAGGCCCCCTGGACAAGGGCTTGAGTGGATGGGA

Table 7. FR3 of Heavy Chains (Kabat definition)

232
 15 AGAGTCACCATGACCACAGACACATCCACGAGCACAGCCTACATGGAGCTGAGGAGCCTGAGATCTGACGA
 CACGGCCGTGTATTACTGTGCGAGA
 233
 AGGGTCACCATGACCAGGGACACGTCCATCAGCACAGCCTACATGGAGCTGAGCAGGCTGAGATCTGACGA
 CACGGCCGTGTATTACTGTGCGAGA
 234
 20 AGAGTCACCATGACCGAGGACACATCTACAGACACAGCCTACATGGAGCTGAGCAGCCTGAGATCTGAGGA
 CACGGCCGTGTATTACTGTGCAACA
 235
 AGAGTCACCATTACCAGGGACACATCCGCGAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTGAGGA
 CATGGCTGTGTATTACTGTGCGAGA
 25 236
 AGAGTCACCATTACCAGGGACAGGTCTATGAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTGAGGA
 CACAGCCATGTATTACTGTGCAAGA
 237
 30 AGAGTCACCATGACCAGGGACACGTCCACGAGCACAGTCTACATGGAGCTGAGCAGCCTGAGATCTGAGGA
 CACGGCCGTGTATTACTGTGCGAGA
 238
 AGAGTCACCATTACCAGGGACATGTCCACAAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCCGAGGA
 CACGGCCGTGTATTACTGTGCGGCA
 239
 35 AGAGTCACGATTACCGCGGACAAATCCACGAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTGAGGA
 CACGGCCGTGTATTACTGTGCGAGA
 240
 AGAGTCACCATGACCAGGAACACCTCCATAAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTGAGGA
 CACGGCCGTGTATTACTGTGCGAGA
 40 241
 AGGCTCACCATCTCCAAGGACACCTCCAAAAGCCAGGTGGTCCTTACCATGACCAACATGGACCCTGTGGAC
 ACAGCCACATATTACTGTGCACGG
 242
 45 AGGCTCACCATCACCAAGGACACCTCCAAAAACCAGGTGGTCCTTACAATGACCAACATGGACCCTGTGGAC
 ACAGCCACATATTACTGTGCACAC
 243
 AGGCTCACCATCTCCAAGGACACCTCCAAAAACCAGGTGGTCCTTACAATGACCAACATGGACCCTGTGGAC
 ACAGCCACGTATTATTGTGCACGG
 244
 50 CGATTACCATCTCCAGGGACAACGCCAAGAACTCACTGTATCTGCAAATGAACAGCCTGAGAGCCGAGGA
 CACGGCCGTGTATTACTGTGCGAGA

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245
CGATTCACCATCTCCAGAGAAAATGCCAAGAACTCCTTGTATCTTCAAATGAACAGCCTGAGAGCCGGGGAC
ACGGCTGTGTATTACTGTGCAAGA

5 246
AGATTCACCATCTCAAGAGATGATTCAAAAAACACGCTGTATCTGCAAATGAACAGCCTGAAAACCGAGGA
CACAGCCGTGTATTACTGTACCACA

247
CGATTCATCATCTCCAGAGACAATTCCAGGAACTCCCTGTATCTGCAAAGAACAGACGGAGAGCCGAGGA
CATGGCTGTGTATTACTGTGTGAGA

10 248
CGATTCACCATCTCCAGAGACAACGCCAAGAACTCCCTGTATCTGCAAATGAACAGTCTGAGAGCCGAGGAC
ACGGCCTTGTATCACTGTGCGAGA

249
CGATTCACCATCTCCAGAGACAACGCCAAGAACTCACTGTATCTGCAAATGAACAGCCTGAGAGCCGAGGA
15 CACGGCTGTGTATTACTGTGCGAGA

250
CGGTTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGCAAATGAACAGCCTGAGAGCCGAGGA
CACGGCCGTATATTACTGTGCGAAA

251
CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGCAAATGAACAGCCTGAGAGCTGAGGAC
20 ACGGCTGTGTATTACTGTGCGAGA

252
CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGCAAATGAACAGCCTGAGAGCCGAGGA
CACGGCTGTGTATTACTGTGCGAGA

25 253
CGATTCATCATCTCCAGAGACAATTCCAGGAACACCCTGTATCTGCAAACGAATAGCCTGAGGGCCGAGGAC
ACGGCTGTGTATTACTGTGTGAGA

254
AGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGAACAACCTGAGAGCTGAGGGC
30 ACGGCCGTGTATTACTGTGCCAGA

255
CGATTCACCATCTCCAGAGACAACAGCAAAAACCTCCCTGTATCTGCAAATGAACAGTCTGAGAACTGAGGAC
ACCGCCTTGTATTACTGTGCAAAA

256
CGATTCACCATCTCCAGAGACAATGCCAAGAACTCACTGTATCTGCAAATGAACAGCCTGAGAGACGAGGA
35 CACGGCTGTGTATTACTGTGCGAGA

257
AGATTCACCATCTCAAGAGATGATTCCAAAAGCATCGCCTATCTGCAAATGAACAGCCTGAAAACCGAGGA
CACAGCCGTGTATTACTGTACTAGA

40 258
CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGAACAGCCTGAGAGCCGAGGAC
ACGGCCGTGTATTACTGTGCGAGA

259
AGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGGGCAGCCTGAGAGCTGAGGAC
45 ATGGCTGTGTATTACTGTGCGAGA

260
CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGAACAGCCTGAGAGCTGAGGAC
ACGGCTGTGTATTACTGTGCGAGA

261
CGATTCACCATCTCCAGAGACAACGCCAAGAACTCACTGTATCTGCAAATGAACAGCCTGAGAGCCGAGGA
50 CACGGCTGTGTATTACTGTGCGAGA

262
AGATTCACCATCTCAAGAGATGATTCAAAGAACCTCACTGTATCTGCAAATGAACAGCCTGAAAACCGAGGAC
ACGGCCGTGTATTACTGTGCTAGA

55 263
AGGTTACCATCTCCAGAGATGATTCAAAGAACACGGCGTATCTGCAAATGAACAGCCTGAAAACCGAGGA
CACGGCCGTGTATTACTGTACTAGA

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264
CGATTCACCATCTCCAGAGACAACGCCAAGAACACGCTGTATCTGCAAATGAACAGTCTGAGAGCCGAGGA
CACGGCTGTGTATTACTGTGCAAGA

265
5 CGATTCACCATCTCCAGAGACAACGCCAAGAAGTCCCTGTATCTGCAAATGAACAGTCTGAGAGCTGAGGAC
ACGGCCTTGTATTACTGTGCAAAA

266
CGAGTCACCATGTCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCGTGGAC
ACGGCCGTGTATTACTGTGCGAGA

10 267
CGAGTTACCATATCAGTAGACACGTCTAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACTGCCGCGGAC
ACGGCCGTGTATTACTGTGCGAGA

268
15 CGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCGCGGAC
ACGGCTGTGTATTACTGTGCGAGA

269
CGAGTCACCATATCCGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCGCGAGAC
ACGGCTGTGTATTACTGTGCGAGA

270
20 CGAGTCACCATGTCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCGCGGAC
ACGGCCGTGTATTACTGTGCGAGA

271
CGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCTGCGGAC
ACGGCCGTGTATTACTGTGCGAGA

25 272
CGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCTGCGGAC
ACGGCCGTGTATTACTGTGCGAGA

273
30 CAGGTCACCATCTCAGCCGACAAGTCCATCAGCACCGCCTACCTGCAGTGGAGCAGCCTGAAGGCCTCGGAC
ACCGCCATGTATTACTGTGCGAGA

274
CGAATAACCATCAACCCAGACACATCCAAGAACCAGTTCTCCCTGCAGCTGAACTCTGTGACTCCCGAGGAC
ACGGCTGTGTATTACTGTGCAAGA

275
35 CGGTTTGTCTTCTCCATGGACACCTCTGCCAGCACAGCATACCTGCAGATCAGCAGCCTAAAGGCTGAGGAC
ATGGCCATGTATTACTGTGCGAGA

Table 8. FR1 of Heavy Chains (Chothia definition)

276
40 CAGGTTTCAGCTGGTGCAGTCTGGAGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGCT
TCT

277
CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGC
TTCT

45 278
CAGGTCCAGCTGGTACAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGTT
TCC

279
50 CAGGTTTCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTTTCCTGCAAGGCT
TCT

280
CAGATGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGACTGGGTCCTCAGTGAAGGTTTCCTGCAAGGCT
TCC

281
55 CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTTTCCTGCAAGGC
ATCT

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282
CAAATGCAGCTGGTGCAGTCTGGGCCTGAGGTGAAGAAGCCTGGGACCTCAGTGAAGGTCTCCTGCAAGGCT
TCT

283
5 CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGTCCTCGGTGAAGGTCTCCTGCAAGGCT
TCT

284
CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGC
TTCT

10 285
CAGGTCACCTTGAAGGAGTCTGGTCCTGTGCTGGTGAAACCCACAGAGACCCTCACGCTGACCTGCACCGTC
TCT

286
15 CAGATCACCTTGAAGGAGTCTGGTCCTACGCTGGTGAAACCCACACAGACCCTCACGCTGACCTGCACCTTC
TCT

287
CAGGTCACCTTGAGGGAGTCTGGTCCTGCGCTGGTGAAACCCACACAGACCCTCACACTGACCTGCACCTTC
TCT

288
20 CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCAAGCCTGGAGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

289
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

25 290
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTAAAGCCTGGGGGGTCCCTTAGACTCTCCTGTGCAGCC
TCT

291
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
30 TCT

292
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGTGTGGTACGGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

293
35 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCCTGGTCAAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

294
GAGGTGCAGCTGTTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

40 295
CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

296
45 CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCCCTGAGACTCTCCTGTGCAGCG
TCT

297
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGATCCCTGAGACTCTCCTGTGCAGCC
TCT

298
50 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTAGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

299
GAAGTGCAGCTGGTGGAGTCTGGGGGAGTCGTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

55 300
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

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301
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCAGGGCGGTCCCTGAGACTCTCCTGTACAGCT
TCT

5 302
GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

303
GAGGTGCAGCTGGTGGAGTCTGGGGAAGGCTTGGTCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

10 304
GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

305
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
15 TCT

306
GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGAGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

20 307
GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTGGTCCAGCCTGGGGGGTCCCTGAAACTCTCCTGTGCAGCC
TCT

308
GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTAGTTCAGCCTGGGGGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

25 309
GAAGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGCAGGTCCCTGAGACTCTCCTGTGCAGCC
TCT

310
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGACACCCTGTCCCTCACCTGCGCTGTC
30 TCT

311
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCACAGACCCTGTCCCTCACCTGTACTGTC
TCT

35 312
CAGGTGCAGCTACAGCAGTGGGGCGCAGGACTGTTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCGCTGTC
TAT

313
CAGCTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
TCT

40 314
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
TCT

315
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
45 TCT

316
CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACCTGCACTGTC
TCT

50 317
GAGGTGCAGCTGGTGCAGTCTGGAGCAGAGGTGAAAAAGCCCGGGGAGTCTCTGAAGATCTCCTGTAAGGG
TTCT

318
CAGGTACAGCTGCAGCAGTCAGGTCCAGGACTGGTGAAGCCTTCGCAGACCCTCTCACTCACCTGTGCCATC
TCC

55 319
CAGGTGCAGCTGGTGCAGTCTGGCCATGAGGTGAAGCAGCCTGGGGCCTCAGTGAAGGTCTCCTGCAAGGCT
TCT

Table 9. FR2 of Heavy Chains (Chothia definition)

	320 TATGGTATCAGCTGGGTGCGACAGGCCCCCTGGACAAGGGCTTGAGTGGATGGGATGGATC
	321 TACTATATGCACTGGGTGCGACAGGCCCCCTGGACAAGGGCTTGAGTGGATGGGATGGATC
	322 TTATCCATGCACTGGGTGCGACAGGCTCCTGGAAAAGGGCTTGAGTGGATGGGAGGTTTT
5	323 TATGCTATGCATTGGGTGCGCCAGGCCCCCGGACAAAGGCTTGAGTGGATGGGATGGAGC
	324 CGCTACCTGCACTGGGTGCGACAGGCCCCCGGACAAGCGCTTGAGTGGATGGGATGGATC
	325 TACTATATGCACTGGGTGCGACAGGCCCCCTGGACAAGGGCTTGAGTGGATGGGAATAATC
	326 TCTGCTATGCAGTGGGTGCGACAGGCTCGTGGACAACGCCTTGAGTGGATAGGATGGATC
	327 TATGCTATCAGCTGGGTGCGACAGGCCCCCTGGACAAGGGCTTGAGTGGATGGGAGGGATC
10	328 TATGATATCAACTGGGTGCGACAGGCCACTGGACAAGGGCTTGAGTGGATGGGATGGATG
	329 ATGGGTGTGAGCTGGATCCGTCAGCCCCCAGGGAAGGCCCTGGAGTGGCTTGACACATT
	330 GTGGGTGTGGGCTGGATCCGTCAGCCCCCAGGAAAGGCCCTGGAGTGGCTTGCACTCATT
	331 ATGTGTGTGAGCTGGATCCGTCAGCCCCCAGGGAAGGCCCTGGAGTGGCTTGCACTCATT
	332 TACTACATGAGCTGGATCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTTTCATACATT
15	333 TACGACATGCACTGGGTCCGCCAAGCTACAGGAAAAGGTCTGGAGTGGGTCTCAGCTATT
	334 GCCTGGATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTGGCCGTATT
	335 AGTGACATGAACTGGGCCCCGCAAGGCTCCAGGAAAGGGGCTGGAGTGGGTATCGGGTGTT
	336 TATGGCATGAGCTGGGTCCGCCAAGCTCCAGGGAAGGGGCTGGAGTGGGTCTCTGGTATT
	337 TATAGCATGAACTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCATCCATT
20	338 TATGCCATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCAGCTATT
	339 TATGGCATGCACTGGGTCCGCCAGGCTCCAGGCAAGGGGCTGGAGTGGGTGGCAGTTATA
	340 TATGGCATGCACTGGGTCCGCCAGGCTCCAGGCAAGGGGCTGGAGTGGGTGGCAGTTATA
	341 AGTGACATGAACTGGGTCCATCAGGCTCCAGGAAAGGGGCTGGAGTGGGTATCGGGTGTT
	342 AATGAGATGAGCTGGATCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCATCCATT
25	343 TATACCATGCACTGGGTCCGTCAAGCTCCGGGGAAGGGTCTGGAGTGGGTCTCTCTTATT
	344 TATAGCATGAACTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTTTCATACATT
	345 TATGCTATGAGCTGGTTCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTAGGTTTCATT
	346 AACTACATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCAGTTATT
	347 TATGCTATGCACTGGGTCCGCCAGGCTCCAGGGAAGGGACTGGAATATGTTTCAGCTATT
30	348 AACTACATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTCTCAGTTATT
	349 TATTGGATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTGGCCAACATA
	350 CACTACATGGACTGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGGGTGGCCGTACT
	351 TCTGCTATGCACTGGGTCCGCCAGGCTTCCGGGAAAGGGCTGGAGTGGGTGGCCGTATT
	352 TACTGGATGCACTGGGTCCGCCAAGCTCCAGGGAAGGGGCTGGTGTGGGTCTCACGTATT
35	353 TATGCCATGCACTGGGTCCGGCAAGCTCCAGGGAAGGGCCTGGAGTGGGTCTCAGGTATT
	354 AACTGGTGGGGCTGGATCCGGCAGCCCCCAGGGAAGGGACTGGAGTGGATTGGGTACATC
	355 TACTACTGGAGCTGGATCCGCCAGCACCCAGGGAAGGGCCTGGAGTGGATTGGGTACATC
	356 TACTACTGGAGCTGGATCCGCCAGCCCCCAGGGAAGGGGCTGGAGTGGATTGGGGAAATC
	357 TACTACTGGGGCTGGATCCGCCAGCCCCCAGGGAAGGGGCTGGAGTGGATTGGGAGTATC
40	358 TACTACTGGAGCTGGATCCGGCAGCCCCCGGGGAAGGGACTGGAGTGGATTGGGCGTATC
	359 TACTACTGGAGCTGGATCCGGCAGCCCCCAGGGAAGGGACTGGAGTGGATTGGGTATATC
	360 TACTACTGGAGCTGGATCCGGCAGCCCCCAGGGAAGGGACTGGAGTGGATTGGGTATATC
	361 TACTGGATCGGCTGGGTGCGCCAGATGCCCGGGAAAGGCCTGGAGTGGATGGGGATCATC
	362 GCTGCTTGGAAGTGGATCAGGCAGTCCCCATCGAGAGGCCTTGAGTGGCTGGGAAGGACA

363 TATGGTATGAATTGGGTGCCACAGGCCCTGGACAAGGGCTTGAGTGGATGGGATGGTTC

Table 10. FR3 of Heavy Chains (Chothia definition)

5	364	ACAAACTATGCACAGAAGCTCCAGGGCAGAGTCACCATGACCACAGACACATCCACGAGCACAGCCTACAT
		GGAGCTGAGGAGCCTGAGATCTGACGACACGGCCGTGTATTACTGTGCGAGA
10	365	ACAAACTATGCACAGAAGTTTCAGGGCAGGGTCACCATGACCAGGGACACGTCCATCAGCACAGCCTACAT
		GGAGCTGAGCAGGCTGAGATCTGACGACACGGCCGTGTATTACTGTGCGAGA
15	366	ACAATCTACGCACAGAAGTTCCAGGGCAGAGTCACCATGACCGAGGACACATCTACAGACACAGCCTACAT
		GGAGCTGAGCAGCCTGAGATCTGAGGACACGGCCGTGTATTACTGTGCAACA
20	367	ACAAAATATTCACAGGAGTTCCAGGGCAGAGTCACCATTACCAGGGACACATCCGCGAGCACAGCCTACAT
		GGAGCTGAGCAGCCTGAGATCTGAGGACATGGCTGTGTATTACTGTGCGAGA
25	368	ACCAACTACGCACAGAAATTCCAGGACAGAGTCACCATTACCAGGGACAGGTCTATGAGCACAGCCTACAT
		GGAGCTGAGCAGCCTGAGATCTGAGGACACAGCCATGTATTACTGTGCAAGA
30	369	ACAAGCTACGCACAGAAGTTCCAGGGCAGAGTCACCATGACCAGGGACACGTCCACGAGCACAGTCTACAT
		GGAGCTGAGCAGCCTGAGATCTGAGGACACGGCCGTGTATTACTGTGCGAGA
35	370	ACAAACTACGCACAGAAGTTCCAGGAAAGAGTCACCATTACCAGGGACATGTCCACAAGCACAGCCTACAT
		GGAGCTGAGCAGCCTGAGATCCGAGGACACGGCCGTGTATTACTGTGCGGCA
40	371	GCAAACCTACGCACAGAAGTTCCAGGGCAGAGTCACGATTACCGCGGACAAATCCACGAGCACAGCCTACAT
		GGAGCTGAGCAGCCTGAGATCTGAGGACACGGCCGTGTATTACTGTGCGAGA
45	372	ACAGGCTATGCACAGAAGTTCCAGGGCAGAGTCACCATGACCAGGAACACCTCCATAAGCACAGCCTACAT
		GGAGCTGAGCAGCCTGAGATCTGAGGACACGGCCGTGTATTACTGTGCGAGA
50	373	AAATCCTACAGCACATCTCTGAAGAGCAGGCTCACCATCTCCAAGGACACCTCCAAAAGCCAGGTGGTCCTT
		ACCATGACCAACATGGACCCTGTGGACACAGCCACATATTACTGTGCACGG
55	374	AAGCGCTACAGCCCATCTCTGAAGAGCAGGCTCACCATCACCAAGGACACCTCCAAAAACCAGGTGGTCCTT
		ACAATGACCAACATGGACCCTGTGGACACAGCCACATATTACTGTGCACAC
60	375	AAATACTACAGCACATCTCTGAAGACCAGGCTCACCATCTCCAAGGACACCTCCAAAAACCAGGTGGTCCTT
		ACAATGACCAACATGGACCCTGTGGACACAGCCACGTATTATTGTGCACGG
65	376	ATATACTACGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGGGACAACGCCAAGAACTCACTGTATCTG
		CAAATGAACAGCCTGAGAGCCGAGGACACGGCCGTGTATTACTGTGCGAGA
70	377	ACATACTATCCAGGCTCCGTGAAGGGCCGATTACCATCTCCAGAGAAAATGCCAAGAACTCCTTGTATCTT
		CAAATGAACAGCCTGAGAGCCGGGGACACGGCTGTGTATTACTGTGCAAGA
75	378	ACAGACTACGCTGCACCCGTGAAAGGCAGATTACCATCTCAAGAGATGATTCAAAAAACACGCTGTATCTG
		CAAATGAACAGCCTGAAAACCGAGGACACAGCCGTGTATTACTGTACCACA
80	379	ACGCACTATGTGGACTCCGTGAAGCGCCGATTCATCATCTCCAGAGACAATTCCAGGAACTCCCTGTATCTG
		CAAAAGAACAGACGGAGAGCCGAGGACATGGCTGTGTATTACTGTGTGAGA
85	380	ACAGGTTATGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAACTCCCTGTATCTG
		CAAATGAACAGTCTGAGAGCCGAGGACACGGCCTTGTATCACTGTGCGAGA
90	381	ATATACTACGCAGACTCAGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAACTCACTGTATCTG
		CAAATGAACAGCCTGAGAGCCGAGGACACGGCTGTGTATTACTGTGCGAGA

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382
ACATACTACGCAGACTCCGTGAAGGGCCGTTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTG
CAAATGAACAGCCTGAGAGCCGAGGACACGGCCGTATATTACTGTGCGAAA

5 383
AAATACTATGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTG
CAAATGAACAGCCTGAGAGCTGAGGACACGGCTGTGTATTACTGTGCGAGA

384
AAATACTATGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTG
CAAATGAACAGCCTGAGAGCCGAGGACACGGCTGTGTATTACTGTGCGAGA

10 385
ACGCACTATGCAGACTCTGTGAAGGGCCGATTCATCATCTCCAGAGACAATTCCAGGAACACCCTGTATCTG
CAAACGAATAGCCTGAGGGCCGAGGACACGGCTGTGTATTACTGTGTGAGA

386
15 ACATACTACGCAGACTCCAGGAAGGGCAGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTT
CAAATGAACAACCTGAGAGCTGAGGGCACGGCCGTGTATTACTGTGCCAGA

387
ACATACTATGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACAGCAAAAACCTCCCTGTATCTG
CAAATGAACAGTCTGAGAACTGAGGACACCGCCTTGTATTACTGTGCAAAA

388
20 ATATACTACGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAATGCCAAGAACTCACTGTATCTG
CAAATGAACAGCCTGAGAGACGAGGACACGGCTGTGTATTACTGTGCGAGA

389
ACAGAATACGCCGCGTCTGTGAAAGGCAGATTACCATCTCAAGAGATGATTCCAAAAGCATCGCCTATCTG
CAAATGAACAGCCTGAAAACCGAGGACACAGCCGTGTATTACTGTACTAGA

25 390
ACATACTACGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTT
CAAATGAACAGCCTGAGAGCCGAGGACACGGCCGTGTATTACTGTGCGAGA

391
30 ACATATTATGCAGACTCTGTGAAGGGCAGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTT
CAAATGGGCAGCCTGAGAGCTGAGGACATGGCTGTGTATTACTGTGCGAGA

392
ACATACTACGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTT
CAAATGAACAGCCTGAGAGCTGAGGACACGGCTGTGTATTACTGTGCGAGA

393
35 AAATACTATGTGGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAACTCACTGTATCTG
CAAATGAACAGCCTGAGAGCCGAGGACACGGCTGTGTATTACTGTGCGAGA

394
ACAGAATACGCCGCGTCTGTGAAAGGCAGATTACCATCTCAAGAGATGATTCAAAGAACTCACTGTATCTG
CAAATGAACAGCCTGAAAACCGAGGACACGGCCGTGTATTACTGTGCTAGA

40 395
ACAGCATATGCTGCGTCGGTGAAAGGCAGGTTACCATCTCCAGAGATGATTCAAAGAACACGGCGTATCTG
CAAATGAACAGCCTGAAAACCGAGGACACGGCCGTGTATTACTGTACTAGA

396
45 ACAAGCTACGCGGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAACACGCTGTATCT
GCAAATGAACAGTCTGAGAGCCGAGGACACGGCTGTGTATTACTGTGCAAGA

397
ATAGGCTATGCGGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAACTCCCTGTATCTG
CAAATGAACAGTCTGAGAGCTGAGGACACGGCCTTGTATTACTGTGCAAAA

398
50 ACCTACTACAACCCGTCCCTCAAGAGTCGAGTCACCATGTCTAGTAGACACGTCCAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACCGCCGTGGACACGGCCGTGTATTACTGTGCGAGA

399
ACCTACTACAACCCGTCCCTCAAGAGTCGAGTTACCATATCAGTAGACACGTCTAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACTGCCGCGGACACGGCCGTGTATTACTGTGCGAGA

55 400
ACCAACTACAACCCGTCCCTCAAGAGTCGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACCGCCGCGGACACGGCTGTGTATTACTGTGCGAGA

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401
ACCTACTACAACCCGTCCCTCAAGAGTCGAGTCACCATATCCGTAGACACGTCCAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACCGCCGCGACACGGCTGTGTATTACTGTGCGAGA

5 402
ACCAACTACAACCCCTCCCTCAAGAGTCGAGTCACCATGTCTAGTAGACACGTCCAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACCGCCGCGGACACGGCCGTGTATTACTGTGCGAGA

403
ACCAACTACAACCCCTCCCTCAAGAGTCGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACCGCTGCGGACACGGCCGTGTATTACTGTGCGAGA

10 404
ACCAACTACAACCCCTCCCTCAAGAGTCGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTG
AAGCTGAGCTCTGTGACCGCTGCGGACACGGCCGTGTATTACTGTGCGAGA

405
ACCAGATACAGCCCGTCCTTCCAAGGCCAGGTCACCATCTCAGCCGACAAGTCCATCAGCACCGCCTACCTG
15 CAGTGGAGCAGCCTGAAGGCCCTCGGACACCGCCATGTATTACTGTGCGAGA

406
AATGATTATGCAGTATCTGTGAAAAGTCGAATAACCATCAACCCAGACACATCCAAGAACCAGTTCTCCCTG
CAGCTGAACTCTGTGACTCCCGAGGACACGGCTGTGTATTACTGTGCAAGA

407
20 CCAACATATGCCCAGGGCTTCACAGGACGGTTTGTCTTCTCCATGGACACCTCTGCCAGCACAGCATACTG
CAGATCAGCAGCCTAAAGGCTGAGGACATGGCCATGTATTACTGTGCGAGA

Table 11. FR4 of Heavy Chain

408 TGGGGCCAGGGCACCCCTGGTCACCGTCTCCTCA

25 409 TGGGGCCGTGGCACCCCTGGTCACTGTCTCCTCA

410 TGGGGCCAAGGGACAATGGTCACCGTCTCTTCA

411 TGGGGCCAAGGAACCCTGGTCACCGTCTCCTCA

412 TGGGGCCAAGGAACCCTGGTCACCGTCTCCTCA

413 TGGGGGCAAGGGACCACGGTCACCGTCTCCTCA

30

As used herein, the term "germline antibody gene" or "gene fragment" refers to an immunoglobulin sequence encoded by non-lymphoid cells that have not undergone the maturation process that leads to genetic rearrangement and mutation for expression of a particular immunoglobulin. (See, e.g., Shapiro *et al.*, Crit. Rev. Immunol. 22(3):183-200 (2002); Marchalonis *et al.*, Adv Exp Med Biol. 484:13-30 (2001)). One of the advantages provided by various embodiments of the present invention stems from the recognition that germline antibody genes are more likely than mature antibody genes to conserve essential amino acid sequence structures characteristic of individuals in the species, hence less likely to be recognized as from a foreign source when used therapeutically in that species.

40 As used herein, the term "humanized antibody" is an antibody or a variant, derivative, analog or fragment thereof which immunospecifically binds to an antigen of interest and which comprises a framework (FR) region having substantially the amino acid sequence of a human antibody and a complementarity determining region (CDR) having

substantially the amino acid sequence of a non-human antibody. As used herein, the term “substantially” in the context of a CDR refers to a CDR having an amino acid sequence at least 80%, preferably at least 85%, at least 90%, at least 95%, at least 98% or at least 99% identical to the amino acid sequence of a non-human antibody CDR. A humanized antibody comprises substantially all of at least one, and typically two, variable domains (Fab, Fab', F(ab')₂, FabC, Fv) in which all or substantially all of the CDR regions correspond to those of a non-human immunoglobulin (*i.e.*, donor antibody) and all or substantially all of the framework regions are those of a human immunoglobulin sequence. Preferably, a humanized antibody also comprises at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin. In some embodiments, a humanized antibody contains both the light chain as well as at least the variable domain of a heavy chain. The antibody also may include the CH1, hinge, CH2, CH3, and CH4 regions of the heavy chain. In some embodiments, a humanized antibody only contains a humanized light chain. In some embodiments, a humanized antibody only contains a humanized heavy chain. In specific embodiments, a humanized antibody only contains a humanized variable domain of a light chain and/or humanized heavy chain.

The humanized antibody can be selected from any class of immunoglobulins, including IgM, IgG, IgD, IgA and IgE, and any isotype, including without limitation IgG₁, IgG₂, IgG₃ and IgG₄. The humanized antibody may comprise sequences from more than one class or isotype, and particular constant domains may be selected to optimize desired effector functions using techniques well-known in the art.

The framework and CDR regions of a humanized antibody need not correspond precisely to the parental sequences, *e.g.*, the donor antibody CDR or the acceptor framework may be mutagenized by substitution, insertion and/or deletion of at least one amino acid residue so that the CDR or framework residue at that site does not correspond to either the donor antibody or the acceptor framework. Such mutations, however, will not be extensive. Usually, at least 80%, preferably at least 85%, more preferably at least 90%, and most preferably at least 95% of the humanized antibody residues will correspond to those of the parental FR and CDR sequences.

As used herein, the term "host cell" includes a to the particular subject cell transfected or transformed with a nucleic acid molecule and the progeny or potential progeny of such a cell. Progeny of such a cell may not be identical to the parent cell transfected with the nucleic acid molecule due to mutations or environmental influences that

may occur in succeeding generations or integration of the nucleic acid molecule into the host cell genome.

As used herein, the term "immunospecifically binds to an antigen" and analogous terms refer to peptides, polypeptides, proteins (including, but not limited to fusion proteins and antibodies) or fragments thereof that specifically bind to an antigen or a
5 fragment and do not specifically bind to other antigens. A peptide, polypeptide, or protein that immunospecifically binds to an antigen may bind to other antigens with lower affinity as determined by, *e.g.*, immunoassays, BIAcore, or other assays known in the art.

Antibodies or fragments that immunospecifically bind to an antigen may be cross-reactive
10 with related antigens. Preferably, antibodies or fragments that immunospecifically bind to an antigen do not cross-react with other antigens.

As used herein, the term "isolated" in the context of a proteinaceous agent (*e.g.*, a peptide, polypeptide or protein (such as fusion protein or antibody)) refers to a proteinaceous agent which is substantially free of cellular material or contaminating
15 proteins, polypeptides, peptides and antibodies from the cell or tissue source from which it is derived, or substantially free of chemical precursors or other chemicals when chemically synthesized. The language "substantially free of cellular material" includes preparations of a proteinaceous agent in which the proteinaceous agent is separated from cellular components of the cells from which it is isolated or recombinantly produced. Thus, a
20 proteinaceous agent that is substantially free of cellular material includes preparations of a proteinaceous agent having less than about 30%, 20%, 10%, or 5% (by dry weight) of heterologous protein, polypeptide or peptide (also referred to as a "contaminating protein"). When the proteinaceous agent is recombinantly produced, it is also preferably substantially free of culture medium, *i.e.*, culture medium represents less than about 20%, 10%, or 5% of
25 the volume of the proteinaceous agent preparation. When the proteinaceous agent is produced by chemical synthesis, it is preferably substantially free of chemical precursors or other chemicals, *i.e.*, it is separated from chemical precursors or other chemicals which are involved in the synthesis of the proteinaceous agent. Accordingly, such preparations of a proteinaceous agent have less than about 30%, 20%, 10%, 5% (by dry weight) of chemical
30 precursors or compounds other than the proteinaceous agent of interest. In a specific embodiment, proteinaceous agents disclosed herein are isolated. In a preferred embodiment, an antibody of the invention is isolated.

As used herein, the term "isolated" in the context of nucleic acid molecules refers to a nucleic acid molecule which is separated from other nucleic acid molecules

which are present in the natural source of the nucleic acid molecule. Moreover, an "isolated" nucleic acid molecule, such as a cDNA molecule, is preferably substantially free of other cellular material, or culture medium when produced by recombinant techniques, or substantially free of chemical precursors or other chemicals when chemically synthesized.

5 In a specific embodiment, nucleic acid molecules are isolated. In a preferred embodiment, a nucleic acid molecule encoding an antibody of the invention is isolated. As used herein, the term "substantially free" refers to the preparation of the "isolated" nucleic acid having less than about 30%, 20%, 10%, or 5% (by dry weight) of heterologous nucleic acids, and preferably other cellular material, culture medium, chemical precursors, or other chemicals.

10 As used herein, the term "in combination" refers to the use of more than one therapies (*e.g.*, more than one prophylactic agent and/or therapeutic agent). The use of the term "in combination" does not restrict the order in which therapies (*e.g.*, prophylactic and/or therapeutic agents) are administered to a subject. A first therapy (*e.g.*, a first prophylactic or therapeutic agent) can be administered prior to (*e.g.*, 5 minutes, 15 minutes,
15 30 minutes, 45 minutes, 1 hour, 2 hours, 4 hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, 96 hours, 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 8 weeks, or 12 weeks before), concomitantly with, or subsequent to (*e.g.*, 5 minutes, 15 minutes, 30 minutes, 45 minutes, 1 hour, 2 hours, 4 hours, 6 hours, 12 hours, 24 hours, 48 hours, 72 hours, 96 hours, 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 8 weeks, or 12
20 weeks after) the administration of a second therapy (*e.g.*, a second prophylactic or therapeutic agent) to a subject.

As used herein, the terms "manage," "managing," and "management" refer to the beneficial effects that a subject derives from a therapy (*e.g.*, a prophylactic or therapeutic agent), which does not result in a cure of the disease. In certain embodiments, a subject is
25 administered one or more therapies (*e.g.*, one or more prophylactic or therapeutic agents) to "manage" a disease so as to prevent the progression or worsening of the disease.

As used herein, the term "mature antibody gene" refers to a genetic sequence encoding an immunoglobulin that is expressed, for example, in a lymphocyte such as a B cell, in a hybridoma or in any antibody producing cell that has undergone a maturation
30 process so that the particular immunoglobulin is expressed. The term includes mature genomic DNA, cDNA and other nucleic acid sequences that encode such mature genes, which have been isolated and/or recombinantly engineered for expression in other cell types. Mature antibody genes have undergone various mutations and rearrangements that structurally distinguish them from antibody genes encoded in all cells other than

lymphocytes. Mature antibody genes in humans, rodents, and many other mammals are formed by fusion of V and J gene segments in the case of antibody light chains and fusion of V, D, and J gene segments in the case of antibody heavy chains. Many mature antibody genes acquire point mutations subsequent to fusion, some of which increase the affinity of
5 the antibody protein for a specific antigen.

As used herein, the term “pharmaceutically acceptable” refers approved by a regulatory agency of the federal or a state government, or listed in the U.S. Pharmacopeia, European Pharmacopeia, or other generally recognized pharmacopeia for use in animals, and more particularly, in humans.

10 As used herein, the terms “prevent,” “preventing,” and “prevention” refer to the inhibition of the development or onset of a disorder or the prevention of the recurrence, onset, or development of one or more symptoms of a disorder in a subject resulting from the administration of a therapy (*e.g.*, a prophylactic or therapeutic agent), or the administration of a combination of therapies (*e.g.*, a combination of prophylactic or therapeutic agents).

15 As used herein, the terms “prophylactic agent” and “prophylactic agents” refer to any agent(s) which can be used in the prevention of a disorder or one or more of the symptoms thereof. In certain embodiments, the term “prophylactic agent” refers to an antibody of the invention. In certain other embodiments, the term “prophylactic agent” refers to an agent other than an antibody of the invention. Preferably, a prophylactic agent
20 is an agent which is known to be useful to or has been or is currently being used to the prevent or impede the onset, development, progression and/or severity of a disorder or one or more symptoms thereof.

As used herein, the term “prophylactically effective amount” refers to the amount of a therapy (*e.g.*, prophylactic agent) which is sufficient to result in the prevention
25 of the development, recurrence, or onset of a disorder or one or more symptoms thereof, or to enhance or improve the prophylactic effect(s) of another therapy (*e.g.*, a prophylactic agent).

As used herein, the phrase “protocol” refers to a regimen for dosing and timing the administration of one or more therapies (*e.g.*, therapeutic agents) that has a
30 therapeutic effective.

As used herein, the phrase “side effects” encompasses unwanted and adverse effects of a prophylactic or therapeutic agent. Side effects are always unwanted, but

unwanted effects are not necessarily adverse. An adverse effect from a therapy (*e.g.*, a prophylactic or therapeutic agent) might be harmful, uncomfortable, or risky.

As used herein, the term "small molecules" and analogous terms include, but are not limited to, peptides, peptidomimetics, amino acids, amino acid analogs, polynucleotides, polynucleotide analogs, nucleotides, nucleotide analogs, organic or inorganic compounds (*i.e.*, including heteroorganic and organometallic compounds) having a molecular weight less than about 10,000 grams per mole, organic or inorganic compounds having a molecular weight less than about 5,000 grams per mole, organic or inorganic compounds having a molecular weight less than about 1,000 grams per mole, organic or inorganic compounds having a molecular weight less than about 500 grams per mole, and salts, esters, and other pharmaceutically acceptable forms of such agents.

As used herein, the terms "subject" and "patient" are used interchangeably. As used herein, the terms "subject" and "subjects" refer to an animal, preferably a mammal including a non-primate (*e.g.*, a cow, pig, horse, cat, dog, rat, and mouse) and a primate (*e.g.*, a monkey, such as a cynomolgous monkey, a chimpanzee, and a human), and most preferably a human. In one embodiment, the subject is a non-human animal such as a bird (*e.g.*, a quail, chicken, or turkey), a farm animal (*e.g.*, a cow, horse, pig, or sheep), a pet (*e.g.*, a cat, dog, or guinea pig), or laboratory animal (*e.g.*, an animal model for a disorder). In a preferred embodiment, the subject is a human (*e.g.*, an infant, child, adult, or senior citizen).

As used herein, the term "synergistic" refers to a combination of therapies (*e.g.*, prophylactic or therapeutic agents) which is more effective than the additive effects of any two or more single therapies (*e.g.*, one or more prophylactic or therapeutic agents). A synergistic effect of a combination of therapies (*e.g.*, a combination of prophylactic or therapeutic agents) permits the use of lower dosages of one or more of therapies (*e.g.*, one or more prophylactic or therapeutic agents) and/or less frequent administration of said therapies to a subject with a disorder. The ability to utilize lower dosages of therapies (*e.g.*, prophylactic or therapeutic agents) and/or to administer said therapies less frequently reduces the toxicity associated with the administration of said therapies to a subject without reducing the efficacy of said therapies in the prevention or treatment of a disorder. In addition, a synergistic effect can result in improved efficacy of therapies (*e.g.*, prophylactic or therapeutic agents) in the prevention or treatment of a disorder. Finally, synergistic effect of a combination of therapies (*e.g.*, prophylactic or therapeutic agents) may avoid or reduce adverse or unwanted side effects associated with the use of any single therapy.

As used herein, the terms “therapeutic agent” and “therapeutic agents” refer to any agent(s) which can be used in the prevention, treatment, management, or amelioration of a disorder or one or more symptoms thereof. In certain embodiments, the term “therapeutic agent” refers to an antibody of the invention. In certain other embodiments, the term “therapeutic agent” refers an agent other than an antibody of the invention. Preferably, a therapeutic agent is an agent which is known to be useful for, or has been or is currently being used for the prevention, treatment, management, or amelioration of a disorder or one or more symptoms thereof.

As used herein, the term “therapeutically effective amount” refers to the amount of a therapy (*e.g.*, an antibody of the invention), which is sufficient to reduce the severity of a disorder, reduce the duration of a disorder, ameliorate one or more symptoms of a disorder, prevent the advancement of a disorder, cause regression of a disorder, or enhance or improve the therapeutic effect(s) of another therapy.

As used herein, the terms “therapies” and “therapy” can refer to any protocol(s), method(s), and/or agent(s) that can be used in the prevention, treatment, management, and/or amelioration of a disorder or one or more symptoms thereof. In certain embodiments, the terms “therapy” and “therapy” refer to anti-viral therapy, anti-bacterial therapy, anti-fungal therapy, anti-cancer agent, biological therapy, supportive therapy, and/or other therapies useful in treatment, management, prevention, or amelioration of a disorder or one or more symptoms thereof known to one skilled in the art, for example, a medical professional such as a physician.

As used herein, the terms “treat,” “treatment,” and “treating” refer to the reduction or amelioration of the progression, severity, and/or duration of a disorder or amelioration of one or more symptoms thereof resulting from the administration of one or more therapies (including, but not limited to, the administration of one or more prophylactic or therapeutic agents).

3.2 BRIEF DESCRIPTION OF THE FIGURES

Figure 1. Nucleic acid and protein sequences of the heavy and light chains of the mouse anti-human EphA2 monoclonal antibody B233. CDR1, 2 and 3 regions as defined by Kabat are boxed. The full amino acid sequences of the variable heavy (V_H) and light (V_L) chains are given using the standard one letter code.

Figure 2. Phage vector used for screening of the framework shuffling libraries and

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expression of the corresponding Fab fragments. Streptavidin purified, single-stranded DNA of each of the V_L and V_H genes is annealed to the vector by hybridization mutagenesis using homology in the gene 3 leader/ $C\kappa$ and gene 3 leader/ $C\gamma 1$ regions, respectively. The unique Xba1 site in the palindromic loops allows elimination of the parental vector. V_H and V_L genes are then expressed in frame with the first constant domain of the human $\kappa 1$ heavy chain and the constant domain of the human kappa (κ) light chain, respectively.

Figure 3. Protein sequences of framework-shuffled, humanized clones of the anti-human EphA2 monoclonal antibody B233 isolated after screening of libraries A and B. CDR1, 2 and 3 regions as defined by Kabat are boxed. The full amino acid sequences of the variable heavy (V_H) and light (V_L) chains are given using the standard one letter code.

Figure 4. ELISA titration using Fab extracts on immobilized human EphA2-Fc.

Figure 5. Sequence analysis of framework shuffled antibodies. ^aPercent identity at the amino acid level was calculated for each individual antibody framework using mAb B233 for reference

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides methods of re-engineering or re-shaping an antibody from a first species, wherein the re-engineered or re-shaped antibody does not elicit undesired immune response in a second species, and the re-engineered or re-shaped antibody retains substantially the same antigen binding-ability of the antibody from the first species. In accordance with the present invention, a combinatorial library comprising the CDRs of the antibody from the first species fused in frame with framework regions from a bank of framework regions derived from a second species can be constructed and screened for the desired modified antibody.

The present invention also provides cells comprising, containing or engineered to express the nucleic acid sequences described herein. The present invention provides a method of producing a heavy chain variable region (preferably, a humanized heavy chain variable region), said method comprising expressing the nucleotide sequence encoding a heavy chain variable region (preferably, a humanized heavy chain variable region) in a cell described herein. The present invention provides a method of producing an light chain variable region (preferably, a humanized light chain variable region), said method comprising expressing the nucleotide sequence encoding a light chain variable

region (preferably, a humanized light chain variable region) in a cell described herein. The present invention also provides a method of producing an antibody (preferably, a humanized antibody) that immunospecifically binds to an antigen, said method comprising expressing the nucleic acid sequence(s) encoding the humanized antibody contained in the cell
5 described herein.

The present invention provides antibodies produced by the methods described herein. In a preferred embodiment, the invention provides humanized antibodies produced by the methods described herein. The present invention also provides a composition comprising an antibody produced by the methods described herein and a
10 carrier, diluent or excipient. In a preferred embodiment, the invention provides a composition comprising a humanized antibody produced by the methods described herein and a carrier, diluent or excipient. Preferably, the compositions of the invention are pharmaceutical compositions in a form for its intended use.

For clarity of disclosure, and not by way of limitation, the detailed
15 description of the invention is divided into the following subsections:

- (i) construction of a global bank of acceptor framework regions
- (ii) selection of CDRs
- (iii) construction of combinatorial sub-libraries
- (iv) construction of combinatorial libraries
- 20 (v) expression of the combinatorial libraries
- (vi) selection of humanized antibodies
- (vii) production and characterization of humanized antibodies
- (viii) antibody conjugates
- (ix) uses of the compositions of the invention
- 25 (x) administration and formulations
- (xi) dosage and frequency of administration
- (xii) biological assays
- (xiii) kits
- (xiv) article of manufacture

2.2 Construction of a Global Bank of Acceptor Framework Regions

According to the present invention, a variable light chain region and/or variable heavy chain region of a donor antibody (*e.g.*, a non-human antibody) can be modified (*e.g.*, humanized) by fusing together nucleic acid sequences encoding framework regions (FR1, FR2, FR3, FR4 of the light chain, and FR1, FR2, FR3, FR4 of the heavy chain) of an acceptor antibody(ies) (*e.g.*, a human antibody) and nucleic acid sequences encoding complementarity-determining regions (CDR1, CDR2, CDR3 of the light chain, and CDR1, CDR2, CDR3 of the heavy chain) of the donor antibody. Preferably, the modified (*e.g.*, humanized) antibody light chain comprises FR1, CDR1, FR2, CDR2, FR3, CDR3, and FR4. A modified (*e.g.*, humanized) antibody heavy chain comprises FR1, CDR1, FR2, CDR2, FR3, CDR3, and FR4. Each acceptor (*e.g.*, human) framework region (FR1, 2, 3, 4 of light chain, and FR1, 2, 3, 4 of heavy chain) can be generated from FR sub-banks for the light chain and FR sub-banks for the heavy chain, respectively. A global bank of acceptor (*e.g.*, human) framework regions comprises two or more FR sub-banks.

2.2.1 Generation of Sub-banks for the Light Chain Frameworks

Light chain sub-banks 1, 2, 3 and 4 are constructed, wherein sub-bank 1 comprises plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding a light chain FR1; sub-bank 2 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding a light chain FR2; sub-bank 3 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding a light chain FR3; and sub-bank 4 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding a light chain FR4. In some embodiments, the FR sequences are obtained or derived from functional human antibody sequences (*e.g.*, an antibody known in the art and/or commercially available). In some embodiments, the FR sequences are derived from human germline light chain sequences. In one embodiment, the sub-bank FR sequences are derived from a human germline kappa chain sequences. In another embodiment, the sub-bank FR sequences are derived from a human germline lambda chain sequences.

By way of example but not limitation, the following describes a method of generating 4 light chain FR sub-banks using Polymerase Chain Reaction (PCR), wherein human germline kappa chain sequences are used as templates. Light chain FR sub-banks 1, 2 and 3 (encoding FR1, 2, 3 respectively) encompass 46 human germline kappa chain sequences (A1, A10, A11, A14, A17, A18, A19, A2, A20, A23, A26, A27, A3, A30, A5,

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A7, B2, B3, L1, L10, L11, L12, L14, L15, L16, L18, L19, L2, L20, L22, L23, L24, L25, L4/18a, L5, L6, L8, L9, O1, O11, O12, O14, O18, O2, O4 and O8). See Kawasaki *et al.*, 2001, Eur. J. Immunol., 31:1017-1028; Schable and Zachau, 1993, Biol. Chem. Hoppe Seyler 374:1001-1022; and Brensing-Kuppers *et al.*, 1997, Gene 191:173-181. The

5 sequences are summarized at the NCBI website:

www.ncbi.nlm.nih.gov/igblast/showGermline.cgi?organism=human&chainType=VK&seqT
ype=nucleotide; each of which is incorporated herein by reference in its entirety. Light
chain FR sub-bank 4 (encoding FR4) encompasses 5 human germline kappa chain

10 sequences (Jk1, Jk2, Jk3, Jk4 and Jk5). See Hieter *et al.*, 1982, J. Biol. Chem. 257:1516-
1522; which is incorporated herein by reference in its entirety. The sequences are
summarized at the NCBI website:

www.ncbi.nlm.nih.gov/igblast/showGermline.cgi?organism=human&chainType=JK&seqT
ype=nucleotide; which is incorporated herein by reference in its entirety.

15 By way of example but not limitation, the construction of light chain FR1
sub-bank is carried out using the Polymerase Chain Reaction by overlap extension using the
oligonucleotides listed in Table 12 and Table 13 (all shown in the 5' to 3' orientation, name
followed by sequence):

Table 12. Light Chain FR1 Forward Primers (for Sub-Bank 1)

20	414	FR1L1	GATGTTGTGATGACTCAGTCTCCACTCTCCCTGCCCGTCACCC
	415	FR1L2	GATGTTGTGATGACTCAGTCTCCACTCTCCCTGCCCGTCACCC
	416	FR1L3	GATATTGTGATGACCCAGACTCCACTCTCTCTGTCCGTCACCC
	417	FR1L4	GATATTGTGATGACTCAGTCTCCACTCTCCCTGCCCGTCACCC
	418	FR1L5	GATATTGTGATGACCCAGACTCCACTCTCTCTGTCCGTCACCC
25	419	FR1L6	GATATTGTGATGACCCAGACTCCACTCTCCTCACCTGTCACCC
	420	FR1L7	GATATTGTGATGACTCAGTCTCCACTCTCCCTGCCCGTCACCC
	421	FR1L8	GAGATTGTGATGACCCAGACTCCACTCTCCTTGTCTATCACCC
	422	FR1L9	GATATTGTGATGACCCAGACTCCACTCTCCTCGCCTGTCACCC
	423	FR1L10	GAAATTGTGCTGACTCAGTCTCCAGACTTTCAGTCTGTGACTC
30	424	FR1L11	GATGTTGTGATGACACAGTCTCCAGCTTTCCTCTCTGTGACTC
	425	FR1L12	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
	426	FR1L13	GAAATTGTGCTGACTCAGTCTCCAGACTTTCAGTCTGTGACTC
	427	FR1L14	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
	428	FR1L15	GAAACGACACTCACGCAGTCTCCAGCATTTCATGTCAGCGACTC
35	429	FR1L16	GACATCCAGATGACCCAGTCTCCATCCTCACTGTCTGCATCTG
	430	FR1L17	GCCATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
	431	FR1L18	GACATCCAGATGACCCAGTCTCCTTCCACCCTGTCTGCATCTG
	432	FR1L19	AACATCCAGATGACCCAGTCTCCATCTGCCATGTCTGCATCTG
	433	FR1L20	GACATCCAGATGACCCAGTCTCCATCCTCACTGTCTGCATCTG

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434	FR1L21	GAAATAGTGATGATGCAGTCTCCAGCCACCCTGTCTGTGTCTC
435	FR1L22	GCCATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
436	FR1L23	GACATCCAGATGACCCAGTCTCCATCTTCTGTGTCTGCATCTG
437	FR1L24	GAAATAGTGATGACGCAGTCTCCAGCCACCCTGTCTGTGTCTC
5 438	FR1L25	GAAATTGTGTTGACACAGTCTCCAGCCACCCTGTCTTTGTCTC
439	FR1L26	GACATCCAGATGATCCAGTCTCCATCTTTCCTGTCTGCATCTG
440	FR1L27	GCCATCCGGATGACCCAGTCTCCATTCTCCCTGTCTGCATCTG
441	FR1L28	GTCATCTGGATGACCCAGTCTCCATCCTTACTCTCTGCATCTA
442	FR1L29	GCCATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
10 443	FR1L30	GACATCCAGATGACCCAGTCTCCATCTTCCGTGTCTGCATCTG
444	FR1L31	GAAATTGTGTTGACACAGTCTCCAGCCACCCTGTCTTTGTCTC
445	FR1L32	GACATCCAGTTGACCCAGTCTCCATCCTTCCTGTCTGCATCTG
446	FR1L33	GCCATCCGGATGACCCAGTCTCCATCCTCATTCTCTGCATCTA
447	FR1L34	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
15 448	FR1L35	GACATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
449	FR1L36	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
450	FR1L37	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
451	FR1L38	GACATCCAGTTGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
452	FR1L39	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGCATCTG
20 453	FR1L40	GAAATTGTAATGACACAGTCTCCACCCACCCTGTCTTTGTCTC
454	FR1L41	GAAATTGTAATGACACAGTCTCCAGCCACCCTGTCTTTGTCTC
455	FR1L42	GAAATTGTGTTGACGCAGTCTCCAGCCACCCTGTCTTTGTCTC
456	FR1L43	GAAATTGTGTTGACGCAGTCTCCAGGCACCCTGTCTTTGTCTC
457	FR1L44	GACATCGTGATGACCCAGTCTCCAGACTCCCTGGCTGTGTCTC
25 458	FR1L45	GATATTGTGATGACCCAGACTCCACTCTCCCTGCCCCGTCACCC
459	4FR1L46	GATATTGTGATGACCCAGACTCCACTCTCCCTGCCCCGTCACCC

Table 13. Light Chain FR1 Reverse Primers (for Sub-Bank 1)

460	FR1L1'	GCAGGAGATGGAGGCCGGCTGTCCAAGGGTGACGGGCAGGGAGAGTG
30 461	FR1L2'	GCAGGAGATGGAGGCCGGCTGTCCAAGGGTGACGGGCAGGGAGAGTG
462	FR1L3'	GCAGGAGATGGAGGCCGGCTGTCCAAGGGTGACGGACAGAGAGAGTG
463	FR1L4'	GCAGGAGATGGAGGCCGGCTCTCCAGGGGTGACGGGCAGGGAGAGTG
464	FR1L5'	GCAGGAGATGGAGGCCGGCTGTCCAAGGGTGACGGACAGAGAGAGTG
465	FR1L6'	GCAGGAGATGGAGGCCGGCTGTCCAAGGGTGACAGGTGAGGAGAGTG
35 466	FR1L7'	GCAGGAGATGGAGGCCGGCTCTCCAGGGGTGACGGGCAGGGAGAGTG
467	FR1L8'	GCAGGAGATGGAGGCCTGCTCTCCAGGGGTGATAGACAAGGAGAGTG
468	FR1L9'	GAAGGAGATGGAGGCCGGCTGTCCAAGGGTGACAGGCGAGGAGAGTG
469	FR1L10'	GCAGGTGATGGTGACTTTCTCCTTTGGAGTCACAGACTGAAAGTCTG
470	FR1L11'	GCAGGTGATGGTGACTTTCTCCCCTGGAGTCACAGAGAGGAAAGCTG
40 471	FR1L12'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
472	FR1L13'	GCAGGTGATGGTGACTTTCTCCTTTGGAGTCACAGACTGAAAGTCTG
473	FR1L14'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
474	FR1L15'	GCAGGAGATGTTGACTTTGTCTCCTGGAGTCGCTGACATGAATGCTG

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	475	FR1L16'	ACAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGTGAGGATG
	476	FR1L17'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
	477	FR1L18'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGTGGAAG
	478	FR1L19'	ACAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACATGGCAGATG
5	479	FR1L20'	ACAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGTGAGGATG
	480	FR1L21'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACACAGACAGGGTGGCTG
	481	FR1L22'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
	482	FR1L23'	ACAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACACAGAAGATG
	483	FR1L24'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACACAGACAGGGTGGCTG
10	484	FR1L25'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACAAAGACAGGGTGGCTG
	485	FR1L26'	GCAAATGATACTGACTCTGTCTCCTACAGATGCAGACAGGAAAGATG
	486	FR1L27'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGAATG
	487	FR1L28'	ACAAGTGATGGTGACTCTGTCTCCTGTAGATGCAGAGAGTAAGGATG
	488	FR1L29'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
15	489	FR1L30'	ACAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACACGGAAGATG
	490	FR1L31'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACAAAGACAGGGTGGCTG
	491	FR1L32'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGAAGGATG
	492	FR1L33'	ACAAGTGATGGTGACTCTGTCTCCTGTAGATGCAGAGAATGAGGATG
	493	FR1L34'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
20	494	FR1L35'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
	495	FR1L36'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
	496	FR1L37'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
	497	FR1L38'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
	498	FR1L39'	GCAAGTGATGGTGACTCTGTCTCCTACAGATGCAGACAGGGAGGATG
25	499	FR1L40'	GCAGGAGAGGGTGACTCTTTCCCCTGGAGACAAAGACAGGGTGGGTG
	500	FR1L41'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACAAAGACAGGGTGGCTG
	501	FR1L42'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACAAAGACAGGGTGGCTG
	502	FR1L43'	GCAGGAGAGGGTGGCTCTTTCCCCTGGAGACAAAGACAGGGTGCCTG
	503	FR1L44'	GCAGTTGATGGTGGCCCTCTCGCCCAGAGACACAGCCAGGGAGTCTG
30	504	FR1L45'	GCAGGAGATGGAGGCCGGCTCTCCAGGGGTGACGGGCAGGGAGAGTG
	505	FR1L46'	GCAGGAGATGGAGGCCGGCTCTCCAGGGGTGACGGGCAGGGAGAGTG

PCR is carried out using the following oligonucleotide combinations (46 in total): FR1L1/FR1L1', FR1L2/FR1L2', FR1L3/FR1L3', FR1L4/FR1L4', FR1L5/FR1L5',
 35 FR1L6/FR1L6', FR1L7/FR1L7', FR1L8/FR1L8', FR1L9/FR1L9', FR1L10/FR1L10',
 FR1L11/FR1L11', FR1L12/FR1L12', FR1L13/FR1L13', FR1L14/FR1L14',
 FR1L15/FR1L15', FR1L16/FR1L16', FR1L17/FR1L17', FR1L18/FR1L18',
 FR1L19/FR1L19', FR1L20/FR1L20', FR1L21/FR1L21', FR1L22/FR1L22',
 FR1L23/FR1L23', FR1L24/FR1L24', FR1L25/FR1L25', FR1L26/FR1L26',
 40 FR1L27/FR1L27', FR1L28/FR1L28', FR1L29/FR1L29', FR1L30/FR1L30',
 FR1L31/FR1L31', FR1L32/FR1L32', FR1L33/FR1L33', FR1L34/FR1L34',

FR1L35/FR1L35', FR1L36/FR1L36', FR1L37/FR1L37', FR1L38/FR1L38',
FR1L39/FR1L39', FR1L40/FR1L40', FR1L41/FR1L41', FR1L42/FR1L42',
FR1L43/FR1L43', FR1L44/FR1L44', FR1L45/FR1L45', and FR1L46/FR1L46'. The
pooling of the PCR products generates sub-bank 1.

5 By way of example but not limitation, the construction of light chain FR2
sub-bank is carried out using the Polymerase Chain Reaction by overlap extension using the
oligonucleotides listed in Table 14 and Table 15 (all shown in the 5' to 3' orientation, name
followed by sequence):

Table 14. Light Chain FR2 Forward Primers (for Sub-Bank 2)

10	506	FR2L1	TGGTTTCAGCAGAGGCCAGGCCAATCTCCAA
	507	FR2L2	TGGTTTCAGCAGAGGCCAGGCCAATCTCCAA
	508	FR2L3	TGGTACCTGCAGAAGCCAGGCCAGTCTCCAC
	509	FR2L4	TGGTACCTGCAGAAGCCAGGGCAGTCTCCAC
	510	FR2L5	TGGTACCTGCAGAAGCCAGGCCAGCCTCCAC
15	511	FR2L6	TGGCTTCAGCAGAGGCCAGGCCAGCCTCCAA
	512	FR2L7	TGGTACCTGCAGAAGCCAGGGCAGTCTCCAC
	513	FR2L8	TGGTTTCTGCAGAAAGCCAGGCCAGTCTCCA
	514	FR2L9	TGGCTTCAGCAGAGGCCAGGCCAGCCTCCAA
	515	FR2L10	TGGTACCAGCAGAAACCAGATCAGTCTCCAA
20	516	FR2L11	TGGTACCAGCAGAAACCAGATCAAGCCCCAA
	517	FR2L12	TGGTATCAGCAGAAACCAGGGAAAGTTCCTA
	518	FR2L13	TGGTACCAGCAGAAACCAGATCAGTCTCCAA
	519	FR2L14	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	520	FR2L15	TGGTACCAACAGAAACCAGGAGAAGCTGCTA
25	521	FR2L16	TGGTTTCAGCAGAAACCAGGGAAAGCCCCTA
	522	FR2L17	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	523	FR2L18	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	524	FR2L19	TGGTTTCAGCAGAAACCAGGGAAAGTCCCTA
	525	FR2L20	TGGTATCAGCAGAAACCAGAGAAAGCCCCTA
30	526	FR2L21	TGGTACCAGCAGAAACCTGGCCAGGCTCCCA
	527	FR2L22	TGGTATCAGCAGAAACCAGGGAAAGCTCCTA
	528	FR2L23	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	529	FR2L24	TGGTACCAGCAGAAACCTGGCCAGGCTCCCA
	530	FR2L25	TGGTACCAGCAGAAACCTGGCCAGGCTCCCA
35	531	FR2L26	TGGTATCTGCAGAAACCAGGGAAATCCCCTA
	532	FR2L27	TGGTATCAGCAAAAACCAGCAAAAGCCCCTA
	533	FR2L28	TGGTATCAGCAAAAACCAGGGAAAGCCCCTG
	534	FR2L29	TGGTATCAGCAGAAACCAGGGAAAGCTCCTA
	535	FR2L30	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
40	536	FR2L31	TGGTACCAACAGAAACCTGGCCAGGCTCCCA
	537	FR2L32	TGGTATCAGCAAAAACCAGGGAAAGCCCCTA

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5	538	FR2L33	TGGTATCAGCAAAAACCAGGGAAAGCCCCTA
	539	FR2L34	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	540	FR2L35	TGGTATCGGCAGAAACCAGGGAAAGTTCCTA
	541	FR2L36	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	542	FR2L37	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	543	FR2L38	TGGTATCGGCAGAAACCAGGGAAAGTTCCTA
	544	FR2L39	TGGTATCAGCAGAAACCAGGGAAAGCCCCTA
	545	FR2L40	TGGTATCAGCAGAAACCTGGCCAGGCGCCCA
10	546	FR2L41	TGGTACCAGCAGAAACCTGGGCAGGCTCCCA
	547	FR2L42	TGGTACCAGCAGAAACCTGGCCTGGCGCCCA
	548	FR2L43	TGGTACCAGCAGAAACCTGGCCAGGCTCCCA
	549	FR2L44	TGGTACCAGCAGAAACCAGGACAGCCTCCTA
	550	FR2L45	TGGTACCTGCAGAAGCCAGGGCAGTCTCCAC
	551	FR2L46	TGGTACCTGCAGAAGCCAGGGCAGTCTCCAC

15

Table 15. Light Chain FR2 Reverse Primers (for Sub-Bank 2)

	552	FR2L1'	ATAAATTAGGCGCCTTGGAGATTGGCCTGGCCTCT
	553	FR2L2'	ATAAATTAGGCGCCTTGGAGATTGGCCTGGCCTCT
	554	FR2L3'	ATAGATCAGGAGCTGTGGAGACTGGCCTGGCTTCT
20	555	FR2L4'	ATAGATCAGGAGCTGTGGAGACTGCCCTGGCTTCT
	556	FR2L5'	ATAGATCAGGAGCTGTGGAGGCTGGCCTGGCTTCT
	557	FR2L6'	ATAAATTAGGAGTCTTGGAGGCTGGCCTGGCCTCT
	558	FR2L7'	ATAGATCAGGAGCTGTGGAGACTGCCCTGGCTTCT
	559	FR2L8'	ATAGATCAGGAGTGTGGAGACTGGCCTGGCTTTCT
25	560	FR2L9'	ATAAATTAGGAGTCTTGGAGGCTGGCCTGGCCTCT
	561	FR2L10'	CTTGATGAGGAGCTTTGGAGACTGATCTGGTTTCT
	562	FR2L11'	CTTGATGAGGAGCTTTGGGGCTTGATCTGGTTTCT
	563	FR2L12'	ATAGATCAGGAGCTTAGGAACTTTCCCTGGTTTCT
	564	FR2L13'	CTTGATGAGGAGCTTTGGAGACTGATCTGGTTTCT
30	565	FR2L14'	ATAGATCAGGCGCTTAGGGGCTTTCCCTGGTTTCT
	566	FR2L15'	TTGAATAATGAAAATAGCAGCTTCTCCTGGTTTCT
	567	FR2L16'	ATAGATCAGGGACTTAGGGGCTTTCCCTGGTTTCT
	568	FR2L17'	ATAGATCAGGAGCTTAGGGGCTTTCCCTGGTTTCT
	569	FR2L18'	ATAGATCAGGAGCTTAGGGGCTTTCCCTGGTTTCT
35	570	FR2L19'	ATAGATCAGGTGCTTAGGGACTTTCCCTGGTTTCT
	571	FR2L20'	ATAGATCAGGGACTTAGGGGCTTTCTCTGGTTTCT
	572	FR2L21'	ATAGATGAGGAGCCTGGGAGCCTGGCCAGGTTTCT
	573	FR2L22'	ATAGATCAGGAGCTTAGGAGCTTTCCCTGGTTTCT
	574	FR2L23'	ATAGATCAGGAGCTTAGGGGCTTTCCCTGGTTTCT
40	575	FR2L24'	ATAGATGAGGAGCCTGGGAGCCTGGCCAGGTTTCT
	576	FR2L25'	ATAGATGAGGAGCCTGGGAGCCTGGCCAGGTTTCT
	577	FR2L26'	ATAGAGGAAGAGCTTAGGGGATTTCCCTGGTTTCT
	578	FR2L27'	ATAGATGAAGAGCTTAGGGGCTTTTGCTGGTTTTT

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579	FR2L28'	ATAGATCAGGAGCTCAGGGGCTTCCCTGGTTTTT
580	FR2L29'	ATAGATCAGGAGCTTAGGAGCTTCCCTGGTTTCT
581	FR2L30'	ATAGATCAGGAGCTTAGGGGCTTCCCTGGTTTCT
582	FR2L31'	ATAGATGAGGAGCCTGGGAGCCTGGCCAGGTTTCT
5 583	FR2L32'	ATAGATCAGGAGCTTAGGGGCTTCCCTGGTTTTT
584	FR2L33'	ATAGATCAGGAGCTTAGGGGCTTCCCTGGTTTTT
585	FR2L34'	ATAGATCAGGAGCTTAGGGGCTTCCCTGGTTTCT
586	FR2L35'	ATAGATCAGGAGCTTAGGAACTTCCCTGGTTTCT
587	FR2L36'	GTAGATCAGGAGCTTAGGGGCTTCCCTGGTTTCT
10 588	FR2L37'	ATAGATCAGGAGCTTAGGGGCTTCCCTGGTTTCT
589	FR2L38'	ATAGATCAGGAGCTTAGGAACTTCCCTGGTTTCT
590	FR2L39'	GTAGATCAGGAGCTTAGGGGCTTCCCTGGTTTCT
591	FR2L40'	ATAGATGAGGAGCCTGGGCGCCTGGCCAGGTTTCT
592	FR2L41'	ATAGATGAGGAGCCTGGGAGCCTGCCCAGGTTTCT
15 593	FR2L42'	ATAGATGAGGAGCCTGGGCGCCAGGCCAGGTTTCT
594	FR2L43'	ATAGATGAGGAGCCTGGGAGCCTGGCCAGGTTTCT
595	FR2L44'	GTAAATGAGCAGCTTAGGAGGCTGTCCTGGTTTCT
596	FR2L45'	ATAGATCAGGAGCTGTGGAGACTGCCCTGGCTTCT
597	FR2L46'	ATAGATCAGGAGCTGTGGAGACTGCCCTGGCTTCT

20

PCR is carried out using the following oligonucleotide combinations (46 in total): FR2L1/FR2L1', FR2L2/FR2L2', FR2L3/FR2L3', FR2L4/FR2L4', FR2L5/FR2L5', FR2L6/FR2L6', FR2L7/FR2L7', FR2L8/FR2L8', FR2L9/FR2L9', FR2L10/FR2L10', FR2L11/FR2L11', FR2L12/FR2L12', FR2L13/FR2L13', FR2L14/FR2L14', FR2L15/FR2L15', FR2L16/FR2L16', FR2L17/FR2L17', FR2L18/FR2L18', FR2L19/FR2L19', FR2L20/FR2L20', FR2L21/FR2L21', FR2L22/FR2L22', FR2L23/FR2L23', FR2L24/FR2L24', FR2L25/FR2L25', FR2L26/FR2L26', FR2L27/FR2L27', FR2L28/FR2L28', FR2L29/FR2L29', FR2L30/FR2L30', FR2L31/FR2L31', FR2L32/FR2L32', FR2L33/FR2L33', FR2L34/FR2L34', FR2L35/FR2L35', FR2L36/FR2L36', FR2L37/FR2L37', FR2L38/FR2L38', FR2L39/FR2L39', FR2L40/FR2L40', FR2L41/FR2L41', FR2L42/FR2L42', FR2L43/FR2L43', FR2L44/FR2L44', FR2L45/FR2L45', and FR2L46/FR2L46'. The pooling of the PCR products generates sub-bank 2.

By way of example but not limitation, the construction of light chain FR3 sub-bank is carried out using the Polymerase Chain Reaction by overlap extension using the oligonucleotides listed in Table 16 and Table 17 (all shown in the 5' to 3' orientation, name followed by sequence):

Table 16. Light Chain FR3 Forward Primers (for Sub-Bank 3)

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598 FR3L1
GGGGTCCCAGACAGATTCAGCGGCAGTGGGTCAGGCACTGATTTCACTGAAAATCAG

599 FR3L2
GGGGTCCCAGACAGATTCAGCGGCAGTGGGTCAGGCACTGATTTCACTGAAAATCAG

5 600 FR3L3
GGAGTGCCAGATAGGTTCACTGGCAGCGGGTCAGGGACAGATTTCACTGAAAATCAG

601 FR3L4
GGGGTCCCTGACAGGTTCACTGGCAGTGGATCAGGCACAGATTTTCACTGAAAATCAG

10 602 FR3L5
GGAGTGCCAGATAGGTTCACTGGCAGCGGGTCAGGGACAGATTTCACTGAAAATCAG

603 FR3L6
GGGGTCCCAGACAGATTCAGTGGCAGTGGGGCAGGGACAGATTTCACTGAAAATCAG

604 FR3L7
GGGGTCCCTGACAGGTTCACTGGCAGTGGATCAGGCACAGATTTTCACTGAAAATCAG

15 605 FR3L8
GGAGTGCCAGATAGGTTCACTGGCAGCGGGTCAGGGACAGATTTCACTGAAAATCAG

606 FR3L9
GGGGTCCCAGACAGATTCAGTGGCAGTGGGGCAGGGACAGATTTCACTGAAAATCAG

20 607 FR3L10
GGGGTCCCCTCGAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAA

608 FR3L11
GGGGTCCCCTCGAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTTTACCATCAG

609 FR3L12
GGGGTCCCATCTCGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG

25 610 FR3L13
GGGGTCCCCTCGAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAA

611 FR3L14
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGAAATTCCTCTCACAATCAG

30 612 FR3L15
GGAATCCCACCTCGATTCAGTGGCAGCGGGTATGGAACAGATTTTCACTCTCACAATTAA

613 FR3L16
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG

614 FR3L17
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGCACAGATTTCACTCTCACCATCAG

35 615 FR3L18
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGAAATTCCTCTCACCATCAG

616 FR3L19
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGAAATTCCTCTCACAATCAG

40 617 FR3L20
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG

618 FR3L21
GGCATCCCAGCCAGGTTCACTGGCAGTGGGTCTGGGACAGAGTTCACTCTCACCATCAG

619 FR3L22
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG

45 620 FR3L23
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACAGATTTCACTCTCACTATCAG

621 FR3L24
GGTATCCCAGCCAGGTTCACTGGCAGTGGGTCTGGGACAGAGTTCACTCTCACCATCAG

50 622 FR3L25
GGCATCCCAGCCAGGTTCACTGGCAGTGGGCCTGGGACAGACTTCACTCTCACCATCAG

623 FR3L26
GGGGTCTCATCGAGGTTCACTGGCAGGGGATCTGGGACGGATTTCACTCTCACCATCAT

624 FR3L27
GGGGTCCCATCAAGGTTCACTGGCAGTGGATCTGGGACGGATTCACTCTCACCATCAG

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625	FR3L28	GGGGTCCCATCAAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG
626	FR3L29	GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG
5 627	FR3L30	GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG
628	FR3L31	GGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAG
10 629	FR3L32	GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAATTCACTCTCACAATCAG
630	FR3L33	GGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG
631	FR3L34	GGGGTCCCATCAAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG
15 632	FR3L35	GGAGTCCCATCTCGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACTATCAG
633	FR3L36	GGGGTCCCATCAAGGTTTCAGTGGAAGTGGATCTGGGACAGATTTTACTTTTACCATCAG
20 634	FR3L37	GGGGTCCCATCAAGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACCATCAG
635	FR3L38	GGAGTCCCATCTCGGTTTCAGTGGCAGTGGATCTGGGACAGATTTCACTCTCACTATCAG
636	FR3L39	GGGGTCCCATCAAGGTTTCAGTGGAAGTGGATCTGGGACAGATTTTACTTTTACCATCAG
25 637	FR3L40	AGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAG
638	FR3L41	GGCATCCCAGCCAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAG
30 639	FR3L42	GGCATCCCAGACAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAG
640	FR3L43	GGCATCCCAGACAGGTTTCAGTGGCAGTGGGTCTGGGACAGACTTCACTCTCACCATCAG
641	FR3L44	GGGGTCCCTGACCGATTTCAGTGGCAGCGGGTCTGGGACAGATTTCACTCTCACCATCAG
35 642	FR3L45	GGAGTCCCAGACAGGTTTCAGTGGCAGTGGGTCAGGCACTGATTTTCACTGAAAATCAG
643	FR3L46	GGAGTCCCAGACAGGTTTCAGTGGCAGTGGGTCAGGCACTGATTTTCACTGAAAATCAG

40 **Table 17. Light Chain FR3 Reverse Primers (for Sub-Bank 3)**

644	FR3L1'	GCAGTAATAAACCCCAACATCCTCAGCCTCCACCCTGCTGATTTTCAGTGTGAAA
645	FR3L2'	GCAGTAATAAACCCCAACATCCTCAGCCTCCACCCTGCTGATTTTCAGTGTGAAA
646	FR3L3	TCAGTAATAAACCCCAACATCCTCAGCCTCCACCCGGCTGATTTTCAGTGTGAAA
647	FR3L4'	GCAGTAATAAACCCCAACATCCTCAGCCTCCACTCTGCTGATTTTCAGTGTAAAA
45 648	FR3L5'	GCAGTAATAAACCCCAACATCCTCAGCCTCCACCCGGCTGATTTTCAGTGTGAAA
649	FR3L6'	GCAGTAATAAACCCCGACATCCTCAGCTTCCACCCTGCTGATTTTCAGTGTGAAA
650	FR3L7'	GCAGTAATAAACCCCAACATCCTCAGCCTCCACTCTGCTGATTTTCAGTGTAAAA
651	FR3L8'	GCAGTAATAAACTCCAAAATCCTCAGCCTCCACCCGGCTGATTTTCAGTGTGAAA
652	FR3L9'	GCAGTAATAAACCCCGACATCCTCAGCTTCCACCCTGCTGATTTTCAGTGTGAAA
50 653	FR3L10'	ACAGTAATACGTTGCAGCATCTTCAGCTTCCAGGCTATTGATGGTGAGGGTGAAA

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	654	FR3L11'	ACAGTAATATGTTGCAGCATCTTCAGCTTCCAGGCTACTGATGGTAAAGGTGAAA
	655	FR3L12'	ACAGTAATAAGTTGCAACATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
	656	FR3L13'	ACAGTAATACGTTGCAGCATCTTCAGCTTCCAGGCTATTGATGGTGAGGGTGAAA
	657	FR3L14'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATTGTGAGAGTGAAT
5	658	FR3L15'	ACAGAAGTAATATGCAGCATCCTCAGATTCTATGTTATTAATTGTGAGGGTAAAA
	659	FR3L16'	GCAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
	660	FR3L17'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
	661	FR3L18'	GCAGTAATAAGTTGCAAAAATCATCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAT
	662	FR3L19'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATTGTGAGAGTGAAT
10	663	FR3L20'	GCAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
	664	FR3L21'	ACAGTAATAAACTGCAAAAATCTTCAGACTGCAGGCTGCTGATGGTGAGAGTGAAC
	665	FR3L22'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
	666	FR3L23'	ACAATAGTAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATAGTGAGAGTGAAA
	667	FR3L24'	ACAGTAATAAACTGCAAAAATCTTCAGACTGCAGGCTGCTGATGGTGAGAGTGAAC
15	668	FR3L25'	ACAGTAATAAACTGCAAAAATCTTCAGGCTCTAGGCTGCTGATGGTGAGAGTGAAG
	669	FR3L26'	ACAGTAATAAGCTGCAAAAATCTTCAGGCTTCAGGCTGATGATGGTGAGAGTGAAA
	670	FR3L27'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGTA
	671	FR3L28'	ACAGTAATAAGTTGCAAAAATCTTCAGACTGCAGGCAACTGATGGTGAGAGTGAAA
	672	FR3L29'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
20	673	FR3L30'	ACAATAGTAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAA
	674	FR3L31'	ACAGTAATAAACTGCAAAAATCTTCAGGCTCTAGGCTGCTGATGGTGAGAGTGAAG
	675	FR3L32'	ACAGTAATAAGTTGCAAAAATCTTCAGGCTGCAGGCTGCTGATTGTGAGAGTGAAT
	676	FR3L33'	ACAGTAATAAGTTGCAAAAATCTTCAGACTGCAGGCAGCTGATGGTGAGAGTGAAA
	677	FR3L34'	ACAGTAGTAAGTTGCAAAAATCTTCAGGTTGCAGACTGCTGATGGTGAGAGTGAAA
25	678	FR3L35'	ACCGTAATAAGTTGCAACATCTTCAGGCTGCAGGCTGCTGATAGTGAGAGTGAAA
	679	FR3L36'	ACAGTAATATGTTGCAATATCTTCAGGCTGCAGGCTGCTGATGGTGAAAGTAAAA
	680	FR3L37'	ACAGTAGTAAGTTGCAAAAATCTTCAGGTTGCAGACTGCTGATGGTGAGAGTGAAA
	681	FR3L38'	ACCGTAATAAGTTGCAACATCTTCAGGCTGCAGGCTGCTGATAGTGAGAGTGAAA
	682	FR3L39'	ACAGTAATATGTTGCAATATCTTCAGGCTGCAGGCTGCTGATGGTGAAAGTAAAA
30	683	FR3L40'	ACAGTAATAAACTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAG
	684	FR3L41'	ACAGTAATAAACTGCAAAAATCTTCAGGCTGCAGGCTGCTGATGGTGAGAGTGAAG
	685	FR3L42'	ACAGTAATACACTGCAAAAATCTTCAGGCTCCAGTCTGCTGATGGTGAGAGTGAAG
	686	FR3L43'	ACAGTAATACACTGCAAAAATCTTCAGGCTCCAGTCTGCTGATGGTGAGAGTGAAG
	687	FR3L44'	ACAGTAATAAACTGCCACATCTTCAGCCTGCAGGCTGCTGATGGTGAGAGTGAAA
35	688	FR3L45'	GCAGTAATAAACTCCAACATCCTCAGCCTCCACCCTGCTGATTTTCAGTGTGAAA
	689	FR3L46'	GCAGTAATAAACTCCAACATCCTCAGCCTCCACCCTGCTGATTTTCAGTGTGAAA

PCR is carried out using the following oligonucleotide combinations (46 in total): FR3L1/FR3L1', FR3L2/FR3L2', FR3L3/FR3L3', FR3L4/FR3L4', FR3L5/FR3L5',
 40 FR3L6/FR3L6', FR3L7/FR3L7', FR3L8/FR3L8', FR3L9/FR3L9', FR3L10/FR3L10',
 FR3L11/FR3L11', FR3L12/FR3L12', FR3L13/FR3L13', FR3L14/FR3L14',
 FR3L15/FR3L15', FR3L16/FR3L16', FR3L17/FR3L17', FR3L18/FR3L18',

FR3L19/FR3L19', FR3L20/FR3L20', FR3L21/FR3L21', FR3L22/FR3L22',
 FR3L23/FR3L23', FR3L24/FR3L24', FR3L25/FR3L25', FR3L26/FR3L26',
 FR3L27/FR3L27', FR3L28/FR3L28', FR3L29/FR3L29', FR3L30/FR3L30',
 FR3L31/FR3L31', FR3L32/FR3L32', FR3L33/FR3L33', FR3L34/FR3L34',
 5 FR3L35/FR3L35', FR3L36/FR3L36', FR3L37/FR3L37', FR3L38/FR3L38',
 FR3L39/FR3L39', FR3L40/FR3L40', FR3L41/FR3L41', FR3L42/FR3L42',
 FR3L43/FR3L43', FR3L44/FR3L44', FR3L45/FR3L45', and FR3L46/FR3L46'. The
 pooling of the PCR products generates sub-bank 3.

By way of example but not limitation, the construction of light chain FR4
 10 sub-bank is carried out using the Polymerase Chain Reaction by overlap extension using the
 oligonucleotides listed in Table 18 and Table 19 (all shown in the 5' to 3' orientation, name
 followed by sequence):

Table 18. Light Chain FR4 Forward Primers (for Sub-Bank 4)

690	FR4L1	TTCGGCCAAGGGACCAAGGTGGAAATCAAA
15 691	FR4L2	TTTGGCCAGGGGACCAAGCTGGAGATCAAA
692	FR4L3	TTCGGCCCTGGGACCAAAGTGGATATCAAA
693	FR4L4	TTCGGCGGAGGGACCAAGGTGGAGATCAAA
694	FR4L5	TTCGGCCAAGGGACACGACTGGAGATTAAA

20 **Table 19. Light Chain FR4 Reverse Primers (for Sub-Bank 4)**

695	FR4L1'	TTTGATTTCACCTTGGTCCCTTGGCCGAA
696	FR4L2'	TTTGATCTCCAGCTTGGTCCCCTGGCCAAA
697	FR4L3'	TTTGATATCCACTTTGGTCCCAGGGCCGAA
698	FR4L4'	TTTGATCTCCACCTTGGTCCCTCCGCCGAA
25 699	FR4L5'	TTTAATCTCCAGTCGTGTCCCTTGGCCGAA

PCR is carried out using the following oligonucleotide combinations (5 in
 total): FR4L1/FR4L1', FR4L2/FR4L2', FR4L3/FR4L3', FR4L4/FR4L4', or
 FR4L5/FR4L5'. The pooling of the PCR products generates sub-bank 4.

30 **2.2.2 Generation of Sub-banks for the Heavy Chain Frameworks**

In some embodiments, heavy chain FR sub-banks 5, 6, 7 and 11 are
 constructed wherein sub-bank 5 comprises a plurality of nucleic acid sequences comprising
 nucleotide sequences, each nucleotide sequence encoding a heavy chain FR1; sub-bank 6
 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each
 35 nucleotide sequence encoding a heavy chain FR2; sub-bank 7 comprises a plurality of

nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding a heavy chain FR3; and sub-bank 11 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding a heavy chain FR4, respectively; wherein the heavy chain FR1, FR2, and FR3 are defined according to Kabat definition for CDR H1 and H2. In some embodiments, the FR sequences are derived from functional human antibody sequences. In other embodiments, the FR sequences are derived from human germline heavy chain sequences.

By way of example but not limitation, the following describes a method of generating 4 heavy chain FR sub-banks using Polymerase Chain Reaction (PCR), wherein human germline heavy chain sequences are used as templates. Heavy chain FR sub-banks 5, 6 and 7 (encoding FR1, 2, 3 respectively) encompass 44 human germline heavy chain sequences (VH1-18, VH1-2, VH1-24, VH1-3, VH1-45, VH1-46, VH1-58, VH1-69, VH1-8, VH2-26, VH2-5, VH2-70, VH3-11, VH3-13, VH3-15, VH3-16, VH3-20, VH3-21, VH3-23, VH3-30, VH3-33, VH3-35, VH3-38, VH3-43, VH3-48, VH3-49, VH3-53, VH3-64, VH3-66, VH3-7, VH3-72, VH3-73, VH3-74, VH3-9, VH4-28, VH4-31, VH4-34, VH4-39, VH4-4, VH4-59, VH4-61, VH5-51, VH6-1 and VH7-81). See Matsuda *et al.*, 1998, J. Exp. Med., 188:1973-1975. The sequences are summarized at the NCBI website: www.ncbi.nlm.nih.gov/igblast/showGermline.cgi?organism=human&chainType=VH&seqType=nucleotide. Heavy chain FR sub-bank 11 (encoding FR4) encompasses 6 human germline heavy chain sequences (JH1, JH2, JH3, JH4, JH5 and JH6). See Ravetch *et al.*, 1981, Cell 27(3 Pt 2):583-591. The sequences are summarized at the NCBI website: www.ncbi.nlm.nih.gov/igblast/showGermline.cgi?organism=human&chainType=JH&seqType=nucleotide.

By way of example but not limitation, the construction of heavy chain FR1 sub-bank (according to Kabat definition) is carried out using the Polymerase Chain Reaction by overlap extension using the oligonucleotides listed in Table 20 and Table 21 (all shown in the 5' to 3' orientation, name followed by sequence):

Table 20. Heavy Chain FR1 (Kabat Definition) Forward Primers (for Sub-Bank 5):

30	700	FR1HK1 CAGGTTTCAGCTGGTGCAGTCTGGAGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGT
	701	FR1HK2 CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGT
	702	FR1HK3 CAGGTCCAGCTGGTACAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGT
35	703	FR1HK4 CAGGTTTCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGT

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704 FR1HK5
 CAGATGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGACTGGGTCCTCAGTGAAGGT
 705 FR1HK6
 CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGT
 5 706 FR1HK7
 CAAATGCAGCTGGTGCAGTCTGGGCCTGAGGTGAAGAAGCCTGGGACCTCAGTGAAGGT
 707 FR1HK8
 CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGTCCTCGGTGAAGGT
 10 708 FR1HK9
 CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGTGAAGGT
 709 FR1HK10
 CAGGTCACCTTGAAGGAGTCTGGTCCTGTGCTGGTGAAACCCACAGAGACCCTCACGCT
 710 FR1HK11
 CAGATCACCTTGAAGGAGTCTGGTCCTACGCTGGTGAAACCCACACAGACCCTCACGCT
 15 711 FR1HK12
 CAGGTCACCTTGAGGGAGTCTGGTCCTGCGCTGGTGAAACCCACACAGACCCTCACACT
 712 FR1HK13
 CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCAAGCCTGGAGGGTCCCTGAGACT
 20 713 FR1HK14
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACT
 714 FR1HK15
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTAAAGCCTGGGGGGTCCCTTAGACT
 715 FR1HK16
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACT
 25 716 FR1HK17
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGTGTGGTACGGCCTGGGGGGTCCCTGAGACT
 717 FR1HK18
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCCTGGTCAAGCCTGGGGGGTCCCTGAGACT
 30 718 FR1HK19
 GAGGTGCAGCTGTTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACT
 719 FR1HK20
 CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCCCTGAGACT
 720 FR1HK21
 CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCCCTGAGACT
 35 721 FR1HK22
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGATCCCTGAGACT
 722 FR1HK23
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTAGGGGGTCCCTGAGACT
 40 723 FR1HK24
 GAAGTGCAGCTGGTGGAGTCTGGGGGAGTCGTGGTACAGCCTGGGGGGTCCCTGAGACT
 724 FR1HK25
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCCCTGAGACT
 725 FR1HK26
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCAGGGCGGTCCCTGAGACT
 45 726 FR1HK27
 GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCCCTGAGACT
 727 FR1HK28
 GAGGTGCAGCTGGTGGAGTCTGGGGAAGGCTTGGTCCAGCCTGGGGGGTCCCTGAGACT
 50 728 FR1HK29
 GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCCCTGAGACT
 729 FR1HK30
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGGGGGTCCCTGAGACT
 730 FR1HK31
 GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGAGGGTCCCTGAGACT

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5	731	FR1HK32	GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTGGTCCAGCCTGGGGGGTCCCTGAAACT
	732	FR1HK33	GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTAGTTCAGCCTGGGGGGTCCCTGAGACT
10	733	FR1HK34	GAAGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGCAGGTCCCTGAGACT
	734	FR1HK35	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGACACCCTGTCCCT
15	735	FR1HK36	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCACAGACCCTGTCCCT
	736	FR1HK37	CAGGTGCAGCTACAGCAGTGGGGCGCAGGACTGTTGAAGCCTTCGGAGACCCTGTCCCT
20	737	FR1HK38	CAGCTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCT
	738	FR1HK39	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCT
25	739	FR1HK40	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCT
	740	FR1HK41	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCT
30	741	FR1HK42	GAGGTGCAGCTGGTGCAGTCTGGAGCAGAGGTGAAAAAGCCCGGGGAGTCTCTGAAGAT
	742	FR1HK43	CAGGTACAGCTGCAGCAGTCAGGTCCAGGACTGGTGAAGCCCTCGCAGACCCTCTCACT
35	743	FR1HK44	CAGGTGCAGCTGGTGCAGTCTGGCCATGAGGTGAAGCAGCCTGGGGCCTCAGTGAAGGT

Table 21. Heavy Chain FR1 (Kabat Definition) Reverse Primers (for Sub-Bank 5):

30	744	FR1HK1'	GGTAAAGGTGTAACCAGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGC
	745	FR1HK2'	GGTGAAGGTGTATCCAGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGC
35	746	FR1HK3'	AGTGAGGGTGTATCCGGAAACCTTGCAGGAGACCTTCACTGAGGCCCCAGGC
	747	FR1HK4'	AGTGAAGGTGTATCCAGAAGCCTTGCAGGAAACCTTCACTGAGGCCCCAGGC
40	748	FR1HK5'	GGTGAAGGTGTATCCGGAAGCCTTGCAGGAAACCTTCACTGAGGACCCAGTC
	749	FR1HK6'	GGTGAAGGTGTATCCAGATGCCTTGCAGGAAACCTTCACTGAGGCCCCAGGC
45	750	FR1HK7'	AGTAAAGGTGAATCCAGAAGCCTTGCAGGAGACCTTCACTGAGGTCCCAGGC
	751	FR1HK8'	GCTGAAGGTGCCTCCAGAAGCCTTGCAGGAGACCTTCACTGAGGACCCAGGC
50	752	FR1HK9'	GGTGAAGGTGTATCCAGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGC
	753	FR1HK10'	GCTGAGTGAGAACCCAGAGACGGTGCAGGTGACGTGAGGGTCTCTGTGGGT
55	754	FR1HK11'	GCTGAGTGAGAACCCAGAGAAGGTGCAGGTGACGTGAGGGTCTGTGTGGGT
	755	FR1HK12'	GCTGAGTGAGAACCCAGAGAAGGTGCAGGTGACGTGAGGGTCTGTGTGGGT
60	756	FR1HK13'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCTCCAGGC
	757	FR1HK14'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
65	758	FR1HK15'	ACTGAAAGTGAATCCAGAGGCTGCACAGGAGAGTCTAAGGGACCCCCCAGGC
	759	FR1HK16'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
70	760	FR1HK17'	ATCAAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	761	FR1HK18'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
75	762	FR1HK19'	GCTAAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	763	FR1HK20'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCTCCCAGGC

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	764	FR1HK21'	ACTGAAGGTGAATCCAGACGCTGCACAGGAGAGTCTCAGGGACCTCCCAGGC
	765	FR1HK22'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGATCCCCCAGGC
	766	FR1HK23'	ACTGACGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCTAGGC
	767	FR1HK24'	ATCAAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
5	768	FR1HK25'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	769	FR1HK26'	ACCAAAGGTGAATCCAGAAGCTGTACAGGAGAGTCTCAGGGACCGCCCTGGC
	770	FR1HK27'	ACTGACGGTGAACCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	771	FR1HK28'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	772	FR1HK29'	ACTGACGGTGAACCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
10	773	FR1HK30'	ACTAAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	774	FR1HK31'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCTCCAGGC
	775	FR1HK32'	ACTGAAGGTGAACCCAGAGGCTGCACAGGAGAGTTTCAGGGACCCCCCAGGC
	776	FR1HK33'	ACTGAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGC
	777	FR1HK34'	ATCAAAGGTGAATCCAGAGGCTGCACAGGAGAGTCTCAGGGACCTGCCAGGC
15	778	FR1HK35'	GCTGATGGAGTAACCAGAGACAGCGCAGGTGAGGGACAGGGTGTCCGAAGGC
	779	FR1HK36'	GCTGATGGAGCCACCAGAGACAGTACAGGTGAGGGACAGGGTCTGTGAAGGC
	780	FR1HK37'	ACTGAAGGACCCACCATAGACAGCGCAGGTGAGGGACAGGGTCTCCGAAGGC
	781	FR1HK38'	GCTGATGGAGCCACCAGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGC
	782	FR1HK39'	ACTGATGGAGCCACCAGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGC
20	783	FR1HK40'	ACTGATGGAGCCACCAGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGC
	784	FR1HK41'	GCTGACGGAGCCACCAGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGC
	785	FR1HK42'	GGTAAAGCTGTATCCAGAACCCTTACAGGAGATCTTCAGAGACTCCCCGGGC
	786	FR1HK43'	AGAGACACTGTCCCCGGAGATGGCACAGGTGAGTGAGAGGGTCTGCGAGGGC
	787	FR1HK44'	GGTGAAACTGTAACCAGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGC
25			

PCR is carried out using the following oligonucleotide combinations (44 in total): FR1HK1/FR1HK1', FR1HK2/FR1HK2', FR1HK3/FR1HK3', FR1HK4/FR1HK4', FR1HK5/FR1HK5', FR1HK6/FR1HK6', FR1HK7/FR1HK7', FR1HK8/FR1HK8', FR1HK9/FR1HK9', FR1HK10/FR1HK10', FR1HK11/FR1HK11', FR1HK12/FR1HK12', FR1HK13/FR1HK13', FR1HK14/FR1HK14', FR1HK15/FR1HK15', FR1HK16/FR1HK16', FR1HK17/FR1HK17', FR1HK18/FR1HK18', FR1HK19/FR1HK19', FR1HK20/FR1HK20', FR1HK21/FR1HK21', FR1HK22/FR1HK22', FR1HK23/FR1HK23', FR1HK24/FR1HK24', FR1HK25/FR1HK25', FR1HK26/FR1HK26', FR1HK27/FR1HK27', FR1HK28/FR1HK28', FR1HK29/FR1HK29', FR1HK30/FR1HK31', FR1HK32/FR1HK32', FR1HK33/FR1HK33', FR1HK34/FR1HK34', FR1HK35/FR1HK35', FR1HK36/FR1HK36', FR1HK37/FR1HK37', FR1HK38/FR1HK38', FR1HK39/FR1HK39', FR1HK40/FR1HK40', FR1HK41/FR1HK41', FR1HK42/FR1HK42', FR1HK43/FR1HK43', or FR1HK44/FR1HK44'. The pooling of the PCR products generates sub-bank 5.

By way of example but not limitation, the construction of heavy chain FR2 sub-bank (according to Kabat definition) is carried out using the Polymerase Chain Reaction by overlap extension using the oligonucleotides listed in Table 22 and Table 23 (all shown in the 5' to 3' orientation, name followed by sequence):

5 **Table 22. Heavy Chain FR2 (Kabat Definition) Forward Primers (for Sub-Bank 6):**

	788	FR2HK1	TGGGTGCGACAGGCCCCCTGGACAAGGGCTTG
	789	FR2HK2	TGGGTGCGACAGGCCCCCTGGACAAGGGCTTG
	790	FR2HK3	TGGGTGCGACAGGCTCCTGGAAAAGGGCTTG
	791	FR2HK4	TGGGTGCGCCAGGCCCCCGGACAAAGGCTTG
10	792	FR2HK5	TGGGTGCGACAGGCCCCCGGACAAGCGCTTG
	793	FR2HK6	TGGGTGCGACAGGCCCCCTGGACAAGGGCTTG
	794	FR2HK7	TGGGTGCGACAGGCTCGTGGACAACGCCTTG
	795	FR2HK8	TGGGTGCGACAGGCCCCCTGGACAAGGGCTTG
	796	FR2HK9	TGGGTGCGACAGGCCACTGGACAAGGGCTTG
15	797	FR2HK10	TGGATCCGTCAGCCCCCAGGGAAGGCCCTGG
	798	FR2HK11	TGGATCCGTCAGCCCCCAGGAAAGGCCCTGG
	799	FR2HK12	TGGATCCGTCAGCCCCCAGGGAAGGCCCTGG
	800	FR2HK13	TGGATCCGCCAGGCTCCAGGGAAGGGGCTGG
	801	FR2HK14	TGGGTCCGCCAAGCTACAGGAAAAGGTCTGG
20	802	FR2HK15	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
	803	FR2HK16	TGGGCCCCGCAAGGCTCCAGGAAAGGGGCTGG
	804	FR2HK17	TGGGTCCGCCAAGCTCCAGGGAAGGGGCTGG
	805	FR2HK18	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
	806	FR2HK19	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
25	807	FR2HK20	TGGGTCCGCCAGGCTCCAGGCAAGGGGCTGG
	808	FR2HK21	TGGGTCCGCCAGGCTCCAGGCAAGGGGCTGG
	809	FR2HK22	TGGGTCCATCAGGCTCCAGGAAAGGGGCTGG
	810	FR2HK23	TGGATCCGCCAGGCTCCAGGGAAGGGGCTGG
	811	FR2HK24	TGGGTCCGTCAAGCTCCGGGGAAGGGTCTGG
30	812	FR2HK25	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
	813	FR2HK26	TGGTTCGCCAGGCTCCAGGGAAGGGGCTGG
	814	FR2HK27	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
	815	FR2HK28	TGGGTCCGCCAGGCTCCAGGGAAGGGACTGG
	816	FR2HK29	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
35	817	FR2HK30	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
	818	FR2HK31	TGGGTCCGCCAGGCTCCAGGGAAGGGGCTGG
	819	FR2HK32	TGGGTCCGCCAGGCTTCCGGGAAAGGGCTGG
	820	FR2HK33	TGGGTCCGCCAAGCTCCAGGGAAGGGGCTGG
	821	FR2HK34	TGGGTCCGGCAAGCTCCAGGGAAGGGCCTGG
40	522	FR2HK35	TGGATCCGGCAGCCCCCAGGGAAGGGACTGG
	823	FR2HK36	TGGATCCGCCAGCACCCAGGGAAGGGCCTGG
	824	FR2HK37	TGGATCCGCCAGCCCCCAGGGAAGGGGCTGG

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	825	FR2HK38	TGGATCCGCCAGCCCCCAGGGAAGGGGCTGG
	826	FR2HK39	TGGATCCGGCAGCCCGCCGGGAAGGGACTGG
	827	FR2HK40	TGGATCCGGCAGCCCCCAGGGAAGGGACTGG
	828	FR2HK41	TGGATCCGGCAGCCCCCAGGGAAGGGACTGG
5	829	FR2HK42	TGGGTGCGCCAGATGCCCCGGGAAAGGCCTGG
	830	FR2HK43	TGGATCAGGCAGTCCCCATCGAGAGGCCTTG
	831	FR2HK44	TGGGTGCCACAGGCCCTGGACAAGGGCTTG

Table 23. Heavy Chain FR2 (Kabat Definition) Reverse Primers (for Sub-Bank 6):

10	832	FR2HK1'	TCCCATCCACTCAAGCCCTTGTCCAGGGGCCT
	833	FR2HK2'	TCCCATCCACTCAAGCCCTTGTCCAGGGGCCT
	834	FR2HK3'	TCCCATCCACTCAAGCCCTTTTCCAGGAGCCT
	835	FR2HK4'	TCCCATCCACTCAAGCCTTTGTCCGGGGGCCT
	836	FR2HK5'	TCCCATCCACTCAAGCGCTTGTCCGGGGGCCT
15	837	FR2HK6'	TCCCATCCACTCAAGCCCTTGTCCAGGGGCCT
	838	FR2HK7'	TCCTATCCACTCAAGGCGTTGTCCACGAGCCT
	839	FR2HK8'	TCCCATCCACTCAAGCCCTTGTCCAGGGGCCT
	840	FR2HK9'	TCCCATCCACTCAAGCCCTTGTCCAGTGGCCT
	841	FR2HK10'	TGCAAGCCACTCCAGGGCCTTCCCTGGGGGCT
20	842	FR2HK11'	TGCAAGCCACTCCAGGGCCTTTCCTGGGGGCT
	843	FR2HK12'	TGCAAGCCACTCCAGGGCCTTCCCTGGGGGCT
	844	FR2HK13'	TGAAACCCACTCCAGCCCCTTCCCTGGAGCCT
	845	FR2HK14'	TGAGACCCACTCCAGACCTTTTCCTGTAGCTT
	846	FR2HK15'	GCCAACCCACTCCAGCCCCTTCCCTGGAGCCT
25	847	FR2HK16'	CGATACCCACTCCAGCCCCTTTCCTGGAGCCT
	848	FR2HK17'	AGAGACCCACTCCAGCCCCTTCCCTGGAGCCT
	849	FR2HK18'	TGAGACCCACTCCAGCCCCTTCCCTGGAGCCT
	850	FR2HK19'	TGAGACCCACTCCAGCCCCTTCCCTGGAGCCT
	851	FR2HK20'	TGCCACCCACTCCAGCCCCTTGCCTGGAGCCT
30	852	FR2HK21'	TGCCACCCACTCCAGCCCCTTGCCTGGAGCCT
	853	FR2HK22'	CGATACCCACTCCAGCCCCTTTCCTGGAGCCT
	854	FR2HK23'	TGAGACCCACTCCAGCCCCTTCCCTGGAGCCT
	855	FR2HK24'	AGAGACCCACTCCAGACCCTTCCCCGGAGCTT
	856	FR2HK25'	TGAAACCCACTCCAGCCCCTTCCCTGGAGCCT
35	857	FR2HK26'	ACCTACCCACTCCAGCCCCTTCCCTGGAGCCT
	858	FR2HK27'	TGAGACCCACTCCAGCCCCTTCCCTGGAGCCT
	859	FR2HK28'	TGAAACATATTCCAGTCCCTTCCCTGGAGCCT
	860	FR2HK29'	TGAGACCCACTCCAGCCCCTTCCCTGGAGCCT
	861	FR2HK30	GGCCACCCACTCCAGCCCCTTCCCTGGAGCCT
40	862	FR2HK31'	GCCAACCCACTCCAGCCCCTTCCCTGGAGCCT
	863	FR2HK32'	GCCAACCCACTCCAGCCCTTTCCCGGAAGCCT
	864	FR2HK33'	TGAGACCCACACCAGCCCCTTCCCTGGAGCTT
	865	FR2HK34'	TGAGACCCACTCCAGGCCCTTCCCTGGAGCTT

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	866	FR2HK35'	CCCAATCCACTCCAGTCCCTTCCCTGGGGGCT
	867	FR2HK36'	CCCAATCCACTCCAGGCCCTTCCCTGGGTGCT
	868	FR2HK37'	CCCAATCCACTCCAGCCCCTTCCCTGGGGGCT
	869	FR2HK38'	CCCAATCCACTCCAGCCCCTTCCCTGGGGGCT
5	870	FR2HK39'	CCCAATCCACTCCAGTCCCTTCCCGGCGGGCT
	871	FR2HK40'	CCCAATCCACTCCAGTCCCTTCCCTGGGGGCT
	872	FR2HK41'	CCCAATCCACTCCAGTCCCTTCCCTGGGGGCT
	873	FR2HK42'	CCCCATCCACTCCAGGCCTTTCCCGGGCATCT
	874	FR2HK43'	TCCCAGCCACTCAAGGCCTCTCGATGGGGACT
10	875	FR2HK44'	TCCCATCCACTCAAGCCCTTGTCCAGGGGCCT

PCR is carried out using the following oligonucleotide combinations (44 in total): FR2HK1/FR2HK1', FR2HK2/FR2HK2', FR2HK3/FR2HK3', FR2HK4/FR2HK4', FR2HK5/FR2HK5', FR2HK6/FR2HK6', FR2HK7/FR2HK7', FR2HK8/FR2HK8', FR2HK9/FR2HK9', FR2HK10/FR2HK10', FR2HK11/FR2HK11', FR2HK12/FR2HK12', FR2HK13/FR2HK13', FR2HK14/FR2HK14', FR2HK15/FR2HK15', FR2HK16/FR2HK16', FR2HK17/FR2HK17', FR2HK18/FR2HK18', FR2HK19/FR2HK19', FR2HK20/FR2HK20', FR2HK21/FR2HK21', FR2HK22/FR2HK22', FR2HK23/FR2HK23', FR2HK24/FR2HK24', FR2HK25/FR2HK25', FR2HK26/FR2HK26', FR2HK27/FR2HK27', FR2HK28/FR2HK28', FR2HK29/FR2HK29', FR2HK30/FR2HK31', FR2HK32/FR2HK32', FR2HK33/FR2HK33', FR2HK34/FR2HK34', FR2HK35/FR2HK35', FR2HK36/FR2HK36', FR2HK37/FR2HK37', FR2HK38/FR2HK38', FR2HK39/FR2HK39', FR2HK40/FR2HK40', FR2HK41/FR2HK41', FR2HK42/FR2HK42', FR2HK43/FR2HK43', or FR2HK44/FR2HK44'. The pooling of the PCR products generates sub-bank 6.

By way of example but not limitation, the construction of heavy chain FR3 sub-bank (according to Kabat definition) is carried out using the Polymerase Chain Reaction by overlap extension using the oligonucleotides listed in Table 24 and Table 25 (all shown in the 5' to 3' orientation, name followed by sequence):

Table 24. Heavy Chain FR3 (Kabat Definition) Forward Primers (for Sub-Bank 7):

	876	FR3HK1	AGAGTCACCATGACCACAGACACATCCACGAGCACAGCCTACATGGAGCTGAGGAGCCTGAGATCTG
	877	FR3HK2	AGGGTCACCATGACCAGGGACACGTCCATCAGCACAGCCTACATGGAGCTGAGCAGGCTGAGATCTG
	878	FR3HK3	AGAGTCACCATGACCGAGGACACATCTACAGACACAGCCTACATGGAGCTGAGCAGCCTGAGATCTG
35	879	FR3HK4	AGAGTCACCATTACCAGGGACACATCCGCGAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTG
	880	FR3HK5	AGAGTCACCATTACCAGGGACAGGTCTATGAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTG
	881	FR3HK6	AGAGTCACCATGACCAGGGACACGTCCACGAGCACAGTCTACATGGAGCTGAGCAGCCTGAGATCTG
	882	FR3HK7	AGAGTCACCATTACCAGGGACATGTCCACAAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCCG

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883	FR3HK8	AGAGTCACGATTACCGCGGACAAATCCACGAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTG
884	FR3HK9	AGAGTCACCATGACCAGGAACACCTCCATAAGCACAGCCTACATGGAGCTGAGCAGCCTGAGATCTG
885	FR3HK10	AGGCTCACCATCTCCAAGGACACCTCCAAAAGCCAGGTGGTCCTTACCATGACCAACATGGACCCTG
886	FR3HK11	AGGCTCACCATCACCAGGACACCTCCAAAACCAGGTGGTCCTTACAATGACCAACATGGACCCTG
5	887	FR3HK12 AGGCTCACCATCTCCAAGGACACCTCCAAAACCAGGTGGTCCTTACAATGACCAACATGGACCCTG
888	FR3HK13	CGATTCACCATCTCCAGGGACAACGCCAAGAAGTCACTGTATCTGCAAATGAACAGCCTGAGAGCCG
889	FR3HK14	CGATTCACCATCTCCAGAGAAAATGCCAAGAAGTCTTGTATCTTCAAATGAACAGCCTGAGAGCCG
890	FR3HK15	AGATTCACCATCTCAAGAGATGATTCAAAAAACACGCTGTATCTGCAAATGAACAGCCTGAAAACCG
891	FR3HK16	CGATTCATCATCTCCAGAGACAATTCCAGGAAGTCCCTGTATCTGCAAAGAAGACAGACGGAGAGCCG
10	892	FR3HK17 CGATTCACCATCTCCAGAGACAACGCCAAGAAGTCCCTGTATCTGCAAATGAACAGTCTGAGAGCCG
893	FR3HK18	CGATTCACCATCTCCAGAGACAACGCCAAGAAGTCACTGTATCTGCAAATGAACAGCCTGAGAGCCG
894	FR3HK19	CGGTTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGCAAATGAACAGCCTGAGAGCCG
895	FR3HK20	CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGCAAATGAACAGCCTGAGAGCTG
896	FR3HK21	CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGCAAATGAACAGCCTGAGAGCCG
15	897	FR3HK22 CGATTCATCATCTCCAGAGACAATTCCAGGAACACCCTGTATCTGCAAACGAATAGCCTGAGGGCCG
898	FR3HK23	AGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGAACAACCTGAGAGCTG
899	FR3HK24	CGATTCACCATCTCCAGAGACAACAGCAAAAAGTCCCTGTATCTGCAAATGAACAGTCTGAGAACTG
900	FR3HK25	CGATTCACCATCTCCAGAGACAATTGCCAAGAAGTCACTGTATCTGCAAATGAACAGCCTGAGAGACG
901	FR3HK26	AGATTCACCATCTCAAGAGATGATTCCAAAAGCATCGCCTATCTGCAAATGAACAGCCTGAAAACCG
20	902	FR3HK27 CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGAACAGCCTGAGAGCCG
903	FR3HK28	AGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGGGCAGCCTGAGAGCTG
904	FR3HK29	CGATTCACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTCAAATGAACAGCCTGAGAGCTG
905	FR3HK30	CGATTCACCATCTCCAGAGACAACGCCAAGAAGTCACTGTATCTGCAAATGAACAGCCTGAGAGCCG
906	FR3HK31	AGATTCACCATCTCAAGAGATGATTCAAAGAAGTCACTGTATCTGCAAATGAACAGCCTGAAAACCG
25	907	FR3HK32 AGGTTACCATCTCCAGAGATGATTCAAAGAACACGGCGTATCTGCAAATGAACAGCCTGAAAACCG
908	FR3HK33	CGATTCACCATCTCCAGAGACAACGCCAAGAACACGCTGTATCTGCAAATGAACAGTCTGAGAGCCG
909	FR3HK34	CGATTCACCATCTCCAGAGACAACGCCAAGAAGTCCCTGTATCTGCAAATGAACAGTCTGAGAGCTG
910	FR3HK35	CGAGTCACCATGTCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCG
911	FR3HK36	CGAGTTACCATATCAGTAGACACGTCTAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACTGCCG
30	912	FR3HK37 CGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCG
913	FR3HK38	CGAGTCACCATATCCGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCG
914	FR3HK39	CGAGTCACCATGTCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCCG
915	FR3HK40	CGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCTG
916	FR3HK41	CGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGAAGCTGAGCTCTGTGACCGCTG
35	917	FR3HK42 CAGGTCACCATCTCAGCCGACAAGTCCATCAGCACCGCCTACCTGCAGTGGAGCAGCCTGAAGGCCT
918	FR3HK43	CGAATAACCATCAACCCAGACACATCCAAGAACCAGTTCTCCCTGCAGCTGAACTCTGTGACTCCCG
919	FR3HK44	CGGTTTGTCTTCTCCATGGACACCTCTGCCAGCACAGCATACCTGCAGATCAGCAGCCTAAAGGCTG

Table 25. Heavy Chain FR3 (Kabat Definition) Reverse Primers (for Sub-Bank 7):

40	920	FR3HK1'	TCTCGCACAGTAATACACGGCCGTGTCGTCAGATCTCAGGCTCCTCAGCT
	921	FR3HK2'	TCTCGCACAGTAATACACGGCCGTGTCGTCAGATCTCAGCCTGCTCAGCT
	922	FR3HK3'	TGTTGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCT
	923	FR3HK4'	TCTCGCACAGTAATACACAGCCATGTCCTCAGATCTCAGGCTGCTCAGCT
	924	FR3HK5'	TCTTGCACAGTAATACATGGCTGTGTCCTCAGATCTCAGGCTGCTCAGCT
45	925	FR3HK6'	TCTCGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCT
	926	FR3HK7'	TGCCGCACAGTAATACACGGCCGTGTCCTCGGATCTCAGGCTGCTCAGCT

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	927	FR3HK8'	TCTCGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCT
	928	FR3HK9'	TCTCGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCT
	929	FR3HK10'	CCGTGCACAGTAATATGTGGCTGTGTCCACAGGGTCCATGTTGGTCATGG
	930	FR3HK11'	GTGTGCACAGTAATATGTGGCTGTGTCCACAGGGTCCATGTTGGTCATTG
5	931	FR3HK12'	CCGTGCACAATAATACGTGGCTGTGTCCACAGGGTCCATGTTGGTCATTG
	932	FR3HK13'	TCTCGCACAGTAATACACGGCCGTGTCCTCGGCTCTCAGGCTGTTTCATTT
	933	FR3HK14'	TCTTGCACAGTAATACACAGCCGTGTCCCCGGCTCTCAGGCTGTTTCATTT
	934	FR3HK15'	TGTGGTACAGTAATACACGGCTGTGTCTCGGTTTTTCAGGCTGTTTCATTT
	935	FR3HK16'	TCTCACACAGTAATACACAGCCATGTCCTCGGCTCTCCGTCTGTTCTTTT
10	936	FR3HK17'	TCTCGCACAGTGATACAAGGCCGTGTCCTCGGCTCTCAGACTGTTTCATTT
	937	FR3HK18'	TCTCGCACAGTAATACACAGCCGTGTCCTCGGCTCTCAGGCTGTTTCATTT
	938	FR3HK19'	TTTCGCACAGTAATATACGGCCGTGTCCTCGGCTCTCAGGCTGTTTCATTT
	939	FR3HK20'	TCTCGCACAGTAATACACAGCCGTGTCCTCAGCTCTCAGGCTGTTTCATTT
	940	FR3HK21'	CTCGCACAGTAATACACAGCCGTGTCCTCGGCTCTCAGGCTGTTTCATTT
15	941	FR3HK22'	TCTCACACAGTAATACACAGCCGTGTCCTCGGCCCTCAGGCTATTCGTTT
	942	FR3HK23'	TCTGGCACAGTAATACACGGCCGTGCCCTCAGCTCTCAGGTTGTTTCATTT
	943	FR3HK24'	TTTTGCACAGTAATACAAGGCGGTGTCCTCAGTTCTCAGACTGTTTCATTT
	944	FR3HK25'	TCTCGCACAGTAATACACAGCCGTGTCCTCGTCTCTCAGGCTGTTTCATTT
	945	FR3HK26'	TCTAGTACAGTAATACACGGCTGTGTCTCGGTTTTTCAGGCTGTTTCATTT
20	946	FR3HK27'	TCTCGCACAGTAATACACGGCCGTGTCCTCGGCTCTCAGGCTGTTTCATTT
	947	FR3HK28'	TCTCGCACAGTAATACACAGCCATGTCCTCAGCTCTCAGGCTGCCCATTT
	948	FR3HK29'	TCTCGCACAGTAATACACAGCCGTGTCCTCAGCTCTCAGGCTGTTTCATTT
	949	FR3HK30'	TCTCGCACAGTAATACACAGCCGTGTCCTCGGCTCTCAGGCTGTTTCATTT
	950	FR3HK31'	TCTAGCACAGTAATACACGGCCGTGTCCTCGGTTTTTCAGGCTGTTTCATTT
25	951	FR3HK32'	TCTAGTACAGTAATACACGGCCGTGTCCTCGGTTTTTCAGGCTGTTTCATTT
	952	FR3HK33'	TCTTGCACAGTAATACACAGCCGTGTCCTCGGCTCTCAGACTGTTTCATTT
	953	FR3HK34'	TTTTGCACAGTAATACAAGGCCGTGTCCTCAGCTCTCAGACTGTTTCATTT
	954	FR3HK35'	TCTCGCACAGTAATACACGGCCGTGTCCACGGCGGTCACAGAGCTCAGCT
	955	FR3HK36'	TCTCGCACAGTAATACACGGCCGTGTCCGCGGCAGTCACAGAGCTCAGCT
30	956	FR3HK37'	TCTCGCACAGTAATACACAGCCGTGTCCGCGGCGGTCACAGAGCTCAGCT
	957	FR3HK38'	TCTCGCACAGTAATACACAGCCGTGTCTGCGGCGGTCACAGAGCTCAGCT
	958	FR3HK39'	TCTCGCACAGTAATACACGGCCGTGTCCGCGGCGGTCACAGAGCTCAGCT
	959	FR3HK40'	TCTCGCACAGTAATACACGGCCGTGTCCGCAGCGGTCACAGAGCTCAGCT
	960	FR3HK41'	TCTCGCACAGTAATACACGGCCGTGTCCGCAGCGGTCACAGAGCTCAGCT
35	961	FR3HK42'	TCTCGCACAGTAATACATGGCGGTGTCCGAGGCCTTCAGGCTGCTCCACT
	962	FR3HK43'	TCTTGCACAGTAATACACAGCCGTGTCCTCGGGAGTCACAGAGTTCAGCT
	963	FR3HK44'	TCTCGCACAGTAATACATGGCCATGTCCTCAGCCTTTAGGCTGCTGATCT

PCR is carried out using the following oligonucleotide combinations (44 in total): FR3HK1/FR3HK1', FR3HK2/FR3HK2', FR3HK3/FR3HK3', FR3HK4/FR3HK4', FR3HK5/FR3HK5', FR3HK6/FR3HK6', FR3HK7/FR3HK7', FR3HK8/FR3HK8', FR3HK9/FR3HK9', FR3HK10/FR3HK10', FR3HK11/FR3HK11', FR3HK12/FR3HK12',

FR3HK13/FR3HK13', FR3HK14/FR3HK14', FR3HK15/FR3HK15',
 FR3HK16/FR3HK16', FR3HK17/FR3HK17', FR3HK18/FR3HK18',
 FR3HK19/FR3HK19', FR3HK20/FR3HK20', FR3HK21/FR3HK21',
 FR3HK22/FR3HK22', FR3HK23/FR3HK23', FR3HK24/FR3HK24',
 5 FR3HK25/FR3HK25', FR3HK26/FR3HK26', FR3HK27/FR3HK27',
 FR3HK28/FR3HK28', FR3HK29/FR3HK29', FR3HK30/FR3HK31',
 FR3HK32/FR3HK32', FR3HK33/FR3HK33', FR3HK34/FR3HK34',
 FR3HK35/FR3HK35', FR3HK36/FR3HK36', FR3HK37/FR3HK37',
 FR3HK38/FR3HK38', FR3HK39/FR3HK39', FR3HK40/FR3HK40',
 10 FR3HK41/FR3HK41', FR3HK42/FR3HK42', FR3HK43/FR3HK43', or
 FR3HK44/FR3HK44'. The pooling of the PCR products generates sub-bank 7.

By way of example but not limitation, the construction of heavy chain FR4
 sub-bank is carried out using the Polymerase Chain Reaction by overlap extension using the
 oligonucleotides listed in Table 26 and Table 27 (all shown in the 5' to 3' orientation, name
 15 followed by sequence):

Table 26. Heavy Chain FR4 Forward Primers (for Sub-Bank 11):

964	FR4H1	TGGGGCCAGGGCACCTGGTCACCGTCTCCTCA
965	FR4H2	TGGGGCCGTGGCACCTGGTCACTGTCTCCTCA
966	FR4H3	TGGGGCCAAGGGACAATGGTCACCGTCTCTTCA
20 967	FR4H4	TGGGGCCAAGGAACCCTGGTCACCGTCTCCTCA
968	FR4H5	TGGGGCCAAGGAACCCTGGTCACCGTCTCCTCA
969	FR4H6	TGGGGGCAAGGGACCACGGTCACCGTCTCCTCA

Table 27. Heavy Chain FR4 Reverse Primers (for Sub-Bank 11):

25 970	FR4H1'	TGAGGAGACGGTGACCAGGGTGCCCTGGCCCCCA
971	FR4H2'	TGAGGAGACAGTGACCAGGGTGCCACGGCCCCCA
972	FR4H3'	TGAAGAGACGGTGACCATTGTCCCTTGGCCCCCA
973	FR4H4'	TGAGGAGACGGTGACCAGGGTTCCTTGGCCCCCA
974	FR4H5'	TGAGGAGACGGTGACCAGGGTTCCTTGGCCCCCA
30 975	FR4H6'	TGAGGAGACGGTGACCGTGGTCCCTTGGCCCCCA

PCR is carried out using the following oligonucleotide combinations (6 in
 total): FR4H1/FR4H1', FR4H2/FR4H2', FR4H3/FR4H3', FR4H4/FR4H4',
 FR4H5/FR4H5', or FR4H6/FR4H6'. The pooling of the PCR products generates sub-bank
 35 11.

In some embodiments, heavy chain FR sub-banks 8, 9, 10 and 11 are constructed wherein sub-bank 8 comprises nucleic acids, each of which encodes a heavy chain FR1; sub-bank 9 comprises nucleic acids, each of which encodes a heavy chain FR2; sub-bank 10 comprises nucleic acids, each of which encodes a heavy chain FR3; and sub-bank 11 comprises nucleic acids, each of which encodes a heavy chain FR4, respectively, and wherein the heavy chain FR1, FR2, and FR3 are defined according to Chothia definition for CDR H1 and H2. In some embodiments, the FR sequences are derived from functional human antibody sequences. In other embodiments, the FR sequences are derived from human germline heavy chain sequences.

By way of example but not limitation, the following describes a method of generating 4 heavy chain FR sub-banks using Polymerase Chain Reaction (PCR), wherein human germline heavy chain sequences are used as templates. Heavy chain FR sub-banks 7, 8 and 9 (encoding FR1, 2, 3 respectively) encompass 44 human germline heavy chain sequences (VH1-18, VH1-2, VH1-24, VH1-3, VH1-45, VH1-46, VH1-58, VH1-69, VH1-8, VH2-26, VH2-5, VH2-70, VH3-11, VH3-13, VH3-15, VH3-16, VH3-20, VH3-21, VH3-23, VH3-30, VH3-33, VH3-35, VH3-38, VH3-43, VH3-48, VH3-49, VH3-53, VH3-64, VH3-66, VH3-7, VH3-72, VH3-73, VH3-74, VH3-9, VH4-28, VH4-31, VH4-34, VH4-39, VH4-4, VH4-59, VH4-61, VH5-51, VH6-1 and VH7-81). See Matsuda *et al.*, 1998, J. Exp. Med., 188:1973-1975. The sequences are summarized at the NCBI website: www.ncbi.nlm.nih.gov/igblast/showGermline.cgi?organism=human&chainType=VH&seqType=nucleotide. Sub-bank 11 (encodes FR4) is the same sub-bank 11 as described above.

By way of example but not limitation, the construction of heavy chain FR1 sub-bank (according to Chothia definition) is carried out using the Polymerase Chain Reaction by overlap extension using the oligonucleotides listed in Table 28 and Table 29 (all shown in the 5' to 3' orientation, name followed by sequence):

Table 28. Heavy Chain FR1 (Chothia Definition) Forward Primers (for Sub-Bank 8):

976	FR1HC1	CAGGTTTCAGCTGGTGCAGTCTGGAGCTGAGGTGAAGAAGCCTGGGGCCTCA
977	FR1HC2	CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCA
978	FR1HC3	CAGGTCCAGCTGGTACAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCA
30 979	FR1HC4	CAGGTTTCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCA
980	FR1HC5	CAGATGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGACTGGGTCCTCA
981	FR1HC6	CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCA
982	FR1HC7	CAAATGCAGCTGGTGCAGTCTGGGCCTGAGGTGAAGAAGCCTGGGACCTCA
983	FR1HC8	CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGTCCTCG
35 984	FR1HC9	CAGGTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCA
985	FR1HC10	CAGGTCACCTTGAAGGAGTCTGGTCCTGTGCTGGTGAAACCCACAGAGACC

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	986	FR1HC11	CAGATCACCTTGAAGGAGTCTGGTCCTACGCTGGTGAAACCCACACAGACC
	987	FR1HC12	CAGGTACCTTGAGGGAGTCTGGTCCTGCGCTGGTGAAACCCACACAGACC
	988	FR1HC13	CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCAAGCCTGGAGGGTCC
	989	FR1HC14	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCC
5	990	FR1HC15	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTAAAGCCTGGGGGGTCC
	991	FR1HC16	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCC
	992	FR1HC17	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGTGTGGTACGGCCTGGGGGGTCC
	993	FR1HC18	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCAAGCCTGGGGGGTCC
	994	FR1HC19	GAGGTGCAGCTGTTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCC
10	995	FR1HC20	CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCC
	996	FR1HC21	CAGGTGCAGCTGGTGGAGTCTGGGGGAGGCGTGGTCCAGCCTGGGAGGTCC
	997	FR1HC22	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCC
	998	FR1HC23	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTAGGGGGTCC
	999	FR1HC24	GAAGTGCAGCTGGTGGAGTCTGGGGGAGTCGTGGTACAGCCTGGGGGGTCC
15	1000	FR1HC25	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGGGGGTCC
	1001	FR1HC26	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCAGGGCGGTCC
	1002	FR1HC27	GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCC
	1003	FR1HC28	GAGGTGCAGCTGGTGGAGTCTGGGGGAAGGCTTGGTCCAGCCTGGGGGGTCC
	1004	FR1HC29	GAGGTGCAGCTGGTGGAGTCTGGAGGAGGCTTGATCCAGCCTGGGGGGTCC
20	1005	FR1HC30	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGGGGGTCC
	1006	FR1HC31	GAGGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTCCAGCCTGGAGGGTCC
	1007	FR1HC32	GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTGGTCCAGCCTGGGGGGTCC
	1008	FR1HC33	GAGGTGCAGCTGGTGGAGTCCGGGGGAGGCTTAGTTCAGCCTGGGGGGTCC
	1009	FR1HC34	GAAGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGCAGGTCC
25	1010	FR1HC35	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGACACC
	1011	FR1HC36	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCACAGACC
	1012	FR1HC37	CAGGTGCAGCTACAGCAGTGGGGCGCAGGACTGTTGAAGCCTTCGGAGACC
	1013	FR1HC38	CAGCTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACC
	1014	FR1HC39	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACC
30	1015	FR1HC40	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACC
	1016	FR1HC41	CAGGTGCAGCTGCAGGAGTCGGGCCCAGGACTGGTGAAGCCTTCGGAGACC
	1017	FR1HC42	GAGGTGCAGCTGGTGCAGTCTGGAGCAGAGGTGAAAAAGCCCGGGGAGTCT
	1018	FR1HC43	CAGGTACAGCTGCAGCAGTCAGGTCCAGGACTGGTGAAGCCCTCGCAGACC
	1019	FR1HC44	CAGGTGCAGCTGGTGCAGTCTGGCCATGAGGTGAAGCAGCCTGGGGCCTCA

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Table 29. Heavy Chain FR1 (Chothia Definition) Reverse Primers (for Sub-Bank 8):

	1020	FR1HC1'	AGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGCTTCTTCAC
	1021	FR1HC2'	AGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGCTTCTTCAC
	1022	FR1HC3'	GGAAACCTTGCAGGAGACCTTCACTGAGGCCCCAGGCTTCTTCAC
40	1023	FR1HC4'	AGAAGCCTTGCAGGAAACCTTCACTGAGGCCCCAGGCTTCTTCAC
	1024	FR1HC5'	GGAAGCCTTGCAGGAAACCTTCACTGAGGACCCAGTCTTCTTCAC
	1025	FR1HC6'	AGATGCCTTGCAGGAAACCTTCACTGAGGCCCCAGGCTTCTTCAC
	1026	FR1HC7'	AGAAGCCTTGCAGGAGACCTTCACTGAGGTCCCAGGCTTCTTCAC

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	1027	FR1HC8'	AGAAGCCTTGCAGGAGACCTTCACCGAGGACCCAGGCTTCTTCAC
	1028	FR1HC9'	AGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGCTTCTTCAC
	1029	FR1HC10'	AGAGACGGTGCAGGTCAGCGTGAGGGTCTCTGTGGGTTTCACCAAG
	1030	FR1HC11'	AGAGAAGGTGCAGGTCAGCGTGAGGGTCTGTGTGGGTTTCACCAAG
5	1031	FR1HC12'	AGAGAAGGTGCAGGTCAGTGTGAGGGTCTGTGTGGGTTTCACCAAG
	1032	FR1HC13'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCTCCAGGCTTGACCAA
	1033	FR1HC14'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGTACCAA
	1034	FR1HC15'	AGAGGCTGCACAGGAGAGTCTAAGGGACCCCCCAGGCTTTACCAA
	1035	FR1HC16'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGTACCAA
10	1036	FR1HC17'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCCGTACCAC
	1037	FR1HC18'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTTGACCAG
	1038	FR1HC19'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGTACCAA
	1039	FR1HC20'	AGAGGCTGCACAGGAGAGTCTCAGGGACCTCCCAGGCTGGACCAC
	1040	FR1HC21'	AGACGCTGCACAGGAGAGTCTCAGGGACCTCCCAGGCTGGACCAC
15	1041	FR1HC22'	AGAGGCTGCACAGGAGAGTCTCAGGGATCCCCCAGGCTGTACCAA
	1042	FR1HC23'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCTAGGCTGTACCAA
	1043	FR1HC24'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGTACCAC
	1044	FR1HC25'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGTACCAA
	1045	FR1HC26'	AGAAGCTGTACAGGAGAGTCTCAGGGACCGCCCTGGCTGTACCAA
20	1046	FR1HC27'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGGATCAA
	1047	FR1HC28'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGGACCAA
	1048	FR1HC29'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGGATCAA
	1049	FR1HC30'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGGACCAA
	1050	FR1HC31'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCTCCAGGCTGGACCAA
25	1051	FR1HC32'	AGAGGCTGCACAGGAGAGTTTCAGGGACCCCCCAGGCTGGACCAA
	1052	FR1HC33'	AGAGGCTGCACAGGAGAGTCTCAGGGACCCCCCAGGCTGAACTAA
	1053	FR1HC34'	AGAGGCTGCACAGGAGAGTCTCAGGGACCTGCCAGGCTGTACCAA
	1054	FR1HC35'	AGAGACAGCGCAGGTGAGGGACAGGGTGTCCGAAGGCTTCACCAG
	1055	FR1HC36'	AGAGACAGTACAGGTGAGGGACAGGGTCTGTGAAGGCTTCACCAG
30	1056	FR1HC37'	ATAGACAGCGCAGGTGAGGGACAGGGTCTCCGAAGGCTTCAACAG
	1057	FR1HC38'	AGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGCTTCACCAG
	1058	FR1HC39'	AGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGCTTCACCAG
	1059	FR1HC40'	AGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGCTTCACCAG
	1060	FR1HC41'	AGAGACAGTGCAGGTGAGGGACAGGGTCTCCGAAGGCTTCACCAG
35	1061	FR1HC42'	AGAACCCTTACAGGAGATCTTCAGAGACTCCCCGGGCTTTTTTCAC
	1062	FR1HC43'	GGAGATGGCACAGGTGAGTGAGAGGGTCTGCGAGGGCTTCACCAG
	1063	FR1HC44'	AGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGCTGCTTCAC

40 PCR is carried out using the following oligonucleotide combinations (44 in total): FR1HC1/FR1HC1', FR1HC2/FR1HC2', FR1HC3/FR1HC3', FR1HC4/FR1HC4', FR1HC5/FR1HC5', FR1HC6/FR1HC6', FR1HC7/FR1HC7', FR1HC8/FR1HC8', FR1HC9/FR1HC9', FR1HC10/FR1HC10', FR1HC11/FR1HC11', FR1HC12/FR1HC12',

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FR1HC13/FR1HC13', FR1HC14/FR1HC14', FR1HC15/FR1HC15', FR1HC16/FR1HC16',
 FR1HC17/FR1HC17', FR1HC18/FR1HC18', FR1HC19/FR1HC19', FR1HC20/FR1HC20',
 FR1HC21/FR1HC21', FR1HC22/FR1HC22', FR1HC23/FR1HC23', FR1HC24/FR1HC24',
 FR1HC25/FR1HC25', FR1HC26/FR1HC26', FR1HC27/FR1HC27', FR1HC28/FR1HC28',
 5 FR1HC29/FR1HC29', FR1HC30/FR1HC30', FR1HC31/FR1HC31', FR1HC32/FR1HC32',
 FR1HC33/FR1HC33', FR1HC34/FR1HC34', FR1HC35/FR1HC35', FR1HC36/FR1HC36',
 FR1HC37/FR1HC37', FR1HC38/FR1HC38', FR1HC39/FR1HC39', FR1HC40/FR1HC40',
 FR1HC41/FR1HC41', FR1HC42/FR1HC42', FR1HC43/FR1HC43', or
 FR1HC44/FR1HC44'. The pooling of the PCR products generates sub-bank 8.

10 By way of example but not limitation, the construction of heavy chain FR2
 sub-bank (according to Chothia definition) is carried out using the Polymerase Chain
 Reaction by overlap extension using the oligonucleotides listed in Table 30 and Table 31
 (all shown in the 5' to 3' orientation, name followed by sequence):

Table 30. Heavy Chain FR2 (Chothia Definition) Forward Primers (for Sub-Bank 9):

15	1064	FR2HC1	TATGGTATCAGCTGGGTGCGACAGGCCCCTGGACAAGGGCTT
	1065	FR2HC2	TACTATATGCACTGGGTGCGACAGGCCCCTGGACAAGGGCTT
	1066	FR2HC3	TTATCCATGCACTGGGTGCGACAGGCTCCTGGAAAAGGGCTT
	1067	FR2HC4	TATGCTATGCATTGGGTGCGCCAGGCCCCCGGACAAAGGCTT
	1068	FR2HC5	CGCTACCTGCACTGGGTGCGACAGGCCCCCGGACAAGCGCTT
20	1069	FR2HC6	TACTATATGCACTGGGTGCGACAGGCCCCTGGACAAGGGCTT
	1070	FR2HC7	TCTGCTATGCAGTGGGTGCGACAGGCTCGTGGACAACGCCTT
	1071	FR2HC8	TATGCTATCAGCTGGGTGCGACAGGCCCCTGGACAAGGGCTT
	1072	FR2HC9	TATGATATCAACTGGGTGCGACAGGCCACTGGACAAGGGCTT
	1073	FR2HC10	ATGGGTGTGAGCTGGATCCGTCAGCCCCCAGGGAAGGCCCTG
25	1074	FR2HC11	GTGGGTGTGGGCTGGATCCGTCAGCCCCCAGGGAAGGCCCTG
	1075	FR2HC12	ATGTGTGTGAGCTGGATCCGTCAGCCCCCAGGGAAGGCCCTG
	1076	FR2HC13	TACTACATGAGCTGGATCCGCCAGGCTCCAGGGAAGGGGCTG
	1077	FR2HC14	TACGACATGCACTGGGTCCGCCAAGCTACAGGAAAAGGTCTG
	1078	FR2HC15	GCCTGGATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
30	1079	FR2HC16	AGTGACATGAACTGGGCCCCGCAAGGCTCCAGGAAAGGGGCTG
	1080	FR2HC17	TATGGCATGAGCTGGGTCCGCCAAGCTCCAGGGAAGGGGCTG
	1081	FR2HC18	TATAGCATGAACTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
	1082	FR2HC19	TATGCCATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
	1083	FR2HC20	TATGGCATGCACTGGGTCCGCCAGGCTCCAGGCAAGGGGCTG
35	1084	FR2HC21	TATGGCATGCACTGGGTCCGCCAGGCTCCAGGCAAGGGGCTG
	1085	FR2HC22	AGTGACATGAACTGGGTCCATCAGGCTCCAGGAAAGGGGCTG
	1086	FR2HC23	AATGAGATGAGCTGGATCCGCCAGGCTCCAGGGAAGGGGCTG
	1087	FR2HC24	TATACCATGCACTGGGTCCGTCAAGCTCCGGGGAAGGGTCTG
	1088	FR2HC25	TATAGCATGAACTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG

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	1089	FR2HC26	TATGCTATGAGCTGGTTC CGCCAGGCTCCAGGGAAGGGGCTG
	1090	FR2HC27	AACTACATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
	1091	FR2HC28	TATGCTATGCACTGGGTCCGCCAGGCTCCAGGGAAGGGACTG
	1092	FR2HC29	AACTACATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
5	1093	FR2HC30	TATTGGATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
	1094	FR2HC31	CACTACATGGACTGGGTCCGCCAGGCTCCAGGGAAGGGGCTG
	1095	FR2HC32	TCTGCTATGCACTGGGTCCGCCAGGCTTCCGGGAAAGGGCTG
	1096	FR2HC33	TACTGGATGCACTGGGTCCGCCAAGCTCCAGGGAAGGGGCTG
	1097	FR2HC34	TATGCCATGCACTGGGTCCGGCAAGCTCCAGGGAAGGGCCTG
10	1098	FR2HC35	AACTGGTGGGGCTGGATCCGGCAGCCCCCAGGGAAGGGACTG
	1099	FR2HC36	TACTACTGGAGCTGGATCCGCCAGCACCCAGGGAAGGGCCTG
	1100	FR2HC37	TACTACTGGAGCTGGATCCGCCAGCCCCCAGGGAAGGGGCTG
	1101	FR2HC38	TACTACTGGGGCTGGATCCGCCAGCCCCCAGGGAAGGGGCTG
	1102	FR2HC39	TACTACTGGAGCTGGATCCGGCAGCCCGCCGGGAAGGGACTG
15	1103	FR2HC40	TACTACTGGAGCTGGATCCGGCAGCCCCCAGGGAAGGGACTG
	1104	FR2HC41	TACTACTGGAGCTGGATCCGGCAGCCCCCAGGGAAGGGACTG
	1105	FR2HC42	TACTGGATCGGCTGGGTGCGCCAGATGCCCGGGAAAGGCCTG
	1106	FR2HC43	GCTGCTTGGAAGTGGATCAGGCAGTCCCCATCGAGAGGCCTT
	1107	FR2HC44	TATGGTATGAATTGGGTGCCACAGGCCCTGGACAAGGGCTT

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Table 31. Heavy Chain FR2 (Chothia Definition) Reverse Primers (for Sub-Bank 9):

	1108	FR2HC1'	GATCCATCCCATCCACTCAAGCCCTTGTCCAGGGGCCTG
	1109	FR2HC2'	GATCCATCCCATCCACTCAAGCCCTTGTCCAGGGGCCTG
	1110	FR2HC3'	AAAACCTCCCATCCACTCAAGCCCTTTTCCAGGAGCCTG
25	1111	FR2HC4'	GCTCCATCCCATCCACTCAAGCCCTTTGTCCGGGGGCCTG
	1112	FR2HC5'	GATCCATCCCATCCACTCAAGCGCTTGTCCGGGGGCCTG
	1113	FR2HC6'	GATTATTCCCATCCACTCAAGCCCTTGTCCAGGGGCCTG
	1114	FR2HC7'	GATCCATCCTATCCACTCAAGGCGTTGTCCACGAGCCTG
	1115	FR2HC8'	GATCCCTCCCATCCACTCAAGCCCTTGTCCAGGGGCCTG
30	1116	FR2HC9'	CATCCATCCCATCCACTCAAGCCCTTGTCCAGTGGCCTG
	1117	FR2HC10'	AATGTGTGCAAGCCACTCCAGGGCCTTCCCTGGGGGCTG
	1118	FR2HC11'	AATGAGTGCAAGCCACTCCAGGGCCTTTCCTGGGGGCTG
	1119	FR2HC12'	AATGAGTGCAAGCCACTCCAGGGCCTTCCCTGGGGGCTG
	1120	FR2HC13'	AATGTATGAAACCCACTCCAGCCCCTTCCCTGGAGCCTG
35	1121	FR2HC14'	AATAGCTGAGACCCACTCCAGACCTTTTCCTGTAGCTTG
	1122	FR2HC15'	AATACGGCCAACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1123	FR2HC16'	AACACCCGATAACCCACTCCAGCCCCTTTCCTGGAGCCTT
	1124	FR2HC17'	AATACCAGAGACCCACTCCAGCCCCTTCCCTGGAGCTTG
	1125	FR2HC18'	AATGGATGAGACCCACTCCAGCCCCTTCCCTGGAGCCTG
40	1126	FR2HC19'	AATAGCTGAGACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1127	FR2HC20'	TATAACTGCCACCCACTCCAGCCCCTTGCCTGGAGCCTG
	1128	FR2HC21'	TATAACTGCCACCCACTCCAGCCCCTTGCCTGGAGCCTG
	1129	FR2HC22'	AACACCCGATAACCCACTCCAGCCCCTTTTCCTGGAGCCTG

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	1130	FR2HC23'	AATGGATGAGACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1131	FR2HC24'	ATAAGAGAGACCCACTCCAGACCCTTCCCCGGAGCTTG
	1132	FR2HC25'	AATGTATGAAACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1133	FR2HC26'	AATGAAACCTACCCACTCCAGCCCCTTCCCTGGAGCCTG
5	1134	FR2HC27'	AATAACTGAGACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1135	FR2HC28'	AATAGCTGAAACATATTCCAGTCCCTTCCCTGGAGCCTG
	1136	FR2HC29'	AATAACTGAGACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1137	FR2HC30'	TATGTTGGCCACCCACTCCAGCCCCTTCCCTGGAGCCTG
	1138	FR2HC31'	AGTACGGCCAACCCACTCCAGCCCCTTCCCTGGAGCCTG
10	1139	FR2HC32'	AATACGGCCAACCCACTCCAGCCCCTTCCCCGGAAGCCTG
	1140	FR2HC33'	AATACGTGAGACCCACACCAGCCCCTTCCCTGGAGCTTG
	1141	FR2HC34'	AATACCTGAGACCCACTCCAGGCCCTTCCCTGGAGCTTG
	1142	FR2HC35'	GATGTACCCAATCCACTCCAGTCCCTTCCCTGGGGGCTG
	1143	FR2HC36'	GATGTACCCAATCCACTCCAGGCCCTTCCCTGGGTGCTG
15	1144	FR2HC37'	GATTTCCCAATCCACTCCAGCCCCTTCCCTGGGGGCTG
	1145	FR2HC38'	GATACTCCCAATCCACTCCAGCCCCTTCCCTGGGGGCTG
	1146	FR2HC39'	GATACGCCCAATCCACTCCAGTCCCTTCCCGGCGGGCTG
	1147	FR2HC40'	GATATACCCAATCCACTCCAGTCCCTTCCCTGGGGGCTG
	1148	FR2HC41'	GATATACCCAATCCACTCCAGTCCCTTCCCTGGGGGCTG
20	1149	FR2HC42'	GATGATCCCCATCCACTCCAGGCCTTTCCCGGGCATCTG
	1150	FR2HC43'	TGTCCTTCCCAGCCACTCAAGGCCTCTCGATGGGGACTG
	1151	FR2HC44'	GAACCATCCCATCCACTCAAGCCCTTGTCCAGGGGCCTG

PCR is carried out using the following oligonucleotide combinations (44 in total): FR2HC1/FR2HC1', FR2HC2/FR2HC2', FR2HC3/FR2HC3', FR2HC4/FR2HC4', FR2HC5/FR2HC5', FR2HC6/FR2HC6', FR2HC7/FR2HC7', FR2HC8/FR2HC8', FR2HC9/FR2HC9', FR2HC10/FR2HC10', FR2HC11/FR2HC11', FR2HC12/FR2HC12', FR2HC13/FR2HC13', FR2HC14/FR2HC14', FR2HC15/FR2HC15', FR2HC16/FR2HC16', FR2HC17/FR2HC17', FR2HC18/FR2HC18', FR2HC19/FR2HC19', FR2HC20/FR2HC20', FR2HC21/FR2HC21', FR2HC22/FR2HC22', FR2HC23/FR2HC23', FR2HC24/FR2HC24', FR2HC25/FR2HC25', FR2HC26/FR2HC26', FR2HC27/FR2HC27', FR2HC28/FR2HC28', FR2HC29/FR2HC29', FR2HC30/FR2HC30', FR2HC31/FR2HC31', FR2HC32/FR2HC32', FR2HC33/FR2HC33', FR2HC34/FR2HC34', FR2HC35/FR2HC35', FR2HC36/FR2HC36', FR2HC37/FR2HC37', FR2HC38/FR2HC38', FR2HC39/FR2HC39', FR2HC40/FR2HC40', FR2HC41/FR2HC41', FR2HC42/FR2HC42', FR2HC43/FR2HC43', or FR2HC44/FR2HC44'. The pooling of the PCR products generates sub-bank 9.

By way of example but not limitation, the construction of heavy chain FR3 sub-bank (according to Chothia definition) is carried out using the Polymerase Chain

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Reaction by overlap extension using the oligonucleotides listed in Table 32 and Table 33
(all shown in the 5' to 3' orientation, name followed by sequence):

Table 32. Heavy Chain FR3 (Chothia Definition) Forward Primers (for Sub-Bank 10):

5	1152	FR3HC1 ACAAACTATGCACAGAAGCTCCAGGGCAGAGTCACCATGACCACAGACACATCCACGAGCACAGCCTACATGG
	1153	FR3HC2 ACAAACTATGCACAGAAGTTTCAGGGCAGGGTCACCATGACCAGGGACACGTCCATCAGCACAGCCTACATGG
	1154	FR3HC3 ACAATCTACGCACAGAAGTTCCAGGGCAGAGTCACCATGACCGAGGACACATCTACAGACACAGCCTACATGG
10	1155	FR3HC4 ACAAAATATTCACAGGAGTTCCAGGGCAGAGTCACCATTACCAGGGACACATCCGCGAGCACAGCCTACATGG
	1156	FR3HC5 ACCAACTACGCACAGAAATTCCAGGACAGAGTCACCATTACCAGGGACAGGTCTATGAGCACAGCCTACATGG
	1157	FR3HC6 ACAAGCTACGCACAGAAGTTCCAGGGCAGAGTCACCATGACCAGGGACACGTCCACGAGCACAGTCTACATGG
15	1158	FR3HC7 ACAAACTACGCACAGAAGTTCCAGGAAAGAGTCACCATTACCAGGGACATGTCCACAAGCACAGCCTACATGG
	1159	FR3HC8 GCAAACTACGCACAGAAGTTCCAGGGCAGAGTCACGATTACCGCGGACAAATCCACGAGCACAGCCTACATGG
	1160	FR3HC9 ACAGGCTATGCACAGAAGTTCCAGGGCAGAGTCACCATGACCAGGAACACCTCCATAAGCACAGCCTACATGG
20	1161	FR3HC10 AAATCCTACAGCACATCTCTGAAGAGCAGGCTCACCATCTCCAAGGACACCTCCAAAAGCCAGGTGGTCCTTA
	1162	FR3HC11 AAGCGCTACAGCCCATCTCTGAAGAGCAGGCTCACCATCACCAAGGACACCTCCAAAACCAGGTGGTCCTTA
	1163	FR3HC12 AAATACTACAGCACATCTCTGAAGACCAGGCTCACCATCTCCAAGGACACCTCCAAAACCAGGTGGTCCTTA
25	1164	FR3HC13 ATATACTACGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGGGACAACGCCAAGAAGTCACTGTATCTGC
	1165	FR3HC14 ACATACTATCCAGGCTCCGTGAAGGGCCGATTACCATCTCCAGAGAAAATGCCAAGAAGTCCCTGTATCTTC
	1166	FR3HC15 ACAGACTACGCTGCACCCGTGAAAGGCAGATTACCATCTCAAGAGATGATTCAAAAAACACGCTGTATCTGC
30	1167	FR3HC16 ACGCACTATGTGGACTCCGTGAAGCGCCGATTATCATCTCCAGAGACAATTCCAGGAAGTCCCTGTATCTGC
	1168	FR3HC17 ACAGGTTATGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAAGTCCCTGTATCTGC
	1169	FR3HC18 ATATACTACGCAGACTCAGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAAGTCACTGTATCTGC
35	1170	FR3HC19 ACATACTACGCAGACTCCGTGAAGGGCCGTTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGC
	1171	FR3HC20 AAATACTATGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGC
	1172	FR3HC21 AAATACTATGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTGC
40	1173	FR3HC22 ACGCACTATGCAGACTCTGTGAAGGGCCGATTATCATCTCCAGAGACAATTCCAGGAACACCCTGTATCTGC
	1174	FR3HC23 ACATACTACGCAGACTCCAGGAAGGGCAGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTC
	1175	FR3HC24 ACATACTATGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACAGCAAAAAGTCCCTGTATCTGC
45	1176	FR3HC25 ATATACTACGCAGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAATGCCAAGAAGTCACTGTATCTGC
	1177	FR3HC26 ACAGAATACGCCGCGTCTGTGAAAGGCAGATTACCATCTCAAGAGATGATTCCAAAAGCATCGCCTATCTGC
	1177	FR3HC26 ACAGAATACGCCGCGTCTGTGAAAGGCAGATTACCATCTCAAGAGATGATTCCAAAAGCATCGCCTATCTGC

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5	1178	FR3HC27 ACATACTACGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTC
	1179	FR3HC28 ACATATTATGCAGACTCTGTGAAGGGCAGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTC
	1180	FR3HC29 ACATACTACGCAGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAATTCCAAGAACACGCTGTATCTTC
	1181	FR3HC30 AAATACTATGTGGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAAGTCACTGTATCTGC
	1182	FR3HC31 ACAGAATACGCCGCGTCTGTGAAAGGCAGATTACCATCTCAAGAGATGATTCAAAGAAGTCACTGTATCTGC
10	1183	FR3HC32 ACAGCATATGCTGCGTCGGTGAAAGGCAGGTTACCATCTCCAGAGATGATTCAAAGAACACGGCGTATCTGC
	1184	FR3HC33 ACAAGCTACGCGGACTCCGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAAGTCACTGTATCTGC
	1185	FR3HC34 ATAGGCTATGCGGACTCTGTGAAGGGCCGATTACCATCTCCAGAGACAACGCCAAGAAGTCCCTGTATCTGC
	1186	FR3HC35 ACCTACTACAACCCGTCCCTCAAGAGTCGAGTCACCATGTCAGTAGACACGTCCAAGAACCAGTTCTCCCTGA
	1187	FR3HC36 ACCTACTACAACCCGTCCCTCAAGAGTCGAGTTACCATATCAGTAGACACGTCTAAGAACCAGTTCTCCCTGA
20	1188	FR3HC37 ACCAACTACAACCCGTCCCTCAAGAGTCGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGA
	1189	FR3HC38 ACCTACTACAACCCGTCCCTCAAGAGTCGAGTCACCATATCCGTAGACACGTCCAAGAACCAGTTCTCCCTGA
	1190	FR3HC39 ACCAACTACAACCCCTCCCTCAAGAGTCGAGTCACCATGTCAGTAGACACGTCCAAGAACCAGTTCTCCCTGA
	1191	FR3HC40 ACCAACTACAACCCCTCCCTCAAGAGTCGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGA
	1192	FR3HC41 ACCAACTACAACCCCTCCCTCAAGAGTCGAGTCACCATATCAGTAGACACGTCCAAGAACCAGTTCTCCCTGA
30	1193	FR3HC42 ACCAGATACAGCCCGTCCCTTCCAAGGCCAGGTCACCATCTCAGCCGACAAGTCCATCAGCACCGCCTACCTGC
	1194	FR3HC43 AATGATTATGCAGTATCTGTGAAAAGTCGAATAACCATCAACCCAGACACATCCAAGAACCAGTTCTCCCTGC
	1195	FR3HC44 CCAACATATGCCCAGGGCTTCACAGGACGGTTTGTCTTCTCCATGGACACCTCTGCCAGCACAGCATAACCTGC

Table 33. Heavy Chain FR3 (Chothia Definition) Reverse Primers (for Sub-Bank 10):

40	1196	FR3HC1' TCTCGCACAGTAATACACGGCCGTGTCGTCAGATCTCAGGCTCCTCAGCTCCATGTAGGCTGTGCTCGTGG
	1197	FR3HC2' TCTCGCACAGTAATACACGGCCGTGTCGTCAGATCTCAGCCTGCTCAGCTCCATGTAGGCTGTGCTGATGG
	1198	FR3HC3' TGTTGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCTCCATGTAGGCTGTGTCTGTAG
	1199	FR3HC4' TCTCGCACAGTAATACACAGCCATGTCCTCAGATCTCAGGCTGCTCAGCTCCATGTAGGCTGTGCTCGCGG
	1200	FR3HC5' TCTTGCACAGTAATACATGGCTGTGTCCTCAGATCTCAGGCTGCTCAGCTCCATGTAGGCTGTGCTCATAG
50	1201	FR3HC6' TCTCGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCTCCATGTAGACTGTGCTCGTGG
	1202	FR3HC7' TGCCGCACAGTAATACACGGCCGTGTCCTCGGATCTCAGGCTGCTCAGCTCCATGTAGGCTGTGCTTGTGG
	1203	FR3HC8' TCTCGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCTCCATGTAGGCTGTGCTCGTGG
	1204	FR3HC9' TCTCGCACAGTAATACACGGCCGTGTCCTCAGATCTCAGGCTGCTCAGCTCCATGTAGGCTGTGCTTATGG

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5	1205	FR3HC10' CCGTGCACAGTAATATGTGGCTGTGTCCACAGGGTCCATGTTGGTCATGGTAAGGACCACCTGGCTTTTGG
	1206	FR3HC11' GTGTGCACAGTAATATGTGGCTGTGTCCACAGGGTCCATGTTGGTCATTGTAAGGACCACCTGGTTTTTGG
	1207	FR3HC12' CCGTGCACAATAATACGTGGCTGTGTCCACAGGGTCCATGTTGGTCATTGTAAGGACCACCTGGTTTTTGG
	1208	FR3HC13' TCTCGCACAGTAATACACGGCCGTGTCTCGGCTCTCAGGCTGTTTCATTTGCAGATACAGTGAGTTCTTGG
	1209	FR3HC14' TCTTGCACAGTAATACACAGCCGTGTCCCCGGCTCTCAGGCTGTTTCATTTGAAGATACAAGGAGTTCTTGG
10	1210	FR3HC15' TGTGGTACAGTAATACACGGCTGTGTCTCGGTTTTTCAGGCTGTTTCATTTGCAGATACAGCGTGTTTTTTG
	1211	FR3HC16' TCTCACACAGTAATACACAGCCATGTCTCGGCTCTCCGTCTGTTCTTTTGCAGATACAGGGAGTTCCTGG
	1212	FR3HC17' TCTCGCACAGTGATACAAGGCCGTGTCTCGGCTCTCAGACTGTTTCATTTGCAGATACAGGGAGTTCCTGG
	1213	FR3HC18' TCTCGCACAGTAATACACAGCCGTGTCTCGGCTCTCAGGCTGTTTCATTTGCAGATACAGTGAGTTCTTGG
	1214	FR3HC19' TTTCGCACAGTAATATACGGCCGTGTCTCGGCTCTCAGGCTGTTTCATTTGCAGATACAGCGTGTTCTTGG
20	1215	FR3HC20' TCTCGCACAGTAATACACAGCCGTGTCTCAGCTCTCAGGCTGTTTCATTTGCAGATACAGCGTGTTCTTGG
	1216	FR3HC21' TCTCGCACAGTAATACACAGCCGTGTCTCGGCTCTCAGGCTGTTTCATTTGCAGATACAGCGTGTTCTTGG
	1217	FR3HC22' TCTCACACAGTAATACACAGCCGTGTCTCGGCCCTCAGGCTATTCGTTTGCAGATACAGGGTGTTCCTGG
	1218	FR3HC23' TCTGGCACAGTAATACACGGCCGTGCCCTCAGCTCTCAGGTTGTTTCATTTGAAGATACAGCGTGTTCTTGG
	1219	FR3HC24' TTTTGCACAGTAATACAAGGCCGTGTCTCAGTTCTCAGACTGTTTCATTTGCAGATACAGGGAGTTTTTGC
30	1220	FR3HC25' TCTCGCACAGTAATACACAGCCGTGTCTCGTCTCTCAGGCTGTTTCATTTGCAGATACAGTGAGTTCTTGG
	1221	FR3HC26' TCTAGTACAGTAATACACGGCTGTGTCTCGGTTTTTCAGGCTGTTTCATTTGCAGATAGGCGATGCTTTTTGG
	1222	FR3HC27' TCTCGCACAGTAATACACGGCCGTGTCTCGGCTCTCAGGCTGTTTCATTTGAAGATACAGCGTGTTCTTGG
	1223	FR3HC28' TCTCGCACAGTAATACACAGCCATGTCTCAGCTCTCAGGCTGCCCATTTCAGATACAGCGTGTTCTTGG
	1224	FR3HC29' TCTCGCACAGTAATACACAGCCGTGTCTCAGCTCTCAGGCTGTTTCATTTGAAGATACAGCGTGTTCTTGG
40	1225	FR3HC30' TCTCGCACAGTAATACACAGCCGTGTCTCGGCTCTCAGGCTGTTTCATTTGCAGATACAGTGAGTTCTTGG
	1226	FR3HC31' TCTAGCACAGTAATACACGGCCGTGTCTCGGTTTTTCAGGCTGTTTCATTTGCAGATACAGTGAGTTCTTTG
	1227	FR3HC32' TCTAGTACAGTAATACACGGCCGTGTCTCGGTTTTTCAGGCTGTTTCATTTGCAGATACGCCGTGTTCTTTG
	1228	FR3HC33' TCTTGCACAGTAATACACAGCCGTGTCTCGGCTCTCAGACTGTTTCATTTGCAGATACAGCGTGTTCTTGG
	1229	FR3HC34' TTTTGCACAGTAATACAAGGCCGTGTCTCAGCTCTCAGACTGTTTCATTTGCAGATACAGGGAGTTCTTGG
50	1230	FR3HC35' TCTCGCACAGTAATACACGGCCGTGTCCACGGCGGTCACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTGG
	1231	FR3HC36' TCTCGCACAGTAATACACGGCCGTGTCCGCGGCAGTCACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTAG
	1232	FR3HC37' TCTCGCACAGTAATACACAGCCGTGTCCGCGGCGGTCACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTGG
	1233	FR3HC38' TCTCGCACAGTAATACACAGCCGTGTCTGCGGCGGTCACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTGG

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1234	FR3HC39'	TCTCGCACAGTAATACACGGCCGTGTCCGCGGCGGTACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTGG
1235	FR3HC40'	TCTCGCACAGTAATACACGGCCGTGTCCGCGGCGGTACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTGG
5 1236	FR3HC41'	TCTCGCACAGTAATACACGGCCGTGTCCGCGGCGGTACAGAGCTCAGCTTCAGGGAGAACTGGTTCTTGG
1237	FR3HC42'	TCTCGCACAGTAATACATGGCGGTGTCCGAGGCCTTCAGGCTGCTCCACTGCAGGTAGGCGGTGCTGATGG
10 1238	FR3HC43'	TCTTGCACAGTAATACACAGCCGTGTCCTCGGGAGTCACAGAGTTCAGCTGCAGGGAGAACTGGTTCTTGG
1239	FR3HC44'	TCTCGCACAGTAATACATGGCCATGTCCTCAGCCTTTAGGCTGCTGATCTGCAGGTATGCTGTGCTGGCAG

PCR is carried out using the following oligonucleotide combinations (44 in total): FR3HC1/FR3HC1', FR3HC2/FR3HC2', FR3HC3/FR3HC3', FR3HC4/FR3HC4', FR3HC5/FR3HC5', FR3HC6/FR3HC6', FR3HC7/FR3HC7', FR3HC8/FR3HC8', FR3HC9/FR3HC9', FR3HC10/FR3HC10', FR3HC11/FR3HC11', FR3HC12/FR3HC12', FR3HC13/FR3HC13', FR3HC14/FR3HC14', FR3HC15/FR3HC15', FR3HC16/FR3HC16', FR3HC17/FR3HC17', FR3HC18/FR3HC18', FR3HC19/FR3HC19', FR3HC20/FR3HC20', FR3HC21/FR3HC21', FR3HC22/FR3HC22', FR3HC23/FR3HC23', FR3HC24/FR3HC24', FR3HC25/FR3HC25', FR3HC26/FR3HC26', FR3HC27/FR3HC27', FR3HC28/FR3HC28', FR3HC29/FR3HC29', FR3HC30/FR3HC30', FR3HC31/FR3HC31', FR3HC32/FR3HC32', FR3HC33/FR3HC33', FR3HC34/FR3HC34', FR3HC35/FR3HC35', FR3HC36/FR3HC36', FR3HC37/FR3HC37', FR3HC38/FR3HC38', FR3HC39/FR3HC39', FR3HC40/FR3HC40', FR3HC41/FR3HC41', FR3HC42/FR3HC42', FR3HC43/FR3HC43', or FR3HC44/FR3HC44'. The pooling of the PCR products generates sub-bank 10.

2.3 Selection of CDRs

In addition to the synthesis of framework region sub-banks, sub-banks of CDRs can be generated and randomly fused in frame with framework regions from framework region sub-banks to produced combinatorial libraries of antibodies (with or without constant regions) that can be screened for their immunospecificity for an antigen of interest, as well as their immunogenicity in an organism of interest. The combinatorial library methodology of the invention is exemplified herein for the production of humanized antibodies for use in human beings. However, the combinatorial library methodology of the invention can readily be applied to the production of antibodies for use in any organism of interest.

The present invention provides for a CDR sub-bank for each CDR of the variable light chain and variable heavy chain. Accordingly, the invention provides a CDR region sub-bank for variable light chain CDR1, variable light chain CDR2, and variable

light CDR3 for each species of interest and for each definition of a CDR (*e.g.*, Kabat and Chothia). The invention also provides a CDR sub-bank for variable heavy chain CDR1, variable heavy CDR2, and variable heavy chain CDR3 for each species of interest and for each definition of a CDR (*e.g.*, Kabat and Chothia). A CDR sub-banks may comprise CDRs
5 that have been identified as part of an antibody that immunospecifically to an antigen of interest. The CDR sub-banks can be readily used to synthesize a combinatorial library of antibodies which can be screened for their immunospecificity for an antigen of interest, as well as their immunogenicity in an organism of interest.

For example, light chain CDR sub-banks 12, 13 and 14 can be constructed,
10 wherein CDR sub-bank 12 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding light chain CDR1 according to Kabat system; CDR sub-bank 13 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding light chain CDR2 according to Kabat system; and CDR sub-bank 14 comprises a plurality of nucleic acid sequences
15 comprising nucleotide sequences, each nucleotide sequence encoding light chain CDR3 according to Kabat system. Light chain CDR sub-banks 15, 16 and 17 can be constructed, wherein CDR sub-bank 15 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding light chain CDR1 according to Chothia system; CDR sub-bank 16 comprises a plurality of nucleic acid sequences
20 comprising nucleotide sequences, each nucleotide sequence encoding light chain CDR2 according to Chothia system; and CDR sub-bank 17 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding light chain CDR3 according to Chothia system

Heavy chain CDR sub-bank 18, 19 and 20 can be constructed, wherein CDR
25 sub-bank 18 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding heavy chain CDR1 according to Kabat system; CDR sub-bank 19 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding heavy chain CDR2 according to Kabat system; and CDR sub-bank 20 comprises a plurality of nucleic acid sequences
30 comprising nucleotide sequences, each nucleotide sequence encoding heavy chain CDR3 according to Kabat system. Heavy chain CDR sub-bank 21, 22 and 23 can be constructed, wherein CDR sub-bank 21 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding heavy chain CDR1 according to Chothia system; CDR sub-bank 22 comprises a plurality of nucleic acid sequences

comprising nucleotide sequences, each nucleotide sequence encoding heavy chain CDR2 according to Chothia system; and CDR sub-bank 23 comprises a plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding heavy chain CDR3 according to Chothia system.

5 In some embodiments, the CDR sequences are derived from functional antibody sequences. In some embodiments, the CDR sequences are random sequences, which comprises at least 5, at least 6, at least 7, at least 8, at least 9, or at least 10 contiguous nucleotide sequence, synthesized by any methods known in the art. The CDR sub-banks can be used for construction of combinatorial sub-libraries. Alternatively, a CDR of
10 particular interest can be selected and then used for the construction of combinatorial sub-libraries (see Section 5.3).

2.4 Construction of Combinatorial Sub-libraries

Combinatorial sub-libraries are constructed by fusing in frame non-human CDRs with corresponding human framework regions of the FR sub-banks. For example,
15 combinatorial sub-library 1 is constructed by fusing in frame non-human CDR with corresponding kappa light chain human framework regions using sub-banks 1; combinatorial sub-library 2 is constructed by fusing in frame non-human CDR with corresponding kappa light chain human framework regions using sub-banks 2; combinatorial sub-library 3 is constructed by fusing in frame non-human CDR with
20 corresponding kappa light chain human framework regions using sub-banks 3; combinatorial sub-library 4 is constructed by fusing in frame non-human CDR with corresponding kappa light chain human framework regions using sub-banks 4; combinatorial sub-libraries 5, 6, and 7 are constructed by fusing in frame non-human CDRs (Kabat definition for CDR H1 and H2) with the corresponding heavy chain human
25 framework regions using sub-banks 5, 6 and 7, respectively; combinatorial sub-libraries 8, 9 and 10 are constructed by fusing in frame non-human CDRs (Chothia definition for CDR H1 and H2) with the corresponding heavy chain human framework regions using sub-banks 8, 9 and 10, respectively; combinatorial sub-library 11 is constructed by fusing in frame non-human CDR H3 (Kabat and Chothia definition) with the corresponding human heavy
30 chain framework regions using sub-bank 11. In some embodiments, the non-human CDRs may also be selected from a CDR library.

The construction of combinatorial sub-libraries can be carried out using any method known in the art. By way of example but not limitation, the combinatorial sub-library 1 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension

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using the oligonucleotides in Table 34 and Table 35 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 34. Light Chain FR1 Antibody-Specific Forward Primers (for Sub-Library 1)

5	1240	AL1	GATGTTGTGATGACWCAGTCT
	1241	AL2	GACATCCAGATGAYCCAGTCT
	1242	AL3	GCCATCCAGWTGACCCAGTCT
	1243	AL4	GAAATAGTGATGAYGCAGTCT
	1244	AL5	GAAATTGTGTTGACRCAGTCT
10	1245	AL6	GAKATTGTGATGACCCAGACT
	1246	AL7	GAAATTGTRMTGACWCAGTCT
	1247	AL8	GAYATYGTGATGACYCAGTCT
	1248	AL9	GAAACGACACTCACGCAGTCT
	1249	AL10	GACATCCAGTTGACCCAGTCT
15	1250	AL11	AACATCCAGATGACCCAGTCT
	1251	AL12	GCCATCCGGATGACCCAGTCT
	1252	AL13	GTCATCTGGATGACCCAGTCT

Table 35. Light Chain FR1 Antibody-Specific Reverse Primers (for Sub-Library 1)

20	1253	AL1'	[first 70% of CDR L1]-GCAGGAGATGGAGGCCGGCTS
	1254	AL2'	[first 70% of CDR L1]-GCAGGAGAGGGTGRCTCTTTC
	1255	AL3'	[first 70% of CDR L1]-ACAASTGATGGTGACTCTGTC
	1256	AL4'	[first 70% of CDR L1]-GAAGGAGATGGAGGCCGGCTG
	1257	AL5'	[first 70% of CDR L1]-GCAGGAGATGGAGGCCTGCTC
25	1258	AL6'	[first 70% of CDR L1]-GCAGGAGATGTTGACTTTGTC
	1259	AL7'	[first 70% of CDR L1]-GCAGGTGATGGTGACTTTCTC
	1260	AL8'	[first 70% of CDR L1]-GCAGTTGATGGTGGCCCTCTC
	1261	AL9'	[first 70% of CDR L1]-GCAAGTGATGGTGACTCTGTC
	1262	AL10'	[first 70% of CDR L1]-GCAAATGATACTGACTCTGTC

30

PCR is carried out with AL1 to AL13 in combination with AL1' to AL10' using sub-bank 1 as a template. This generates combinatorial sub-library 1 or a pool of oligonucleotides corresponding to sequences described in Table 1.

By way of example but not limitation, the combinatorial sub-library 2 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 36 and Table 37 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

35

Table 36. Light Chain FR2 Antibody-Specific Forward Primers (for Sub-Library 2):

	1263	BL1	[last 70% of CDR L1]-TGGYTTTCAGCAGAGGCCAGGC
	1264	BL2	[last 70% of CDR L1]-TGGTACCTGCAGAAGCCAGGS
	1265	BL3	[last 70% of CDR L1]-TGGTATCRGCAGAAACCAGGG
5	1266	BL4	[last 70% of CDR L1]-TGGTACCARCAGAAACCAGGA
	1267	BL5	[last 70% of CDR L1]-TGGTACCARCAGAAACCTGGC
	1268	BL6	[last 70% of CDR L1]-TGGTAYCWGCAGAAACCWGGG
	1269	BL7	[last 70% of CDR L1]-TGGTATCAGCARAAACCWGGS
	1270	BL8	[last 70% of CDR L1]-TGGTAYCAGCARAAACCAG
10	1271	BL9	[last 70% of CDR L1]-TGGTTTCTGCAGAAAGCCAGG
	1272	BL10	[last 70% of CDR L1]-TGGTTTCAGCAGAAACCAGGG

Table 37. Light Chain FR2 Antibody-Specific Reverse Primers (for Sub-Library 2)

	1273	BL1'	[first 70% of CDR L2]-ATAGATCAGGAGCTGTGGAGR
15	1274	BL2'	[first 70% of CDR L2]-ATAGATCAGGAGCTTAGGRGC
	1275	BL3'	[first 70% of CDR L2]-ATAGATGAGGAGCCTGGGMGC
	1276	BL4'	[first 70% of CDR L2]-RTAGATCAGGMGCTTAGGGGC
	1277	BL5'	[first 70% of CDR L2]-ATAGATCAGGWGCTTAGGRAC
	1278	BL6'	[first 70% of CDR L2]-ATAGATGAAGAGCTTAGGGGC
20	1279	BL7'	[first 70% of CDR L2]-ATAAATTAGGAGTCTTGGAGG
	1280	BL8'	[first 70% of CDR L2]-GTAAATGAGCAGCTTAGGAGG
	1281	BL9'	[first 70% of CDR L2]-ATAGATCAGGAGTGTGGAGAC
	1281	BL10'	[first 70% of CDR L2]-ATAGATCAGGAGCTCAGGGGC
	1283	BL11'	[first 70% of CDR L2]-ATAGATCAGGGACTTAGGGGC
25	1284	BL12'	[first 70% of CDR L2]-ATAGAGGAAGAGCTTAGGGGA
	1285	BL13'	[first 70% of CDR L2]-CTTGATGAGGAGCTTTGGAGA
	1286	BL14'	[first 70% of CDR L2]-ATAAATTAGGCGCCTTGGAGA
	1287	BL15'	[first 70% of CDR L2]-CTTGATGAGGAGCTTTGGGGC
	1288	BL16'	[first 70% of CDR L2]-TTGAATAATGAAAATAGCAGC

30

PCR is carried out with BL1 to BL10 in combination with BL1' to BL16' using sub-bank 2 as a template. This generates combinatorial sub-library 2 or a pool of oligonucleotides corresponding to sequences described in Table 2.

By way of example but not limitation, the combinatorial sub-library 3 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 38 and Table 39 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 38. Light Chain FR3 Antibody-Specific Forward Primers (for Sub-Library 3):

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1289	CL1 [Last 70% of CDR L2]-GGGGTCCCAGACAGATTCAGY
1290	CL2 [Last 70% of CDR L2]-GGGGTCCCATCAAGGTTTCAGY
1291	CL3 [Last 70% of CDR L2]-GGYATCCCAGCCAGGTTTCAGT
1292	CL4 [Last 70% of CDR L2]-GGRGTCCCWGACAGGTTTCAGT
5 1293	CL5 [Last 70% of CDR L2]-AGCATCCCAGCCAGGTTTCAGT
1294	CL6 [Last 70% of CDR L2]-GGGGTCCCCTCGAGGTTTCAGT
1295	CL7 [Last 70% of CDR L2]-GGAATCCCACCTCGATTCAGT
1296	CL8 [Last 70% of CDR L2]-GGGGTCCCTGACCGATTCAGT
1297	CL9 [Last 70% of CDR L2]-GGCATCCCAGACAGGTTTCAGT
10 1298	CL10 [Last 70% of CDR L2]-GGGGTCTCATCGAGGTTTCAGT
1299	CL11 [Last 70% of CDR L2]-GGAGTGCCAGATAGGTTTCAGT

Table 39. Light Chain FR3 Antibody-Specific Reverse Primers (for Sub-Library 3)

1300	CL1' [First 70% of CDR L3]-KCAGTAATAAACCCCAACATC
15 1301	CL2' [First 70% of CDR L3]-ACAGTAATAYGTTGCAGCATC
1302	CL3' [First 70% of CDR L3]-ACMGTAATAAGTTGCAACATC
1303	CL4' [First 70% of CDR L3]-RCAGTAATAAGTTGCAAAATC
1304	CL5' [First 70% of CDR L3]-ACAGTAATAARCTGCAAAATC
1305	CL6' [First 70% of CDR L3]-ACARTAGTAAGTTGCAAAATC
20 1306	CL7' [First 70% of CDR L3]-GCAGTAATAAACTCCAAMATC
1307	CL8' [First 70% of CDR L3]-GCAGTAATAAACCCCGACATC
1308	CL9' [First 70% of CDR L3]-ACAGAAGTAATATGCAGCATC
1309	CL10' [First 70% of CDR L3]-ACAGTAATATGTTGCAATATC
1310	CL11' [First 70% of CDR L3]-ACAGTAATACACTGCAAAATC
25 1311	CL12' [First 70% of CDR L3]-ACAGTAATAAACTGCCACATC

PCR is carried out with CL1 to CL11 in combination with CL1' to CL12' using sub-bank 3 as a template. This generates combinatorial sub-library 3 or a pool of oligonucleotides corresponding to sequences described in Table 3.

30 By way of example but not limitation, the combinatorial sub-library 4 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 40 and Table 41 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 40. Light Chain FR4 Antibody-Specific Forward Primers (for Sub-Library 4):

1312	DL1 [Last 70% of CDR L3]-TTYGGCCARGGGACCAAGSTG
1313	DL2 [Last 70% of CDR L3]-TTCGGCCAAGGGACACGACTG
1314	DL3 [Last 70% of CDR L3]-TTCGGCCCTGGGACCAAAGTG
1315	DL4 [Last 70% of CDR L3]-TTCGGCGGAGGGACCAAGGTG

Table 41. Light Chain FR4 Antibody-Specific Reverse Primers (for Sub-Library 4)

1316	DL1'	TTTGATYTCCACCTTGGTCCC
1317	DL2'	TTTGATCTCCAGCTTGGTCCC
5 1318	DL3'	TTTGATATCCACTTTGGTCCC
1319	DL4'	TTTAATCTCCAGTCGTGTCCC

PCR is carried out with DL1 to DL4 in combination with DL1' to DL14' using sub-bank 4 as a template. This generates combinatorial sub-library 4 or a pool of oligonucleotides corresponding to sequences described in Table 4.

By way of example but not limitation, the combinatorial sub-library 5 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 42 and Table 43 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 42. Heavy Chain FR1 (Kabat Definition) Antibody-Specific Forward Primers (for Sub-Library 5):

1320	AH1	CAGGTKCAGCTGGTGCAGTCT
1321	AH2	GAGGTGCAGCTGKTGGAGTCT
20 1322	AH3	CAGSTGCAGCTGCAGGAGTCG
1323	AH4	CAGGTCACCTTGARGGAGTCT
1324	AH5	CARATGCAGCTGGTGCAGTCT
1325	AH6	GARGTGCAGCTGGTGSAGTC
1326	AH7	CAGATCACCTTGAAGGAGTCT
25 1327	AH8	CAGGTSCAGCTGGTRSAGTCT
1328	AH9	CAGGTACAGCTGCAGCAGTCA
1329	AH10	CAGGTGCAGCTACAGCAGTGG

Table 43. Heavy Chain FR1 (Kabat Definition) Antibody-Specific Reverse Primers (for Sub-Library 5):

1330	AHK1'	[First 70% of CDR H1]-RGTGAAGGTGTATCCAGAAGC
1331	AHK2'	[First 70% of CDR H1]-GCTGAGTGAGAACCCAGAGAM
1332	AHK3'	[First 70% of CDR H1]-ACTGAARGTGAATCCAGAGGC
1333	AHK4'	[First 70% of CDR H1]-ACTGACGGTGAAYCCAGAGGC
35 1334	AHK5'	[First 70% of CDR H1]-GCTGAYGGAGCCACCAGAGAC
1335	AHK6'	[First 70% of CDR H1]-RGTAAGGTGWAWCCAGAAGC
1336	AHK7'	[First 70% of CDR H1]-ACTRAAGGTGAAYCCAGAGGC

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1337	AHK8' [First 70% of CDR H1]-GGTRAARCTGTAWCCAGAASC
1338	AHK9' [First 70% of CDR H1]-AYCAAAGGTGAATCCAGARGC
1339	AHK10' [First 70% of CDR H1]-RCTRAAGGTGAATCCAGASGC
1340	AHK12 [First 70% of CDR H1]-GGTGAAGGTGTATCCRGAWGC
5 1341	AHK13' [First 70% of CDR H1]-ACTGAAGGACCCACCATAGAC
1342	AHK14' [First 70% of CDR H1]-ACTGATGGAGCCACCAGAGAC
1343	AHK15' [First 70% of CDR H1]-GCTGATGGAGTAACCAGAGAC
1344	AHK16 [First 70% of CDR H1]-AGTGAGGGTGTATCCGGAAAC
1345	AHK17' [First 70% of CDR H1]-GCTGAAGGTGCCTCCAGAAGC
10 1346	AHK18' [First 70% of CDR H1]-AGAGACACTGTCCCCGGAGAT

PCR is carried out with AH1 to AH10 in combination with AHK1' to AHK18' using sub-bank 5 as a template. This generates combinatorial sub-library 5 or a pool of oligonucleotides corresponding to sequences described in Table 5.

15 By way of example but not limitation, the combinatorial sub-library 6 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 44 and Table 45 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

20 **Table 44. Heavy Chain FR2 (Kabat Definition) Antibody-Specific Forward Primers (for Sub-Library 6):**

1347	BHK1 [Last 70% of CDR H1]-TGGGTGCGACAGGCYCCTGGA
1348	BHK2 [Last 70% of CDR H1]-TGGGTGCGMCAGGCCCCCGGA
1349	BHK3 [Last 70% of CDR H1]-TGGATCCGTCAGCCCCCAGGR
25 1350	BHK4 [Last 70% of CDR H1]-TGGRTCCGCCAGGCTCCAGGG
1351	BHK5 [Last 70% of CDR H1]-TGGATCCGSCAGCCCCCAGGG
1352	BHK6 [Last 70% of CDR H1]-TGGGTCCGSCAAGCTCCAGGG
1353	BHK7 [Last 70% of CDR H1]-TGGGTCCRTCARGCTCCRGGR
1354	BHK8 [Last 70% of CDR H1]-TGGGTSCGMCARGCYACWGGA
30 1355	BHK9 [Last 70% of CDR H1]-TGGKTCCGCCAGGCTCCAGGS
1356	BHK10 [Last 70% of CDR H1]-TGGATCAGGCAGTCCCCATCG
1357	BHK11 [Last 70% of CDR H1]-TGGGCCCCGCAAGGCTCCAGGA
1358	BHK12 [Last 70% of CDR H1]-TGGATCCGCCAGCACCCAGGG
1359	BHK13 [Last 70% of CDR H1]-TGGGTCCGCCAGGCTTCCGGG
35 1360	BHK14 [Last 70% of CDR H1]-TGGGTGCGCCAGATGCCCGGG
1361	BHK15 [Last 70% of CDR H1]-TGGGTGCGACAGGCTCGTGGA
1362	BHK16 [Last 70% of CDR H1]-TGGATCCGGCAGCCCGCCGGG
1363	BHK17 [Last 70% of CDR H1]-TGGGTGCCACAGGCCCTGGA

Table 45. Heavy Chain FR2 (Kabat Definition) Antibody-Specific Reverse Primers (for Sub-Library 6):

	1364	BHK1' [First 70% of CDR H2]-TCCCATCCACTCAAGCCYTTG
	1365	BHK2' [First 70% of CDR H2]-TCCCATCCACTCAAGCSCTT
5	1366	BHK3' [First 70% of CDR H2]-WGAGACCCACTCCAGCCCCTT
	1367	BHK4' [First 70% of CDR H2]-CCCAATCCACTCCAGKCCCTT
	1368	BHK5' [First 70% of CDR H2]-TGAGACCCACTCCAGRCCCTT
	1369	BHK6' [First 70% of CDR H2]-GCCAACCCACTCCAGCCCYTT
	1370	BHK7' [First 70% of CDR H2]-KGCCACCCACTCCAGCCCCTT
10	1371	BHK8' [First 70% of CDR H2]-TCCCAGCCACTCAAGGCCTC
	1372	BHK9' [First 70% of CDR H2]-CCCCATCCACTCCAGGCCTT
	1373	BHK10' [First 70% of CDR H2]-TGARACCCACWCCAGCCCCTT
	1374	BHK12' [First 70% of CDR H2]-MGAKACCCACTCCAGMCCCTT
	1375	BHK13' [First 70% of CDR H2]-YCCMATCCACTCMAGCCCYTT
15	1376	BHK14' [First 70% of CDR H2]-TCCTATCCACTCAAGGCGTTG
	1377	BHK15' [First 70% of CDR H2]-TGCAAGCCACTCCAGGGCCTT
	1378	BHK16' [First 70% of CDR H2]-TGAAACATATTCAGTCCCTT
	1379	BHK17' [First 70% of CDR H2]-CGATACCCACTCCAGCCCCTT

20 PCR is carried out with BHK1 to BHK17 in combination with BHK1' to BHK17' using sub-bank 6 as a template. This generates combinatorial sub-library 6 or a pool of oligonucleotides corresponding to sequences described in Table 6.

By way of example but not limitation, the combinatorial sub-library 7 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the
 25 oligonucleotides in Table 46 and Table 47 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 46. Heavy Chain FR3 (Kabat Definition) Antibody-Specific Forward Primers (for Sub-Library 7):

30	1380	CHK1 [Last 70% of CDR H2]-AGAGTCACCATGACCAGGRAC
	1381	CHK2 [Last 70% of CDR H2]-AGGCTCACCATCWCCAAGGAC
	1382	CHK3 [Last 70% of CDR H2]-CGAGTYACCATATCAGTAGAC
	1383	CHK4 [Last 70% of CDR H2]-CGATTCACCATCTCCAGRGAC
	1384	CHK5 [Last 70% of CDR H2]-AGATTCACCATCTCMAGAGA
35	1385	CHK6 [Last 70% of CDR H2]-MGGTTCACCATCTCCAGAGA
	1386	CHK7 [Last 70% of CDR H2]-CGATTCAYCATCTCCAGAGA
	1387	CHK8 [Last 70% of CDR H2]-CGAGTCACCATRTCMGTAGAC
	1388	CHK9 [Last 70% of CDR H2]-AGRGTCACCATKACCAGGGAC
	1389	CHK10 [Last 70% of CDR H2]-CAGGTCACCATCTCAGCCGAC

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1390	CHK11 [Last 70% of CDR H2]-CGAATAACCATCAACCCAGAC
1391	CHK12 [Last 70% of CDR H2]-CGGTTTGTCTTCTCCATGGAC
1392	CHK13 [Last 70% of CDR H2]-AGAGTCACCATGACCGAGGAC
1393	CHK14 [Last 70% of CDR H2]-AGAGTCACGATTACCGCGGAC
5 1394	CHK15 [Last 70% of CDR H2]-AGAGTCACCATGACCACAGAC

Table 47. Heavy Chain FR3 (Kabat Definition) Antibody-Specific Reverse Primers (for Sub-Library 7)

1395	CHK1' [First 70% of CDR H3]-TCTAGYACAGTAATACACGGC
10 1396	CHK2' [First 70% of CDR H3]-TCTCGCACAGTAATACAYGGC
1397	CHK3' [First 70% of CDR H3]-TCTYGCACAGTAATACACAGC
1398	CHK4' [First 70% of CDR H3]-TGYYGCACAGTAATACACGGC
1399	CHK5' [First 70% of CDR H3]-CCGTGCACARTAATAYGTGGC
1400	CHK6' [First 70% of CDR H3]-TCTGGCACAGTAATACACGGC
15 1401	CHK7' [First 70% of CDR H3]-TGTGGTACAGTAATACACGGC
1402	CHK8' [First 70% of CDR H3]-TCTCGCACAGTGATACAAGGC
1403	CHK9' [First 70% of CDR H3]-TTTTGCACAGTAATACAAGGC
1404	CHK10' [First 70% of CDR H3]-TCTTGCACAGTAATACATGGC
1405	CHK11' [First 70% of CDR H3]-GTGTGCACAGTAATATGTGGC
20 1406	CHK12' [First 70% of CDR H3]-TTTCGCACAGTAATATACGGC
1407	CHK13' [First 70% of CDR H3]-TCTCACACAGTAATACACAGC

PCR is carried out with CHK1 to CHK15 in combination with CHK1' to CHK13' using sub-bank 7 as a template. This generates combinatorial sub-library 7 or a pool of oligonucleotides corresponding to sequences described in Table 7.

By way of example but not limitation, the combinatorial sub-library 8 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 48 and Table 49 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 48. Heavy Chain FR1 (Chothia Definition) Antibody-Specific Forward Primers (for Sub-Library 8):

1408	AH1	CAGGTKCAGCTGGTGCAGTCT
1409	AH2	GAGGTGCAGCTGKTGGAGTCT
35 1410	AH3	CAGSTGCAGCTGCAGGAGTCG
1411	AH4	CAGGTCACCTTGARGGAGTCT
1412	AH5	CARATGCAGCTGGTGCAGTCT
1413	AH6	GARGTGCAGCTGGTGSAGTC

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1414 AH7 CAGATCACCTTGAAGGAGTCT
 1415 AH8 CAGGTSCAGCTGGTRSAGTCT
 1416 AH9 CAGGTACAGCTGCAGCAGTCA
 1417 AH10 CAGGTGCAGCTACAGCAGTGG

5

Table 49. Heavy Chain FR1 (Chothia Definition) Antibody-Specific Reverse Primers (for Sub-Library 8)

1418	AHC1'	[First 70% of CDR H1]- RGAARCCTTGCAGGAGACCTT
1419	AHC2'	[First 70% of CDR H1]- RGAAGCCTTGCAGGAAACCTT
1420	AHC3'	[First 70% of CDR H1]- AGATGCCTTGCAGGAAACCTT
1421	AHC4'	[First 70% of CDR H1]- AGAGAMGGTGCAGGTCAGCGT
1422	AHC5'	[First 70% of CDR H1]- AGASGCTGCACAGGAGAGTCT
1423	AHC6'	[First 70% of CDR H1]- AGAGACAGTRCAGGTGAGGGA
1424	AHC7'	[First 70% of CDR H1]- AKAGACAGCGCAGGTGAGGGA
1425	AHC8'	[First 70% of CDR H1]- AGAGAAGGTGCAGGTCAGTGT
1426	AHC9'	[First 70% of CDR H1]- AGAAGCTGTACAGGAGAGTCT
1427	AHC10'	[First 70% of CDR H1]- AGAGGCTGCACAGGAGAGTTT
1428	AHC12'	[First 70% of CDR H1]- AGAACCCCTTACAGGAGATCTT
1429	AHC13'	[First 70% of CDR H1]- GGAGATGGCACAGGTGAGTGA

20

PCR is carried out with AH1 to AH10 in combination with AHC1' to AHC13' using sub-bank 8 as a template. This generates combinatorial sub-library 8 or a pool of oligonucleotides corresponding to sequences described in Table 8.

By way of example but not limitation, the combinatorial sub-library 9 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 50 and Table 51 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

Table 50. Heavy Chain FR2 (Chothia Definition) Antibody-Specific Forward Primers (for Sub-Library 9):

1430	BHC1	[Last 70% of CDR H1]-TATGGYATSAGCTGGGTGCGM
1431	BHC2	[Last 70% of CDR H1]-ATGKGTGTGAGCTGGATCCGT
1432	BHC3	[Last 70% of CDR H1]-TACTACTGGRGCTGGATCCGS
1433	BHC4	[Last 70% of CDR H1]-TATGCIYATSAGCTGGGTSCGM
1434	BHC5	[Last 70% of CDR H1]-TCTGCTATGCASTGGGTSCGM
1435	BHC6	[Last 70% of CDR H1]-TATGCIYATGCAYTGGGTSCGS
1436	BHC7	[Last 70% of CDR H1]-CGCTACCTGCACTGGGTGCGA
1437	BHC8	[Last 70% of CDR H1]-TTATCCATGCACTGGGTGCGA

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1438	BHC9 [Last 70% of CDR H1]-GCCTGGATGAGCTGGGTCCGC
1439	BHC10 [Last 70% of CDR H1]-GCTGCTTGGAAGTGGATCAGG
1440	BHC11 [Last 70% of CDR H1]-AATGAGATGAGCTGGATCCGC
1441	BHC12 [Last 70% of CDR H1]-AACTACATGAGCTGGGTCCGC
5 1442	BHC13 [Last 70% of CDR H1]-AACTGGTGGGGCTGGATCCGG
1443	BHC14 [Last 70% of CDR H1]-GTGGGTGTGGGCTGGATCCGT
1444	BHC15 [Last 70% of CDR H1]-CACTACATGGACTGGGTCCGC
1445	BHC16 [Last 70% of CDR H1]-AGTGACATGAACTGGGCCCCGC
1446	BHC17 [Last 70% of CDR H1]-AGTGACATGAACTGGGTCCAT
10 1447	BHC18 [Last 70% of CDR H1]-TATACCATGCACTGGGTCCGT
1448	BHC19 [Last 70% of CDR H1]-TATGCTATGCACTGGGTCCGC
1449	BHC20 [Last 70% of CDR H1]-TATGCTATGAGCTGGTTCCGC
1450	BHC21 [Last 70% of CDR H1]-TATAGCATGAACTGGGTCCGC
1451	BHC22 [Last 70% of CDR H1]-TATGGCATGCACTGGGTCCGC
15 1452	BHC23 [Last 70% of CDR H1]-TATTGGATGAGCTGGGTCCGC
1453	BHC24 [Last 70% of CDR H1]-TACGACATGCACTGGGTCCGC
1454	BHC25 [Last 70% of CDR H1]-TACTACATGAGCTGGATCCGC
1455	BHC26 [Last 70% of CDR H1]-TACTGGATGCACTGGGTCCGC
1456	BHC27 [Last 70% of CDR H1]-TACTGGATCGGCTGGGTGCGC
20 1457	BHC28 [Last 70% of CDR H1]-TACTATATGCACTGGGTGCGA
1458	BHC29 [Last 70% of CDR H1]-TATGATATCAACTGGGTGCGA
1459	BHC30 [Last 70% of CDR H1]-TATGGTATGAATTGGGTGCCA

**Table 51. Heavy Chain FR2 (Chothia Definition) Antibody-Specific Reverse Primers
(for Sub-Library 9)**

1460	BHC1' [First 70% of CDR H2]-AATASCWGAGACCCACTCCAG
1461	BHC2' [First 70% of CDR H2]-AATAASWGAGACCCACTCCAG
1462	BHC3' [First 70% of CDR H2]-GMTCCATCCCATCCACTCAAG
1463	BHC4' [First 70% of CDR H2]-GATACKCCCAATCCACTCCAG
30 1464	BHC5' [First 70% of CDR H2]-GATRTACCCAATCCACTCCAG
1465	BHC6' [First 70% of CDR H2]-AATGWGTGCAAGCCACTCCAG
1466	BHC7' [First 70% of CDR H2]-AAYACCYGAKACCCACTCCAG
1467	BHC8' [First 70% of CDR H2]-AATGKATGARACCCACTCCAG
1468	BHC9' [First 70% of CDR H2]-ARTACGGCCAACCCACTCCAG
35 1469	BHC10' [First 70% of CDR H2]-AAAACCTCCCATCCACTCAAG
1470	BHC12' [First 70% of CDR H2]-GATTATTCCCATCCACTCAAG
1471	BHC13' [First 70% of CDR H2]-GATCCATCCTATCCACTCAAG
1472	BHC14' [First 70% of CDR H2]-GAACCATCCCATCCACTCAAG
1473	BHC15' [First 70% of CDR H2]-GATCCCTCCCATCCACTCAAG
40 1474	BHC16' [First 70% of CDR H2]-CATCCATCCCATCCACTCAAG
1475	BHC17' [First 70% of CDR H2]-TGTCTTCCCAGCCACTCAAG
1476	BHC18' [First 70% of CDR H2]-AATACGTGAGACCCACACCAG
1477	BHC19' [First 70% of CDR H2]-AATAGCTGAAACATATTCCAG

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1478 BHC20' [First 70% of CDR H2]-GATTTCCCAATCCACTCCAG
 1479 BHC21' [First 70% of CDR H2]-GATGATCCCCATCCACTCCAG
 1480 BHC22' [First 70% of CDR H2]-TATAACTGCCACCCACTCCAG
 1481 BHC23' [First 70% of CDR H2]-AATGAAACCTACCCACTCCAG
 5 1482 BHC24' [First 70% of CDR H2]-TATGTTGGCCACCCACTCCAG

PCR is carried out with BHC1 to BHC30 in combination with BHC1' to BHC24' using sub-bank 9 as a template. This generates combinatorial sub-library 9 or a pool of oligonucleotides corresponding to sequences described in Table 9.

10 By way of example but not limitation, the combinatorial sub-library 10 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 52 and Table 53 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

15 **Table 52. Heavy Chain FR3 (Chothia Definition) Antibody-Specific Forward Primers (for Sub-Library 10):**

	1483	CHC1	[Last 70% of CDR H2]-ACCAACTACAACCCSTCCCTC
	1484	CHC2	[Last 70% of CDR H2]-ATATACTACGCAGACTCWGTG
	1485	CHC3	[Last 70% of CDR H2]-ACATACTAYGCAGACTCYGTG
20	1486	CHC4	[Last 70% of CDR H2]-ACMAACTACGCACAGAARTTC
	1487	CHC5	[Last 70% of CDR H2]-ACAAACTATGCACAGAAGYT
	1488	CHC6	[Last 70% of CDR H2]-ACARGCTAYGCACAGAAGTTC
	1489	CHC7	[Last 70% of CDR H2]-AYAGGYTATGCRGACTCTGTG
	1490	CHC8	[Last 70% of CDR H2]-AAATMCTACAGCACATCTCTG
25	1491	CHC9	[Last 70% of CDR H2]-AAATACTATGTGGACTCTGTG
	1492	CHC10	[Last 70% of CDR H2]-CCAACATATGCCAGGGCTTC
	1493	CHC11	[Last 70% of CDR H2]-GCAAACTACGCACAGAAGTTC
	1494	CHC12	[Last 70% of CDR H2]-AAATACTATGCAGACTCCGTG
	1495	CHC13	[Last 70% of CDR H2]-AAGCGCTACAGCCCATCTCTG
30	1496	CHC14	[Last 70% of CDR H2]-AATGATTATGCAGTATCTGTG
	1497	CHC15	[Last 70% of CDR H2]-ACCAGATACAGCCCGTCCTTC
	1498	CHC16	[Last 70% of CDR H2]-ACAGAATACGCCGCGTCTGTG
	1499	CHC17	[Last 70% of CDR H2]-ACGCACTATGCAGACTCTGTG
	1500	CHC18	[Last 70% of CDR H2]-ACGCACTATGTGGACTCCGTG
35	1501	CHC19	[Last 70% of CDR H2]-ACAATCTACGCACAGAAGTTC
	1502	CHC20	[Last 70% of CDR H2]-ACAAAATATTCACAGGAGTTC
	1503	CHC21	[Last 70% of CDR H2]-ACATACTACGCAGACTCCAGG
	1504	CHC22	[Last 70% of CDR H2]-ACAAGCTACGCGGACTCCGTG
	1505	CHC23	[Last 70% of CDR H2]-ACATATTATGCAGACTCTGTG
40	1506	CHC24	[Last 70% of CDR H2]-ACAGACTACGCTGCACCCGTG

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1507	CHC25	[Last 70% of CDR H2]-ACAGCATATGCTGCGTCGGTG
1508	CHC26	[Last 70% of CDR H2]-ACATACTATCCAGGCTCCGTG
1509	CHC27	[Last 70% of CDR H2]-ACCTACTACAACCCGTCCCTC

5 Table 53. Heavy Chain FR3 (Chothia Definition) Antibody-Specific Reverse Primers (for Sub-Library 10):

1510	CHC1'	[First 70% of CDR H3]- TSTYGCACAGTAATACACGGC
1511	CHC2'	[First 70% of CDR H3]- TCTYGCACAGTAATACATGGC
1512	CHC3'	[First 70% of CDR H3]- TCTAGYACAGTAATACACGGC
10 1513	CHC4'	[First 70% of CDR H3]- CCGTGCACARTAATAYGTGGC
1514	CHC5'	[First 70% of CDR H3]- TCTYGCACAGTAATACACAGC
1515	CHC6'	[First 70% of CDR H3]- GTGTGCACAGTAATATGTGGC
1516	CHC7'	[First 70% of CDR H3]- TGCCGCACAGTAATACACGGC
1517	CHC8'	[First 70% of CDR H3]- TGTGGTACAGTAATACACGGC
15 1518	CHC9'	[First 70% of CDR H3]- TCTCACACAGTAATACACAGC
1519	CHC10'	[First 70% of CDR H3]- TCTCGCACAGTGATACAAGGC
1520	CHC11'	[First 70% of CDR H3]- TTTCGCACAGTAATATACGGC
1521	CHC12'	[First 70% of CDR H3]- TCTGGCACAGTAATACACGGC
1522	CHC13'	[First 70% of CDR H3]- TTTTGCACAGTAATACAAGGC

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PCR is carried out with CHC1 to CHC27 in combination with CHC1' to CHC13' using sub-bank 10 as a template. This generates combinatorial sub-library 10 or a pool of oligonucleotides corresponding to sequences described in Table 10.

By way of example but not limitation, the combinatorial sub-library 11 is constructed using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides in Table 54 and Table 55 (all shown in the 5' to 3' orientation, name followed by sequence) where K= G or T, M= A or C, R= A or G, S= C or G, W= A or T and Y= C or T.

30 Table 54. Heavy Chain FR4 (Kabat and Chothia Definition) Antibody-Specific Forward Primers (for Sub-Library 11):

1523	DH1	[Last 70% of CDR H3]-TGGGGCCARGGMACCCTGGTC
1524	DH2	[Last 70% of CDR H3]-TGGGGSCAAGGGACMAYGGTC
1525	DH3	[Last 70% of CDR H3]-TGGGGCCGTGGCACCCCTGGTC

35 Table 55. Heavy Chain FR4 (Kabat and Chothia Definition) Antibody-Specific Reverse Primers (for Sub-Library 11)

1526	DH1'	TGAGGAGACRGTGACCAGGGT
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1527 DH2' TGARGAGACGGTGACCR TKGT

1528 DH3' TGAGGAGACGGTGACCAGGGT

5 PCR is carried out with DH1 to DHC3 in combination with DH1' to DH3' using sub-bank 11 as a template. This generates combinatorial sub-library 11 or a pool of oligonucleotides corresponding to sequences described in Table 11.

In some embodiments, nine combinatorial sub-libraries can be constructed using direct ligation of non-human CDRs and the human frameworks of the sub-banks. For example, combinatorial sub-libraries 1', 2' and 3' are built separately by direct ligation of
 10 the non-human CDRs L1, L2 and L3 (in a single stranded or double stranded form) to sub-banks 1, 2 and 3, respectively. In one embodiment, the non-human CDRs (L1, L2 and L3) are single strand nucleic acids. In another embodiment, the non-human CDRs (L1, L2 and L3) are double strand nucleic acids. Alternatively, combinatorial sub-libraries 1', 2' and 3' can be obtained by direct ligation of the non-human CDRs (L1, L2 and L3) in a single
 15 stranded (+) form to the nucleic acid 1-46 listed in Table 1, nucleic acid 47-92 listed in Table 2, and nucleic acid 93-138 listed in Table 3, respectively.

In some embodiments, combinatorial sub-libraries 5' and 6' are built separately by direct ligation of the non-human CDRs H1 and H2 (in a single stranded or double stranded form and according to Kabat definition) to sub-banks 5 and 6, respectively.
 20 Alternatively, sub-libraries 5' and 6' can be obtained by direct ligation of the non-human CDRs H1 and H2 (according to Kabat definition and in a single stranded (+) form) to nucleic acid 1 to 44 listed in Table 5 and 45 to 88 listed in Table 6, respectively.

In some embodiments, combinatorial sub-libraries 8' and 9' are built separately by direct ligation of the non-human CDRs H1 and H2 (in a single stranded or
 25 double stranded form and according to Chothia definition) to sub-banks 8 and 9, respectively. Alternatively, sub-libraries 8' and 9' can be obtained by direct ligation of the non-human CDRs H1 and H2 (according to Chothia definition and in a single stranded (+) form) to nucleic acid 133 to 176 listed in Table 8 and 177 to 220 of Table 9, respectively.

Combinatorial sub-libraries 11' and 12' are built separately by direct ligation
 30 of the non-human CDR H3 (in a single stranded or double stranded form) to sub-bank 7 (Kabat definition) and 10 (Chothia definition), respectively. Alternatively, sub-libraries 11' and 12' can be obtained by direct ligation of non-human CDR H3 (in a single stranded (+) form) to nucleic acid 89 to 132 listed in Table 7 and 221 to 264 of Table 10, respectively.

Direct ligation of DNA fragments can be carried out according to standard protocols. It can be followed by purification/separation of the ligated products from the unligated ones.

2.5 Construction of Combinatorial Libraries

Combinatorial libraries are constructed by assembling together combinatorial sub-libraries of corresponding variable light chain region or variable heavy chain region. For example, combinatorial library of human kappa light chain germline frameworks (combination library 1) can be built by assembling together sub-libraries 1, 2, 3 and 4 through overlapping regions in the CDRs as described below; two combinatorial libraries of human heavy chain germline frameworks (one for Kabat definition of the CDRs, combination library 2, and one for Chothia definition of the CDRs, combination library 3) can be built by assembling together sub-libraries 5, 6, 7, 11 (Kabat definition) or sub-libraries 8, 9, 10, 11 (Chothia definition) through overlapping regions in the CDRs as described below.

In one embodiment, the construction of combinatorial library 1 is carried out using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides listed in Table 56 and Table 57 (all shown in the 5' to 3' orientation, the name of the primer followed by the sequence):

Table 56. Light Chain Forward Primers (for Combinatorial Library 1):

20	1529	AL1	GATGTTGTGATGACWCAGTCT
	1530	AL2	GACATCCAGATGAYCCAGTCT
	1531	AL3	GCCATCCAGWTGACCCAGTCT
	1532	AL4	GAAATAGTGATGAYGCAGTCT
	1533	AL5	GAAATTGTGTTGACRCAGTCT
25	1534	AL6	GAKATTGTGATGACCCAGACT
	1535	AL7	GAAATTGTRMTGACWCAGTCT
	1536	AL8	GAYATYGTGATGACYCAGTCT
	1537	AL9	GAAACGACACTCACGCAGTCT
	1538	AL10	GACATCCAGTTGACCCAGTCT
30	1539	AL11	AACATCCAGATGACCCAGTCT
	1540	AL12	GCCATCCGGATGACCCAGTCT
	1541	AL13	GTCATCTGGATGACCCAGTCT

Table 57. Light Chain Reverse Primers (for Combinatorial Library 1):

35	1542	DL1'	TTTGATYTCCACCTTGGTCCC
	1543	DL2'	TTTGATCTCCAGCTTGGTCCC
	1544	DL3'	TTTGATATCCACTTGGTCCC

PCR is carried out with AL1 to AL13 in combination with DL1' to DL4' using sub-libraries 1, 2, 3 and 4 together or a pool of oligonucleotides corresponding to sequences described in Table 1, 2, 3 and 4 as a template. This generates combinatorial library 1.

In one embodiment, the construction of combinatorial library 2 and 3 is carried out using the Polymerase Chain Reaction (PCR) by overlap extension using the oligonucleotides listed in Table 58 and Table 59 (all shown in the 5' to 3' orientation, name followed by sequence):

Table 58. Heavy Chain Forward Primers (for Combinatorial Library 2 and 3, Kabat and Chothia Definition):

1546	AH1	CAGGTKCAGCTGGTGCAGTCT
1547	AH2	GAGGTGCAGCTGKTGGAGTCT
1548	AH3	CAGSTGCAGCTGCAGGAGTCG
1549	AH4	CAGGTCACCTTGARGGAGTCT
1550	AH5	CARATGCAGCTGGTGCAGTCT
1551	AH6	GARGTGCAGCTGGTGSAGTC
1552	AH7	CAGATCACCTTGAAGGAGTCT
1553	AH8	CAGGTSCAGCTGGTRSAGTCT
1554	AH9	CAGGTACAGCTGCAGCAGTCA
1555	AH10	CAGGTGCAGCTACAGCAGTGG

Table 59. Heavy Chain Reverse Primers (for Combinatorial Library 2 and 3, Kabat and Chothia Definition):

1556	DH1'	TGAGGAGACRGTGACCAGGGT
1557	DH2'	TGARGAGACGGTGACCRKGT
1558	DH3'	TGAGGAGACGGTGACCAGGGT

PCR is carried out with AH1 to AH10 in combination with DH1' to DH3' using sub-libraries 5, 6, 7, 11 together, or a pool of oligonucleotides corresponding to sequences described in Table 5, 6, 7 and 11, or sub-libraries 8, 9, 10, 11, or a pool of oligonucleotides corresponding to sequences described in Table 8, 9, 10 and 11, together as a template. This generates combinatorial library 2 or 3, respectively.

In another embodiment, combinatorial libraries are constructed by direct ligation. For example, combinatorial library of human kappa light chain germline

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frameworks (combination library 1') is built by direct sequential ligation of sub-libraries 1', 2', 3' and sub-bank 4 (or nucleic acids 139 to 143, see Table 4) together. This is followed by a Polymerase Chain Reaction step using the oligonucleotides described in Table 60 and Table 61. Two combinatorial libraries of human heavy chain germline framework regions (one for Kabat definition of the CDRs, combination library 2'; and one for Chothia definition of the CDRs, combination library 3') are built by direct sequential ligation of sub-libraries 5', 6', 11' and sub-bank 11 (Kabat definition) or of sub-libraries 8', 9', 12' and sub-bank 11 (Chothia definition) together. Alternatively, sub-bank 11 can be substituted with nucleic acids 265 to 270 (see Table 11) in the ligation reactions. This is followed by a Polymerase Chain Reaction step using the oligonucleotides described in Table 62 and Table 63.

Table 60. Light Chain Forward Primers (for Combinatorial Library 1'):

1559	AL1	GATGTTGTGATGACWCAGTCT
1560	AL2	GACATCCAGATGAYCCAGTCT
1561	AL3	GCCATCCAGWTGACCCAGTCT
1562	AL4	GAAATAGTGATGAYGCAGTCT
1563	AL5	GAAATTGTGTTGACRCAGTCT
1564	AL6	GAKATTGTGATGACCCAGACT
1565	AL7	GAAATTGTRMTGACWCAGTCT
1566	AL8	GAYATYGTGATGACYCAGTCT
1567	AL9	GAAACGACACTCACGCAGTCT
1568	AL10	GACATCCAGTTGACCCAGTCT
1569	AL11	AACATCCAGATGACCCAGTCT
1570	AL12	GCCATCCGGATGACCCAGTCT
1571	AL13	GTCATCTGGATGACCCAGTCT

Table 61. Light Chain Reverse Primers (for Combinatorial Library 1'):

1572	DL1'	TTTGATYTCCACCTTGGTCCC
1573	DL2'	TTTGATCTCCAGCTTGGTCCC
1574	DL3'	TTTGATATCCACTTGGTCCC
1575	DL4'	TTTAATCTCCAGTCGTGTCCC

PCR is carried out with AL1 to AL13 in combination with DL1' to DL4' using sub-libraries 1', 2', 3' and sub-bank 4 (or nucleic acids 139 to 143, see Table 4) previously ligated together as a template. This generates combinatorial library 1'.

Table 62. Heavy Chain Forward Primers (for Combinatorial Library 2' and 3', Kabat and Chothia Definition):

1576	AH1	CAGGTKCAGCTGGTGCAGTCT
1577	AH2	GAGGTGCAGCTGKTGGAGTCT
1578	AH3	CAGSTGCAGCTGCAGGAGTCG
1579	AH4	CAGGTCACCTTGARGGAGTCT
5 1580	AH5	CARATGCAGCTGGTGCAGTCT
1581	AH6	GARGTGCAGCTGGTGSAGTC
1582	AH7	CAGATCACCTTGAAGGAGTCT
1583	AH8	CAGGTSCAGCTGGTRSAGTCT
1584	AH9	CAGGTACAGCTGCAGCAGTCA
10 1585	AH10	CAGGTGCAGCTACAGCAGTGG

Table 63. Heavy Chain Reverse Primers (for Combinatorial Library 2' and 3', Kabat and Chothia Definition):

1586	DH1'	TGAGGAGACRGTGACCAGGGT
15 1587	DH2'	TGARGAGACGGTGACCRTKGT
1588	DH3'	TGAGGAGACGGTGACCAGGGT

PCR is carried out with AH1 to AH10 in combination with DH1' to DH3' using sub-libraries 5', 6', 11' and sub-bank 11 (or nucleic acids 265 to 270, see Table 11) previously ligated together or sub-libraries 8', 9', 12' and sub-bank 11 (or nucleic acids 265 to 270, see Table 11) previously ligated together as a template. This generates combinatorial library 2' or 3', respectively.

The sub-banks of framework regions, sub-banks of CDRs, combinatorial sub-libraries, and combinatorial libraries constructed in accordance with the present invention can be stored for a later use. The nucleic acids can be stored in a solution, as a dry sterilized lyophilized powder, or a water free concentrate in a hermetically sealed container. In cases where the nucleic acids are not stored in a solution, the nucleic acids can be reconstituted (*e.g.*, with water or saline) to the appropriate concentration for a later use. The sub-banks, combinatorial sub-libraries and combinatorial libraries of the invention are preferably stored at between 2°C and 8°C in a container indicating the quantity and concentration of the nucleic acids.

2.6 Expression of the Combinatorial Libraries

The combinatorial libraries constructed in accordance with the present invention can be expressed using any methods known in the art, including but not limited to, bacterial expression system, mammalian expression system, and *in vitro* ribosomal display system.

In preferred embodiments, the present invention encompasses the use of phage vectors to express the combinatorial libraries. Phage vectors have particular advantages of providing a means for screening a very large population of expressed display proteins and thereby locate one or more specific clones that code for a desired binding activity.

The use of phage display vectors to express a large population of antibody molecules are well known in the art and will not be reviewed in detail herein. The method generally involves the use of a filamentous phage (phagemid) surface expression vector system for cloning and expressing antibody species of a library. See, *e.g.*, Kang *et al.*, Proc. Natl. Acad. Sci., USA, 88:4363-4366 (1991); Barbas *et al.*, Proc. Natl. Acad. Sci., USA, 88:7978-7982 (1991); Zebedee *et al.*, Proc. Natl. Acad. Sci., USA, 89:3175-3179 (1992); Kang *et al.*, Proc. Natl. Acad. Sci., USA, 88:11120-11123 (1991); Barbas *et al.*, Proc. Natl. Acad. Sci., USA, 89:4457-4461 (1992); Gram *et al.*, Proc. Natl. Acad. Sci., USA, 89:3576-3580 (1992); Brinkman *et al.*, J. Immunol. Methods 182:41-50 (1995); Ames *et al.*, J. Immunol. Methods 184:177-186 (1995); Kettleborough *et al.*, Eur. J. Immunol. 24:952-958 (1994); Persic *et al.*, Gene 187 9-18 (1997); Burton *et al.*, Advances in Immunology 57:191-280 (1994); PCT application No. PCT/GB91/01134; PCT publication Nos. WO 90/02809; WO 91/10737; WO 92/01047; WO 92/18619; WO 93/11236; WO 95/15982; WO 95/20401; and U.S. Patent Nos. 5,698,426; 5,223,409; 5,403,484; 5,580,717; 5,427,908; 5,750,753; 5,821,047; 5,571,698; 5,427,908; 5,516,637; 5,780,225; 5,658,727; 5,733,743 and 5,969,108, all of which are incorporated herein by reference in their entireties.

A preferred phagemid vector of the present invention is a recombinant DNA molecule containing a nucleotide sequence that codes for and is capable of expressing a fusion polypeptide containing, in the direction of amino- to carboxy-terminus, (1) a prokaryotic secretion signal domain, (2) a heterologous polypeptide defining an immunoglobulin heavy or light chain variable region, and (3) a filamentous phage membrane anchor domain. The vector includes DNA expression control sequences for expressing the fusion polypeptide, preferably prokaryotic control sequences.

The filamentous phage membrane anchor is preferably a domain of the cpIII or cpVIII coat protein capable of associating with the matrix of a filamentous phage particle, thereby incorporating the fusion polypeptide onto the phage surface.

Preferred membrane anchors for the vector are obtainable from filamentous phage M13, f1, fd, and equivalent filamentous phage. Preferred membrane anchor domains are found in the coat proteins encoded by gene III and gene VIII. (See Ohkawa *et al.*, J. Biol. Chem., 256:9951-9958, 1981). The membrane anchor domain of a filamentous phage coat protein is a portion of the carboxy terminal region of the coat protein and includes a region of hydrophobic amino acid residues for spanning a lipid bilayer membrane, and a region of charged amino acid residues normally found at the cytoplasmic face of the membrane and extending away from the membrane. For detailed descriptions of the structure of filamentous phage particles, their coat proteins and particle assembly, see the reviews by Rached *et al.*, Microbiol. Rev., 50:401-427 (1986); and Model *et al.*, in "The Bacteriophages: Vol. 2", R. Calendar, ed. Plenum Publishing Co., pp. 375-456 (1988).

The secretion signal is a leader peptide domain of a protein that targets the protein to the periplasmic membrane of gram negative bacteria. A preferred secretion signal is a pelB secretion signal. (Better *et al.*, Science, 240:1041-1043 (1988); Sastry *et al.*, Proc. Natl. Acad. Sci., USA, 86:5728-5732 (1989); and Mullinax *et al.*, Proc. Natl. Acad. Sci., USA, 87:8095-8099 (1990)). The predicted amino acid residue sequences of the secretion signal domain from two pelB gene product variants from *Erwinia carotova* are described in Lei *et al.*, Nature, 331:543-546 (1988). Amino acid residue sequences for other secretion signal polypeptide domains from *E. coli* useful in this invention as described in Oliver, *Escherichia coli* and *Salmonella Typhimurium*, Neidhard, F. C. (ed.), American Society for Microbiology, Washington, D.C., 1:56-69 (1987).

DNA expression control sequences comprise a set of DNA expression signals for expressing a structural gene product and include both 5' and 3' elements, as is well known, operatively linked to the gene. The 5' control sequences define a promoter for initiating transcription and a ribosome binding site operatively linked at the 5' terminus of the upstream translatable DNA sequence. The 3' control sequences define at least one termination (stop) codon in frame with and operatively linked to the heterologous fusion polypeptide.

In preferred embodiments, the vector used in this invention includes a prokaryotic origin of replication or replicon, *i.e.*, a DNA sequence having the ability to direct autonomous replication and maintenance of the recombinant DNA molecule extra-

chromosomally in a prokaryotic host cell, such as a bacterial host cell, transformed therewith. Such origins of replication are well known in the art. Preferred origins of replication are those that are efficient in the host organism. A preferred host cell is *E. coli*. See Sambrook *et al.*, in "Molecular Cloning: a Laboratory Manual", 2nd edition, Cold
5 Spring Harbor Laboratory Press, New York (1989).

In addition, those embodiments that include a prokaryotic replicon can also include a nucleic acid whose expression confers a selective advantage, such as drug resistance, to a bacterial host transformed therewith. Typical bacterial drug resistance genes are those that confer resistance to ampicillin, tetracycline, neomycin/kanamycin or
10 chloramphenicol. Vectors typically also contain convenient restriction sites for insertion of translatable DNA sequences.

In some embodiments, the vector is capable of co-expression of two cistrons contained therein, such as a nucleotide sequence encoding a variable heavy chain region and a nucleotide sequence encoding a variable light chain region. Co-expression has been
15 accomplished in a variety of systems and therefore need not be limited to any particular design, so long as sufficient relative amounts of the two gene products are produced to allow assembly and expression of functional heterodimer.

In some embodiments, a DNA expression vector is designed for convenient manipulation in the form of a filamentous phage particle encapsulating a genome. In this
20 embodiment, a DNA expression vector further contains a nucleotide sequence that defines a filamentous phage origin of replication such that the vector, upon presentation of the appropriate genetic complementation, can replicate as a filamentous phage in single stranded replicative form and be packaged into filamentous phage particles. This feature provides the ability of the DNA expression vector to be packaged into phage particles for
25 subsequent segregation of the particle, and vector contained therein, away from other particles that comprise a population of phage particles.

A filamentous phage origin of replication is a region of the phage genome, as is well known, that defines sites for initiation of replication, termination of replication and packaging of the replicative form produced by replication (see for example, Rasched *et al.*,
30 Microbiol. Rev., 50:401-427, 1986; and Horiuchi, J. Mol. Biol., 188:215-223, 1986). A preferred filamentous phage origin of replication for use in the present invention is an M13, f1 or fd phage origin of replication (Short *et al.*, Nucl. Acids Res., 16:7583-7600, 1988).

The method for producing a heterodimeric immunoglobulin molecule generally involves (1) introducing a large population of display vectors each capable of expressing different putative binding sites displayed on a phagemid surface display protein to a filamentous phage particle, (3) expressing the display protein and binding site on the surface of a filamentous phage particle, and (3) isolating (screening) the surface-expressed phage particle using affinity techniques such as panning of phage particles against a preselected antigen, thereby isolating one or more species of phagemid containing a display protein containing a binding site that binds a preselected antigen.

The isolation of a particular vector capable of expressing an antibody binding site of interest involves the introduction of the dicistronic expression vector able to express the phagemid display protein into a host cell permissive for expression of filamentous phage genes and the assembly of phage particles. Typically, the host is *E. coli*. Thereafter, a helper phage genome is introduced into the host cell containing the phagemid expression vector to provide the genetic complementation necessary to allow phage particles to be assembled.

The resulting host cell is cultured to allow the introduced phage genes and display protein genes to be expressed, and for phage particles to be assembled and shed from the host cell. The shed phage particles are then harvested (collected) from the host cell culture media and screened for desirable antibody binding properties. Typically, the harvested particles are "panned" for binding with a preselected antigen. The strongly binding particles are then collected, and individual species of particles are clonally isolated and further screened for binding to the antigen. Phages which produce a binding site of desired antigen binding specificity are selected.

After phage selection, the antibody coding regions from the phage can be isolated and used to generate whole antibodies or any other desired antigen binding fragment, and expressed in any desired host, including mammalian cells, insect cells, plant cells, yeast, and bacteria, *e.g.*, as described in detail below. For example, techniques to recombinantly produce Fab, Fab' and F(ab')₂ fragments can also be employed using methods known in the art such as those disclosed in International Publication No. WO 92/22324; Mullinax *et al.*, BioTechniques 12(6):864-869 (1992); and Sawai *et al.*, AJRI 34:26-34 (1995); and Better *et al.*, Science 240:1041-1043 (1988) (said references incorporated by reference in their entireties). Examples of techniques which can be used to produce single-chain Fvs and antibodies include those described in U.S. Patent Nos. 4,946,778 and

5,258,498; Huston *et al.*, Methods in Enzymology 203:46-88 (1991); Shu *et al.*, PNAS 90:7995-7999 (1993); and Skerra *et al.*, Science 240:1038-1040 (1988).

The invention also encompasses a host cell containing a vector or nucleotide sequence of this invention. In a specific embodiment, the host cell is *E. coli*.

5 In a preferred embodiment, a combinatorial library of the invention is cloned into a M13-based phage vector. This vector allows the expression of Fab fragments that contain the first constant domain of the human $\gamma 1$ heavy chain and the constant domain of the human kappa (κ) light chain under the control of the lacZ promoter. This can be carried out by hybridization mutagenesis as described in Wu & An, 2003, Methods Mol. Biol., 207, 10 213-233; Wu, 2003, Methods Mol. Biol., 207, 197-212; and Kunkel *et al.*, 1987, Methods Enzymol. 154, 367-382; all of which are incorporated herein by reference in their entireties. Briefly, purified minus strands corresponding to the heavy and light chains to be cloned are annealed to two regions containing each one palindromic loop. Those loops contain a unique XbaI site which allows for the selection of the vectors that contain both V_L and V_H 15 chains fused in frame with the human kappa (κ) constant and first human $\gamma 1$ constant regions, respectively (Wu & An, 2003, Methods Mol. Biol., 207, 213-233, Wu, 2003, Methods Mol. Biol., 207, 197-212). Synthesized DNA is then electroporated into XL1-blue for plaque formation on XL1-blue bacterial lawn or production of Fab fragments as described in Wu, 2003, Methods Mol. Biol., 207, 197-212.

20 In addition to bacterial/phage expression systems, other host-vector systems may be utilized in the present invention to express the combinatorial libraries of the present invention. These include, but are not limited to, mammalian cell systems transfected with a vector or infected with virus (*e.g.*, vaccinia virus, adenovirus, etc.); insect cell systems transfected with a vector or infected with virus (*e.g.*, baculovirus); microorganisms such as 25 yeast containing yeast vectors; or bacteria transformed with DNA, plasmid DNA, or cosmid DNA. *See e.g.*, Verma *et al.*, J Immunol Methods. 216(1-2):165-81 (1998), which is incorporated herein by reference.

The expression elements of vectors vary in their strengths and specificities. Depending on the host-vector system utilized, any one of a number of suitable transcription and translation elements may be used. In a preferred aspect, each nucleic acid of a 30 combinatorial library of the invention is part of an expression vector that expresses the humanized heavy and/or light chain or humanized heavy and/or light variable regions in a suitable host. In particular, such nucleic acids have promoters, preferably heterologous promoters, operably linked to the antibody coding region, said promoter being inducible or

constitutive, and, optionally, tissue-specific. (See Section 5.7 for more detail.) In another particular embodiment, nucleic acid molecules are used in which the antibody coding sequences and any other desired sequences are flanked by regions that promote homologous recombination at a desired site in the genome, thus providing for intrachromosomal expression of the antibody encoding nucleic acids (Koller and Smithies, 1989, Proc. Natl. Acad. Sci. USA 86:8932-8935; Zijlstra et al., 1989, Nature 342:435-438).

The combinatorial libraries can also be expressed using *in vitro* systems, such as the ribosomal display systems (see Section 5.6 for detail).

2.7 Selection of Humanized Antibodies

The expressed combinatorial libraries can be screened for binding to the antigen recognized by the donor antibody using any methods known in the art. In preferred embodiments, a phage display library constructed and expressed as described in section 5.4. and 5.6, respectively, is screened for binding to the antigen recognized by the donor antibody, and the phage expressing V_H and/or V_L domain with significant binding to the antigen can be isolated from a library using the conventional screening techniques (*e.g.* as described in Harlow, E., and Lane, D., 1988, *supra* Gherardi, E et al. 1990. J. Immunol. meth. 126 p61-68). The shed phage particles from host cells are harvested (collected) from the host cell culture media and screened for desirable antibody binding properties. Typically, the harvested particles are "panned" for binding with a preselected antigen. The strongly binding particles are then collected, and individual species of particles are clonally isolated and further screened for binding to the antigen. Phages which produce a binding site of desired antigen binding specificity are selected. Preferably, a humanized antibody of the invention has affinity of at least $1 \times 10^6 \text{ M}^{-1}$, preferably at least $1 \times 10^7 \text{ M}^{-1}$, at least $1 \times 10^8 \text{ M}^{-1}$, or at least $1 \times 10^9 \text{ M}^{-1}$ for an antigen of interest.

In a preferred embodiment, a phage library is first screened using a modified plaque lifting assay, termed capture lift. See Watkins *et al.*, 1997, Anal. Biochem., 253:37-45. Briefly, phage infected bacteria are plated on solid agar lawns and subsequently, are overlaid with nitrocellulose filters that have been coated with a Fab-specific reagent (*e.g.*, an anti-Fab antibody). Following the capture of nearly uniform quantities of phage-expressed Fab, the filters are probed with desired antigen-Ig fusion protein at a concentration substantially below the K_d value of the Fab.

In another embodiment, the combinatorial libraries are expressed and screened using *in vitro* systems, such as the ribosomal display systems (*see, e.g.*, Graddis *et al.*, Curr Pharm Biotechnol. 3(4):285-97 (2002); Hanes and Plutchau PNAS USA 94:4937-

4942 (1997); He, 1999, J. Immunol. Methods, 231:105; Jermutus et al. (1998) Current Opinion in Biotechnology, 9:534-548; each of which is incorporated herein by reference).

The ribosomal display system works by translating a library of antibody or fragment thereof *in vitro* without allowing the release of either antibody (or fragment thereof) or the mRNA

5 from the translating ribosome. This is made possible by deleting the stop codon and utilizing a ribosome stabilizing buffer system. The translated antibody (or fragment thereof) also contains a C-terminal tether polypeptide extension in order to facilitate the newly synthesized antibody or fragment thereof to emerge from the ribosomal tunnel and fold independently. The folded antibody or fragment thereof can be screened or captured with a
10 cognate antigen. This allows the capture of the mRNA, which is subsequently enriched *in vitro*. The *E. coli* and rabbit reticulocyte systems are commonly used for the ribosomal display.

Other methods known in the art, *e.g.*, PROfusion™ (U.S. Patent No. 6,281,344, Phyllos Inc., Lexington, MA), Covalent Display (International Publication No.
15 WO 9837186, Actinova Ltd., Cambridge, U.K.), can also be used in accordance with the present invention.

In another embodiment, an antigen can be bound to a solid support(s), which can be provided by a petri dish, chromatography beads, magnetic beads and the like. As used herein, the term "solid support" is not limited to a specific type of solid support.

20 Rather a large number of supports are available and are known to one skilled in the art. Solid supports include silica gels, resins, derivatized plastic films, glass beads, cotton, plastic beads, polystyrene beads, alumina gels, and polysaccharides. A suitable solid support may be selected on the basis of desired end use and suitability for various synthetic protocols. For example, for peptide synthesis, a solid support can be a resin such as p-
25 methylbenzhydrylamine (pMBHA) resin (Peptides International, Louisville, KY), polystyrenes (*e.g.*, PAM-resin obtained from Bachem Inc., Peninsula Laboratories, etc.), including chloromethylpolystyrene, hydroxymethylpolystyrene and aminomethylpolystyrene, poly (dimethylacrylamide)-grafted styrene co-divinyl-benzene (*e.g.*, POLYHIPE resin, obtained from Aminotech, Canada), polyamide resin (obtained from
30 Peninsula Laboratories), polystyrene resin grafted with polyethylene glycol (*e.g.*, TENTAGEL or ARGOGEL, Bayer, Tübingen, Germany) polydimethylacrylamide resin (obtained from Milligen/Bioscience, California), or Sepharose (Pharmacia, Sweden).

The combinatorial library is then passed over the antigen, and those individual antibodies that bind are retained after washing, and optionally detected with a

detection system. If samples of bound population are removed under increasingly stringent conditions, the binding affinity represented in each sample will increase. Conditions of increased stringency can be obtained, for example, by increasing the time of soaking or changing the pH of the soak solution, etc.

5 In another embodiment, enzyme linked immunosorbent assay (ELISA) is used to screen for an antibody with desired binding activity. ELISAs comprise preparing antigen, coating the wells of a microtiter plate with the antigen, washing away antigen that did not bind the wells, adding the antibody of interest conjugated to a detectable compound such as an enzymatic substrate (*e.g.*, horseradish peroxidase or alkaline phosphatase) to the
10 wells and incubating for a period of time, washing away unbound antibodies or non-specifically bound antibodies, and detecting the presence of the antibodies specifically bound to the antigen coating the well. In ELISAs, the antibody of interest does not have to be conjugated to a detectable compound; instead, a second antibody (which recognizes the antibody of interest) conjugated to a detectable compound may be added to the well.
15 Further, instead of coating the well with the antigen, the antibody may be coated to the well. In this case, the detectable molecule could be the antigen conjugated to a detectable compound such as an enzymatic substrate (*e.g.*, horseradish peroxidase or alkaline phosphatase). One of skill in the art would be knowledgeable as to the parameters that can be modified to increase the signal detected as well as other variations of ELISAs known in
20 the art. For further discussion regarding ELISAs see, *e.g.*, Ausubel et al., eds, 1994, Current Protocols in Molecular Biology, Vol. I, John Wiley & Sons, Inc., New York at 11.2.1.

 In another embodiment, BIAcore kinetic analysis is used to determine the binding on and off rates (K_d) of antibodies of the invention to a specific antigen. BIAcore kinetic analysis comprises analyzing the binding and dissociation of an antigen from chips
25 with immobilized antibodies of the invention on their surface. *See Wu et al.*, 1999, J. Mol. Biol., 294:151-162, which is incorporated herein by reference in its entirety. Briefly, antigen-Ig fusion protein is immobilized to a (1-ethyl-3-[3-dimethylaminopropyl]-carbodiimide hydrochloride) and N-hydroxy-succinimide-activated sensor chip CM5 by injecting antigen-Ig in sodium acetate. Antigen-Ig is immobilized at a low density to
30 prevent rebinding of Fabs during the dissociation phase. To obtain association rate constant (K_{on}), the binding rate at six different Fab concentrations is determined at certain flow rate. Dissociation rate constant (K_{off}) are the average of six measurements obtained by analyzing the dissociation phase. Sensorgrams are analyzed with the BIAevaluation 3.0 program. K_d is calculated from $K_d = K_{off}/K_{on}$. Residual Fab is removed after each measurement by

prolonged dissociation. In a more preferred embodiment, positive plaques are picked, re-plated at a lower density, and screened again.

In another embodiment, the binding affinity of an antibody (including a scFv or other molecule comprising, or alternatively consisting of, antibody fragments or variants thereof) to an antigen and the off-rate of an antibody-antigen interaction can be determined by competitive binding assays. One example of a competitive binding assay is a radioimmunoassay comprising the incubation of labeled antigen (*e.g.*, ^3H or ^{125}I) with the antibody of interest in the presence of increasing amounts of unlabeled antigen, and the detection of the antibody bound to the labeled antigen. The affinity of the antibody of the present invention and the binding off-rates can be determined from the data by Scatchard plot analysis. Competition with a second antibody can also be determined using radioimmunoassays. In this case, an antigen is incubated with an antibody of the present invention conjugated to a labeled compound (*e.g.*, ^3H or ^{125}I) in the presence of increasing amounts of an unlabeled second antibody.

Other assays, such as immunoassays, including but not limited to, competitive and non-competitive assay systems using techniques such as western blots, radioimmunoassays, ELISA (enzyme linked immunosorbent assay), sandwich immunoassays, immunoprecipitation assays, precipitin reactions, gel diffusion precipitin reactions, immunodiffusion assays, agglutination assays, complement-fixation assays, fluorescent immunoassays, and protein A immunoassays, can also be used to screen or further characterization of the binding specificity of a humanized antibody. Such assays are routine and well known in the art (see, *e.g.*, Ausubel et al., eds, 1994, Current Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York, which is incorporated by reference herein in its entirety). Exemplary immunoassays are described briefly below (which are not intended by way of limitation).

In a preferred embodiment, ELISA is used as a secondary screening on supernatant prepared from bacterial culture expressing Fab fragments in order to confirm the clones identified by the capture lift assay. Two ELISAs can be carried out: (1) Quantification ELISA: this can be carried out essentially as described in Wu, 2003, Methods Mol. Biol., 207, 197-212, which is incorporated herein by reference in its entirety. Briefly, concentrations can be determined by an anti-human Fab ELISA: individual wells of a 96-well Maxisorp Immunoplate are coated with 50 ng of a goat anti-human Fab antibody and then incubated with samples (supernatant-expressed Fabs) or standard (human IgG Fab). Incubation with a goat anti-human kappa horseradish peroxidase (HRP) conjugate then

followed. HRP activity can be detected with TMB substrate and the reaction quenched with 0.2 M H₂SO₄. Plates are read at 450 nm. Clones that express detectable amount of Fab are then selected for the next part of the secondary screening. (2) Functional ELISA: briefly, a particular antigen binding activity is determined by the antigen-based ELISA: individual wells of a 96-well Maxisorp Immunoplate are coated with 50 ng of the antigen of interest, blocked with 1%BSA/0.1%Tween 20 and then incubated with samples (supernatant-expressed Fabs). Incubation with a goat anti-human kappa horseradish peroxidase (HRP) conjugate then followed. HRP activity is detected with TMB substrate and the reaction quenched with 0.2 M H₂SO₄. Plates are read at 450 nm.

Immunoprecipitation protocols generally comprise lysing a population of cells in a lysis buffer such as RIPA buffer (1 % NP-40 or Triton X- 100, 1 % sodium deoxycholate, 0.1 % SDS, 0.15 M NaCl, 0.01 M sodium phosphate at pH 7.2, 1 % Trasyol) supplemented with protein phosphatase and/or protease inhibitors (*e.g.*, EDTA, PMSF, 159 aprotinin, sodium vanadate), adding the antibody of interest to the cell lysate, incubating for a period of time (*e.g.*, to 4 hours) at 40 degrees C, adding protein A and/or protein G sepharose beads to the cell lysate, incubating for about an hour or more at 40 degrees C, washing the beads in lysis buffer and re-suspending the beads in SDS/sample buffer. The ability of the antibody of interest to immunoprecipitate a particular antigen can be assessed by, *e.g.*, western blot analysis. One of skill in the art would be knowledgeable as to the parameters that can be modified to increase the binding of the antibody to an antigen and decrease the background (*e.g.*, pre-clearing the cell lysate with sepharose beads). For further discussion regarding immunoprecipitation protocols see, *e.g.*, Ausubel et al., eds, 1994, Current Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York, at 10.16.1.

Western blot analysis generally comprises preparing protein samples, electrophoresis of the protein samples in a polyacrylamide gel (*e.g.*, 8%- 20% SDS-PAGE depending on the molecular weight of the antigen), transferring the protein sample from the polyacrylamide gel to a membrane such as nitrocellulose, PVDF or nylon, blocking the membrane in blocking solution (*e.g.*, PBS with 3% BSA or non-fat milk), washing the membrane in washing buffer (*e.g.*, PBSTween 20), blocking the membrane with primary antibody (the antibody of interest) diluted in blocking buffer, washing the membrane in washing buffer, blocking the membrane with a secondary antibody (which recognizes the primary antibody, *e.g.*, an anti-human antibody) conjugated to an enzymatic substrate (*e.g.*, horseradish peroxidase or alkaline phosphatase) or radioactive molecule (*e.g.*, ¹²⁵I or ¹²⁵P)

diluted in blocking buffer, washing the membrane in wash buffer, and detecting the presence of the antigen. One of skill in the art would be knowledgeable as to the parameters that can be modified to increase the signal detected and to reduce the background noise. For further discussion regarding western blot protocols see, *e.g.*, Ausubel et al., eds, 1994, 5 GinTent Protocols in Molecular Biology, Vol. 1, John Wiley & Sons, Inc., New York at 10.8.1.

A nucleic acid encoding a modified (*e.g.*, humanized) antibody or fragment thereof with desired antigen binding activity can be characterized by sequencing, such as dideoxynucleotide sequencing using a ABI300 genomic analyzer. Other immunoassays, 10 such as the two-part secondary ELISA screen described above, can be used to compare the modified (*e.g.*, humanized) antibodies to each other and to the donor antibody in terms of binding to a particular antigen of interest.

2.8 Production and Characterization of Humanized Antibodies

Once one or more nucleic acids encoding a humanized antibody or fragment 15 thereof with desired binding activity are selected, the nucleic acid can be recovered by standard techniques known in the art. In a preferred embodiment, the selected phage particles are recovered and used to infect fresh bacteria before recovering the desired nucleic acids.

A phage displaying a protein comprising a humanized variable region with a 20 desired specificity or affinity can be eluted from an affinity matrix by any method known in the art. In one embodiment, a ligand with better affinity to the matrix is used. In a specific embodiment, the corresponding non-humanized antibody is used. In another embodiment, an elution method which is not specific to the antigen-antibody complex is used.

The method of mild elution uses binding of the phage antibody population to 25 biotinylated antigen and binding to streptavidin magnetic beads. Following washing to remove non-binding phage, the phage antibody is eluted and used to infect cells to give a selected phage antibody population. A disulfide bond between the biotin and the antigen molecule allows mild elution with dithiothreitol. In one embodiment, biotinylated antigen can be used in excess but at or below a concentration equivalent to the desired dissociation 30 constant for the antigen-antibody binding. This method is advantageous for the selection of high affinity antibodies (R. E. Hawkins, S. J. Russell and G. Winter J. Mol. Biol. 226 889-896, 1992). Antibodies may also be selected for slower off rates for antigen selection as described in Hawkins et al, 1992, *supra*. The concentration of biotinylated antigen may gradually be reduced to select higher affinity phage antibodies. As an alternative, the phage

antibody may be in excess over biotinylated antigen in order that phage antibodies compete for binding, in an analogous way to the competition of peptide phage to biotinylated antibody described by J. K. Scott & G. P. Smith (Science 249 386-390, 1990).

In another embodiment, a nucleotide sequence encoding amino acids
5 constituting a recognition site for cleavage by a highly specific protease can be introduced between the foreign nucleic acid inserted, *e.g.*, between a nucleic acid encoding an antibody fragment, and the sequence of the remainder of gene III. Non-limiting examples of such highly specific proteases are Factor X and thrombin. After binding of the phage to an affinity matrix and elution to remove non-specific binding phage and weak binding phage,
10 the strongly bound phage would be removed by washing the column with protease under conditions suitable for digestion at the cleavage site. This would cleave the antibody fragment from the phage particle eluting the phage. These phage would be expected to be infective, since the only protease site should be the one specifically introduced. Strongly binding phage could then be recovered by infecting, *e.g.*, *E. coli* TG1 cells.

15 An alternative procedure to the above is to take the affinity matrix which has retained the strongly bound pAb and extract the DNA, for example by boiling in SDS solution. Extracted DNA can then be used to directly transform *E. coli* host cells or alternatively the antibody encoding sequences can be amplified, for example using PCR with suitable primers, and then inserted into a vector for expression as a soluble antibody for
20 further study or a pAb for further rounds of selection.

In another embodiment, a population of phage is bound to an affinity matrix which contains a low amount of antigen. There is competition between phage, displaying high affinity and low affinity proteins, for binding to the antigen on the matrix. Phage displaying high affinity protein is preferentially bound and low affinity protein is washed
25 away. The high affinity protein is then recovered by elution with the ligand or by other procedures which elute the phage from the affinity matrix (International Publication No. WO92/01047 demonstrates this procedure).

The recovered nucleic acid encoding donor CDRs and humanized framework can be used by itself or can be used to construct nucleic acid for a complete antibody
30 molecule by joining them to the constant region of the respective human template. When the nucleic acids encoding antibodies are introduced into a suitable host cell line, the transfected cells can secrete antibodies with all the desirable characteristics of monoclonal antibodies.

Once a nucleic acid encoding an antibody molecule or a heavy or light chain of an antibody, or fragment thereof (preferably, containing the heavy or light chain variable region) of the invention has been obtained, the vector for the production of the antibody molecule may be produced by recombinant DNA technology using techniques well known in the art. Thus, methods for preparing a protein by expressing a nucleic acid encoding an antibody are described herein. Methods which are well known to those skilled in the art can be used to construct expression vectors containing antibody coding sequences and appropriate transcriptional and translational control signals. These methods include, for example, *in vitro* recombinant DNA techniques, synthetic techniques, and *in vivo* genetic recombination. The invention, thus, provides replicable vectors comprising a nucleotide sequence encoding an antibody molecule of the invention, a heavy or light chain of an antibody, a heavy or light chain variable domain of an antibody or a fragment thereof, or a heavy or light chain CDR, operably linked to a promoter. In a specific embodiment, the expression of an antibody molecule of the invention, a heavy or light chain of an antibody, a heavy or light chain variable domain of an antibody or a fragment thereof, or a heavy or light chain CDR is regulated by a constitutive promoter. In another embodiment, the expression of an antibody molecule of the invention, a heavy or light chain of an antibody, a heavy or light chain variable domain of an antibody or a fragment thereof, or a heavy or light chain CDR is regulated by an inducible promoter. In another embodiment, the expression of an antibody molecule of the invention, a heavy or light chain of an antibody, a heavy or light chain variable domain of an antibody or a fragment thereof, or a heavy or light chain CDR is regulated by a tissue specific promoter. Such vectors may also include the nucleotide sequence encoding the constant region of the antibody molecule (*see, e.g.*, International Publication No. WO 86/05807; International Publication No. WO 89/01036; and U.S. Patent No. 5,122,464) and the variable domain of the antibody may be cloned into such a vector for expression of the entire heavy, the entire light chain, or both the entire heavy and light chains.

The expression vector is transferred to a host cell by conventional techniques and the transfected cells are then cultured by conventional techniques to produce an antibody of the invention. Thus, the invention includes host cells containing a polynucleotide encoding an antibody of the invention or fragments thereof, or a heavy or light chain thereof, or portion thereof, or a single chain antibody of the invention, operably linked to a heterologous promoter. In preferred embodiments for the expression of double-chained antibodies, vectors encoding both the heavy and light chains may be co-expressed in the host cell for expression of the entire immunoglobulin molecule, as detailed below.

Preferably, the cell line which is transformed to produce the altered antibody is an immortalized mammalian cell line of lymphoid origin, including but not limited to, a myeloma, hybridoma, trioma or quadroma cell line. The cell line may also comprise a normal lymphoid cell, such as a B cell, which has been immortalized by transformation with a virus, such as the Epstein Barr virus. Most preferably, the immortalized cell line is a myeloma cell line or a derivative thereof.

It is known that some immortalized lymphoid cell lines, such as myeloma cell lines, in their normal state, secrete isolated immunoglobulin light or heavy chains. If such a cell line is transformed with the recovered nucleic acid from phage library, it will not be necessary to reconstruct the recovered fragment to a constant region, provided that the normally secreted chain is complementary to the variable domain of the immunoglobulin chain encoded by the recovered nucleic acid from the phage library.

Although the cell line used to produce the antibodies of the invention is preferably a mammalian cell line, any other suitable cell line may alternatively be used. These include, but are not limited to, microorganisms such as bacteria (*e.g.*, *E. coli* and *B. subtilis*) transformed with recombinant bacteriophage DNA, plasmid DNA or cosmid DNA expression vectors containing antibody coding sequences; yeast (*e.g.*, *Saccharomyces Pichia*) transformed with recombinant yeast expression vectors containing antibody coding sequences; insect cell systems infected with recombinant virus expression vectors (*e.g.*, baculovirus) containing antibody coding sequences; plant cell systems infected with recombinant virus expression vectors (*e.g.*, cauliflower mosaic virus, CaMV; tobacco mosaic virus, TMV) or transformed with recombinant plasmid expression vectors (*e.g.*, Ti plasmid) containing antibody coding sequences; or mammalian cell systems (*e.g.*, COS, CHO, BHK, 293, NS0, and 3T3 cells) harboring recombinant expression constructs containing promoters derived from the genome of mammalian cells (*e.g.*, metallothionein promoter) or from mammalian viruses (*e.g.*, the adenovirus late promoter; the vaccinia virus 7.5K promoter). Preferably, bacterial cells such as *Escherichia coli*, and more preferably, eukaryotic cells, especially for the expression of whole recombinant antibody molecule, are used for the expression of a recombinant antibody molecule. For example, mammalian cells such as Chinese hamster ovary cells (CHO), in conjunction with a vector such as the major intermediate early gene promoter element from human cytomegalovirus is an effective expression system for antibodies (Foecking *et al.*, 1986, Gene 45:101; and Cockett *et al.*, 1990, Bio/Technology 8:2).

In bacterial systems, a number of expression vectors may be advantageously selected depending upon the use intended for the antibody molecule being expressed. For example, when a large quantity of such a protein is to be produced, for the generation of pharmaceutical compositions of an antibody molecule, vectors which direct the expression of high levels of fusion protein products that are readily purified may be desirable. Such vectors include, but are not limited to, the *E. coli* expression vector pUR278 (Ruther *et al.*, 1983, EMBO 12:1791), in which the antibody coding sequence may be ligated individually into the vector in frame with the lac Z coding region so that a fusion protein is produced; pIN vectors (Inouye & Inouye, 1985, Nucleic Acids Res. 13:3101-3109; Van Heeke & Schuster, 1989, J. Biol. Chem. 24:5503-5509); and the like. pGEX vectors may also be used to express foreign polypeptides as fusion proteins with glutathione 5-transferase (GST). In general, such fusion proteins are soluble and can easily be purified from lysed cells by adsorption and binding to matrix glutathione agarose beads followed by elution in the presence of free glutathione. The pGEX vectors are designed to include thrombin or factor Xa protease cleavage sites so that the cloned target can be released from the GST moiety.

In an insect system, Autographa californica nuclear polyhedrosis virus (AcNPV) is used as a vector to express foreign genes. The virus grows in *Spodoptera frugiperda* cells. The antibody coding sequence may be cloned individually into non-essential regions (for example the polyhedrin gene) of the virus and placed under control of an AcNPV promoter (for example the polyhedrin promoter).

In mammalian host cells, a number of viral-based expression systems may be utilized. In cases where an adenovirus is used as an expression vector, the antibody coding sequence of interest may be ligated to an adenovirus transcription/translation control complex, e.g., the late promoter and tripartite leader sequence. This chimeric gene may then be inserted in the adenovirus genome by *in vitro* or *in vivo* recombination. Insertion in a non-essential region of the viral genome (e.g., region E1 or E3) will result in a recombinant virus that is viable and capable of expressing the antibody molecule in infected hosts (e.g., see Logan & Shenk, 1984, Proc. Natl. Acad. Sci. USA 81:355-359). Specific initiation signals may also be required for efficient translation of inserted antibody coding sequences. These signals include the ATG initiation codon and adjacent sequences. Furthermore, the initiation codon must be in phase with the reading frame of the desired coding sequence to ensure translation of the entire insert. These exogenous translational control signals and initiation codons can be of a variety of origins, both natural and synthetic. The efficiency of expression may be enhanced by the inclusion of appropriate transcription enhancer

elements, transcription terminators, etc. (*see, e.g., Bittner et al., 1987, Methods in Enzymol.* 153:516-544).

In addition, a host cell strain may be chosen which modulates the expression of the inserted sequences, or modifies and processes the nucleic acid in a specific fashion
5 desired. Such modifications (*e.g., glycosylation*) and processing (*e.g., cleavage*) of protein products may be important for the function of the protein. Different host cells have characteristic and specific mechanisms for the post-translational processing and modification of proteins and gene products. Appropriate cell lines or host systems can be chosen to ensure the correct modification and processing of the foreign protein expressed.
10 To this end, eukaryotic host cells which possess the cellular machinery for proper processing of the primary transcript, glycosylation, and phosphorylation of the gene product may be used. Such mammalian host cells include but are not limited to CHO, VERY, BHK, Hela, COS, MDCK, 293, 3T3, W138, BT483, Hs578T, HTB2, BT2O and T47D, NS0 (a murine myeloma cell line that does not endogenously produce any immunoglobulin chains),
15 CRL7O3O and HsS78Bst cells.

For long-term, high-yield production of recombinant proteins, stable expression is preferred. For example, cell lines which stably express the antibody molecule may be engineered. Rather than using expression vectors which contain viral origins of replication, host cells can be transformed with DNA controlled by appropriate expression
20 control elements (*e.g., promoter, enhancer, sequences, transcription terminators, polyadenylation sites, etc.*), and a selectable marker. Following the introduction of the foreign DNA, engineered cells may be allowed to grow for 1-2 days in an enriched media, and then are switched to a selective media. The selectable marker in the recombinant plasmid confers resistance to the selection and allows cells to stably integrate the plasmid
25 into their chromosomes and grow to form foci which in turn can be cloned and expanded into cell lines. This method may advantageously be used to engineer cell lines which express the antibody molecule. Such engineered cell lines may be particularly useful in screening and evaluation of compositions that interact directly or indirectly with the antibody molecule.

30 A number of selection systems may be used, including but not limited to, the herpes simplex virus thymidine kinase (Wigler et al., 1977, Cell 11:223), hypoxanthineguanine phosphoribosyltransferase (Szybalska & Szybalski, 1992, Proc. Natl. Acad. Sci. USA 48:202), and adenine phosphoribosyltransferase (Lowy et al., 1980, Cell 22:8-17) genes can be employed in tk-, hgp^{rt}- or ap^{rt}- cells, respectively. Also,

antimetabolite resistance can be used as the basis of selection for the following genes: *dhfr*, which confers resistance to methotrexate (Wigler et al., 1980, Natl. Acad. Sci. USA 77:357; O'Hare et al., 1981, Proc. Natl. Acad. Sci. USA 78:1527); *gpt*, which confers resistance to mycophenolic acid (Mulligan & Berg, 1981, Proc. Natl. Acad. Sci. USA 78:2072); neo, which confers resistance to the aminoglycoside G-418 (Wu and Wu, 1991, Biotherapy 3:87-95; Tolstoshev, 1993, Ann. Rev. Pharmacol. Toxicol. 32:573-596; Mulligan, 1993, Science 260:926-932; and Morgan and Anderson, 1993, Ann. Rev. Biochem. 62: 191-217; May, 1993, TIB TECH 11(5):155-2 15); and *hygro*, which confers resistance to hygromycin (Santerre et al., 1984, Gene 30:147). Methods commonly known in the art of recombinant DNA technology may be routinely applied to select the desired recombinant clone, and such methods are described, for example, in Ausubel *et al.* (eds.), Current Protocols in Molecular Biology, John Wiley & Sons, NY (1993); Kriegler, Gene Transfer and Expression, A Laboratory Manual, Stockton Press, NY (1990); and in Chapters 12 and 13, Dracopoli *et al.* (eds), Current Protocols in Human Genetics, John Wiley & Sons, NY (1994); Colberre-Garapin et al., 1981, J. Mol. Biol. 150:1, which are incorporated by reference herein in their entireties.

The expression levels of an antibody molecule can be increased by vector amplification (for a review, see Bebbington and Hentschel, The use of vectors based on gene amplification for the expression of cloned genes in mammalian cells in DNA cloning, Vol.3. (Academic Press, New York, 1987)). When a marker in the vector system expressing antibody is amplifiable, increase in the level of inhibitor present in culture of host cell will increase the number of copies of the marker gene. Since the amplified region is associated with the antibody gene, production of the antibody will also increase (Crouse et al., 1983, Mol. Cell. Biol. 3:257).

The host cell may be co-transfected with two expression vectors of the invention, the first vector encoding a heavy chain derived polypeptide and the second vector encoding a light chain derived polypeptide. The two vectors may contain identical selectable markers which enable equal expression of heavy and light chain polypeptides. Alternatively, a single vector may be used which encodes, and is capable of expressing, both heavy and light chain polypeptides. In such situations, the light chain should be placed before the heavy chain to avoid an excess of toxic free heavy chain (Proudfoot, 1986, Nature 322:52; and Kohler, 1980, Proc. Natl. Acad. Sci. USA 77:2 197). The coding sequences for the heavy and light chains may comprise cDNA or genomic DNA.

The antibodies of the invention can also be introduced into a transgenic animal (*e.g.*, transgenic mouse). *See, e.g.*, Bruggemann, Arch. Immunol. Ther. Exp. (Warsz). 49(3):203-8 (2001); Bruggemann and Neuberger, Immunol. Today 8:391-7 (1996), each of which is incorporated herein by reference. Transgene constructs or transloci can be obtained by, *e.g.*, plasmid assembly, cloning in yeast artificial chromosomes, and the use of chromosome fragments. Translocus integration and maintenance in transgenic animal strains can be achieved by pronuclear DNA injection into oocytes and various transfection methods using embryonic stem cells.

For example, nucleic acids encoding humanized heavy and/or light chain or humanized heavy and/or light variable regions may be introduced randomly or by homologous recombination into mouse embryonic stem cells. The mouse heavy and light chain immunoglobulin genes may be rendered non-functional separately or simultaneously with the introduction of nucleic acids encoding humanized antibodies by homologous recombination. In particular, homozygous deletion of the JH region prevents endogenous antibody production. The modified embryonic stem cells are expanded and microinjected into blastocysts to produce chimeric mice. The chimeric mice are then be bred to produce homozygous offspring which express humanized antibodies.

Once an antibody molecule of the invention has been produced by recombinant expression, it may be purified by any method known in the art for purification of an immunoglobulin molecule, for example, by chromatography (*e.g.*, ion exchange, affinity, particularly by affinity for the specific antigen after Protein A, and sizing column chromatography), centrifugation, differential solubility, or by any other standard technique for the purification of proteins. Further, the antibodies of the present invention or fragments thereof may be fused to heterologous polypeptide sequences described herein or otherwise known in the art to facilitate purification.

2.9 Antibody Conjugates

The present invention encompasses antibodies or fragments thereof that are conjugated or fused to one or more moieties, including but not limited to, peptides, polypeptides, proteins, fusion proteins, nucleic acid molecules, small molecules, mimetic agents, synthetic drugs, inorganic molecules, and organic molecules.

The present invention encompasses antibodies or fragments thereof that are recombinantly fused or chemically conjugated (including both covalent and non-covalent conjugations) to a heterologous protein or polypeptide (or fragment thereof, preferably to a polypeptide of at least 10, at least 20, at least 30, at least 40, at least 50, at least 60, at least

70, at least 80, at least 90 or at least 100 amino acids) to generate fusion proteins. The fusion does not necessarily need to be direct, but may occur through linker sequences. For example, antibodies may be used to target heterologous polypeptides to particular cell types, either *in vitro* or *in vivo*, by fusing or conjugating the antibodies to antibodies specific for particular cell surface receptors. Antibodies fused or conjugated to heterologous polypeptides may also be used in *in vitro* immunoassays and purification methods using methods known in the art. See *e.g.*, International publication No. WO 93/21232; European Patent No. EP 439,095; Naramura *et al.*, 1994, Immunol. Lett. 39:91-99; U.S. Patent No. 5,474,981; Gillies *et al.*, 1992, PNAS 89:1428-1432; and Fell *et al.*, 1991, J. Immunol. 146:2446-2452, which are incorporated by reference in their entireties.

The present invention further includes compositions comprising heterologous proteins, peptides or polypeptides fused or conjugated to antibody fragments. For example, the heterologous polypeptides may be fused or conjugated to a Fab fragment, Fd fragment, Fv fragment, F(ab)₂ fragment, a VH domain, a VL domain, a VH CDR, a VL CDR, or fragment thereof. Methods for fusing or conjugating polypeptides to antibody portions are well-known in the art. See, *e.g.*, U.S. Patent Nos. 5,336,603, 5,622,929, 5,359,046, 5,349,053, 5,447,851, and 5,112,946; European Patent No.s EP 307,434 and EP 367,166; International publication Nos. WO 96/04388 and WO 91/06570; Ashkenazi *et al.*, 1991, Proc. Natl. Acad. Sci. USA 88: 10535-10539; Zheng *et al.*, 1995, J. Immunol. 154:5590-5600; and Vil *et al.*, 1992, Proc. Natl. Acad. Sci. USA 89:11337- 11341 (said references incorporated by reference in their entireties).

Additional fusion proteins may be generated through the techniques of gene-shuffling, motif-shuffling, exon-shuffling, and/or codon-shuffling (collectively referred to as "DNA shuffling"). DNA shuffling may be employed to alter the activities of antibodies of the invention or fragments thereof (*e.g.*, antibodies or fragments thereof with higher affinities and lower dissociation rates). See, generally, U.S. Patent Nos. 5,605,793; 5,811,238; 5,830,721; 5,834,252; and 5,837,458, and Patten *et al.*, 1997, Curr. Opinion Biotechnol. 8:724-33 ; Harayama, 1998, Trends Biotechnol. 16(2):76-82; Hansson, *et al.*, 1999, J. Mol. Biol. 287:265-76; and Lorenzo and Blasco, 1998, Biotechniques 24(2):308-313 (each of these patents and publications are hereby incorporated by reference in its entirety). Antibodies or fragments thereof, or the encoded antibodies or fragments thereof, may be altered by being subjected to random mutagenesis by error-prone PCR, random nucleotide insertion or other methods prior to recombination. One or more portions of a polynucleotide encoding an antibody or antibody fragment may be recombined with one or

more components, motifs, sections, parts, domains, fragments, etc. of one or more heterologous molecules.

Moreover, the antibodies or fragments thereof can be fused to marker sequences, such as a peptide to facilitate purification. In preferred embodiments, the marker amino acid sequence is a hexa-histidine peptide, such as the tag provided in a pQE vector (QIAGEN, Inc., 9259 Eton Avenue, Chatsworth, CA, 91311), among others, many of which are commercially available. As described in Gentz *et al.*, 1989, Proc. Natl. Acad. Sci. USA 86:821-824, for instance, hexa-histidine provides for convenient purification of the fusion protein. Other peptide tags useful for purification include, but are not limited to, the hemagglutinin "HA" tag, which corresponds to an epitope derived from the influenza hemagglutinin protein (Wilson *et al.*, 1984, Cell 37:767) and the "flag" tag.

In other embodiments, antibodies of the present invention or fragments, analogs or derivatives thereof can be conjugated to a diagnostic or detectable agent. Such antibodies can be useful for monitoring or prognosing the development or progression of a disorder as part of a clinical testing procedure, such as determining the efficacy of a particular therapy. Such diagnosis and detection can be accomplished by coupling the antibody to detectable substances including, but not limited to various enzymes, such as but not limited to horseradish peroxidase, alkaline phosphatase, beta-galactosidase, or acetylcholinesterase; prosthetic groups, such as but not limited to streptavidin/biotin and avidin/biotin; fluorescent materials, such as but not limited to, umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; luminescent materials, such as but not limited to, luminol; bioluminescent materials, such as but not limited to, luciferase, luciferin, and aequorin; radioactive materials, such as but not limited to iodine (^{131}I , ^{125}I , ^{123}I , ^{121}I), carbon (^{14}C), sulfur (^{35}S), tritium (^3H), indium (^{115}In , ^{113}In , ^{112}In , ^{111}In), and technetium (^{99}Tc), thallium (^{201}Tl), gallium (^{68}Ga , ^{67}Ga), palladium (^{103}Pd), molybdenum (^{99}Mo), xenon (^{133}Xe), fluorine (^{18}F), ^{153}Sm , ^{177}Lu , ^{159}Gd , ^{149}Pm , ^{140}La , ^{175}Yb , ^{166}Ho , ^{90}Y , ^{47}Sc , ^{186}Re , ^{188}Re , ^{142}Pr , ^{105}Rh , ^{97}Ru , ^{68}Ge , ^{57}Co , ^{65}Zn , ^{85}Sr , ^{32}P , ^{153}Gd , ^{169}Yb , ^{51}Cr , ^{54}Mn , ^{75}Se , ^{113}Sn , and ^{117}Sn ; positron emitting metals using various positron emission tomographies, noradioactive paramagnetic metal ions, and molecules that are radiolabelled or conjugated to specific radioisotopes.

The present invention further encompasses antibodies or fragments thereof that are conjugated to a therapeutic moiety. An antibody or fragment thereof may be conjugated to a therapeutic moiety such as a cytotoxin, *e.g.*, a cytostatic or cytotoxic agent, a therapeutic agent or a radioactive metal ion, *e.g.*, alpha-emitters. A cytotoxin or cytotoxic

agent includes any agent that is detrimental to cells. Therapeutic moieties include, but are not limited to, antimetabolites (*e.g.*, methotrexate, 6-mercaptopurine, 6-thioguanine, cytarabine, 5-fluorouracil decarbazine), alkylating agents (*e.g.*, mechlorethamine, thioepa chlorambucil, melphalan, carmustine (BCNU) and lomustine (CCNU), cyclophosphamide, busulfan, dibromomannitol, streptozotocin, mitomycin C, and cisdichlorodiamine platinum (II) (DDP) cisplatin), anthracyclines (*e.g.*, daunorubicin (formerly daunomycin) and doxorubicin), antibiotics (*e.g.*, dactinomycin (formerly actinomycin), bleomycin, mithramycin, and anthramycin (AMC)), Auristatin molecules (*e.g.*, auristatin PHE, bryostatin 1, and solastatin 10; *see* Woyke *et al.*, *Antimicrob. Agents Chemother.* 46:3802-8 (2002), Woyke *et al.*, *Antimicrob. Agents Chemother.* 45:3580-4 (2001), Mohammad *et al.*, *Anticancer Drugs* 12:735-40 (2001), Wall *et al.*, *Biochem. Biophys. Res. Commun.* 266:76-80 (1999), Mohammad *et al.*, *Int. J. Oncol.* 15:367-72 (1999), all of which are incorporated herein by reference), hormones (*e.g.*, glucocorticoids, progestins, androgens, and estrogens), DNA-repair enzyme inhibitors (*e.g.*, etoposide or topotecan), kinase inhibitors (*e.g.*, compound ST1571, imatinib mesylate (Kantarjian *et al.*, *Clin Cancer Res.* 8(7):2167-76 (2002)), cytotoxic agents (*e.g.*, paclitaxel, cytochalasin B, gramicidin D, ethidium bromide, emetine, mitomycin, etoposide, tenoposide, vincristine, vinblastine, colchicin, doxorubicin, daunorubicin, dihydroxy anthracin dione, mitoxantrone, mithramycin, actinomycin D, 1-dehydrotestosterone, procaine, tetracaine, lidocaine, propranolol, and puromycin and analogs or homologs thereof) and those compounds disclosed in U.S. Pat. Nos. 6,245,759, 6,399,633, 6,383,790, 6,335,156, 6,271,242, 6,242,196, 6,218,410, 6,218,372, 6,057,300, 6,034,053, 5,985,877, 5,958,769, 5,925,376, 5,922,844, 5,911,995, 5,872,223, 5,863,904, 5,840,745, 5,728,868, 5,648,239, 5,587,459), farnesyl transferase inhibitors (*e.g.*, R115777, BMS-214662, and those disclosed by, for example, U.S. Patent Nos: 6,458,935, 6,451,812, 6,440,974, 6,436,960, 6,432,959, 6,420,387, 6,414,145, 6,410,541, 6,410,539, 6,403,581, 6,399,615, 6,387,905, 6,372,747, 6,369,034, 6,362,188, 6,342,765, 6,342,487, 6,300,501, 6,268,363, 6,265,422, 6,248,756, 6,239,140, 6,232,338, 6,228,865, 6,228,856, 6,225,322, 6,218,406, 6,211,193, 6,187,786, 6,169,096, 6,159,984, 6,143,766, 6,133,303, 6,127,366, 6,124,465, 6,124,295, 6,103,723, 6,093,737, 6,090,948, 6,080,870, 6,077,853, 6,071,935, 6,066,738, 6,063,930, 6,054,466, 6,051,582, 6,051,574, and 6,040,305), topoisomerase inhibitors (*e.g.*, camptothecin; irinotecan; SN-38; topotecan; 9-aminocamptothecin; GG-211 (GI 147211); DX-8951f; IST-622; rubitecan; pyrazoloacridine; XR-5000; saintopin; UCE6; UCE1022; TAN-1518A; TAN-1518B; KT6006; KT6528; ED-110; NB-506; ED-110; NB-506; and rebeccamycin); bulgarein; DNA minor groove binders such as Hoescht dye 33342 and Hoechst dye 33258; nitidine; fagaronine; epiberberine; coralyne; beta-lapachone;

BC-4-1; bisphosphonates (*e.g.*, alendronate, cimadronate, clodronate, tiludronate, etidronate, ibandronate, neridronate, olpandronate, risedronate, piridronate, pamidronate, zolendronate) HMG-CoA reductase inhibitors, (*e.g.*, lovastatin, simvastatin, atorvastatin, pravastatin, fluvastatin, statin, cerivastatin, lescol, lupitor, rosuvastatin and atorvastatin) and

5 pharmaceutically acceptable salts, solvates, clathrates, and prodrugs thereof. See, *e.g.*, Rothenberg, M.L., *Annals of Oncology* 8:837-855(1997); and Moreau, P., *et al.*, *J. Med. Chem.* 41:1631-1640(1998)), antisense oligonucleotides (*e.g.*, those disclosed in the U.S. Pat. Nos. 6,277,832, 5,998,596, 5,885,834, 5,734,033, and 5,618,709), immunomodulators (*e.g.*, antibodies and cytokines), antibodies, and adenosine deaminase inhibitors (*e.g.*,

10 Fludarabine phosphate and 2-Chlorodeoxyadenosine).

Further, an antibody or fragment thereof may be conjugated to a therapeutic moiety or drug moiety that modifies a given biological response. Therapeutic moieties or drug moieties are not to be construed as limited to classical chemical therapeutic agents. For example, the drug moiety may be a protein or polypeptide possessing a desired

15 biological activity. Such proteins may include, for example, a toxin such as abrin, ricin A, pseudomonas exotoxin, cholera toxin, or diphtheria toxin; a protein such as tumor necrosis factor, α -interferon, β -interferon, nerve growth factor, platelet derived growth factor, tissue plasminogen activator, an apoptotic agent, *e.g.*, TNF- α , TNF- β , AIM I (see, International publication No. WO 97/33899), AIM II (see, International Publication No. WO 97/34911),

20 Fas Ligand (Takahashi *et al.*, 1994, *J. Immunol.*, 6:1567-1574), and VEGI (see, International publication No. WO 99/23105), a thrombotic agent or an anti-angiogenic agent, *e.g.*, angiostatin, endostatin or a component of the coagulation pathway (*e.g.*, tissue factor); or, a biological response modifier such as, for example, a lymphokine (*e.g.*, interleukin-1 ("IL-1"), interleukin-2 ("IL-2"), interleukin-6 ("IL-6"), granulocyte

25 macrophage colony stimulating factor ("GM-CSF"), and granulocyte colony stimulating factor ("G-CSF")), a growth factor (*e.g.*, growth hormone ("GH")), or a coagulation agent (*e.g.*, calcium, vitamin K, tissue factors, such as but not limited to, Hageman factor (factor XII), high-molecular-weight kininogen (HMWK), prekallikrein (PK), coagulation proteins-factors II (prothrombin), factor V, XIIa, VIII, XIIIa, XI, XIa, IX, IXa, X,

30 phospholipid, fibrinopeptides A and B from the α and β chains of fibrinogen, fibrin monomer).

Moreover, an antibody can be conjugated to therapeutic moieties such as a radioactive metal ion, such as alpha-emitters such as ^{213}Bi or macrocyclic chelators useful for conjugating radiometal ions, including but not limited to, ^{131}In , ^{131}Lu , ^{131}Y , ^{131}Ho , ^{131}Sm , to

polypeptides. In certain embodiments, the macrocyclic chelator is 1,4,7,10-tetraazacyclododecane-N,N',N'',N'''-tetraacetic acid (DOTA) which can be attached to the antibody via a linker molecule. Such linker molecules are commonly known in the art and described in Denardo *et al.*, 1998, Clin Cancer Res. 4(10):2483-90; Peterson *et al.*, 1999, Bioconjug. Chem. 10(4):553-7; and Zimmerman *et al.*, 1999, Nucl. Med. Biol. 26(8):943-50, each incorporated by reference in their entireties.

Techniques for conjugating therapeutic moieties to antibodies are well known, *see, e.g.*, Arnon *et al.*, "Monoclonal Antibodies For Immunotargeting Of Drugs In Cancer Therapy", in Monoclonal Antibodies And Cancer Therapy, Reisfeld *et al.* (eds.), pp. 243-56 (Alan R. Liss, Inc. 1985); Hellstrom *et al.*, "Antibodies For Drug Delivery", in Controlled Drug Delivery (2nd Ed.), Robinson *et al.* (eds.), pp. 623-53 (Marcel Dekker, Inc. 1987); Thorpe, "Antibody Carriers Of Cytotoxic Agents In Cancer Therapy: A Review", in Monoclonal Antibodies 84: Biological And Clinical Applications, Pinchera *et al.* (eds.), pp. 475-506 (1985); "Analysis, Results, And Future Prospective Of The Therapeutic Use Of Radiolabeled Antibody In Cancer Therapy", in Monoclonal Antibodies For Cancer Detection And Therapy, Baldwin *et al.* (eds.), pp. 303-16 (Academic Press 1985), and Thorpe *et al.*, 1982, Immunol. Rev. 62:119-58.

Alternatively, an antibody can be conjugated to a second antibody to form an antibody heteroconjugate as described by Segal in U.S. Patent No. 4,676,980, which is incorporated herein by reference in its entirety.

The therapeutic moiety or drug conjugated to an antibody or fragment thereof should be chosen to achieve the desired prophylactic or therapeutic effect(s) for a particular disorder in a subject. A clinician or other medical personnel should consider the following when deciding on which therapeutic moiety or drug to conjugate to an antibody or fragment thereof: the nature of the disease, the severity of the disease, and the condition of the subject.

Antibodies may also be attached to solid supports, which are particularly useful for immunoassays or purification of the target antigen. Such solid supports include, but are not limited to, glass, cellulose, polyacrylamide, nylon, polystyrene, polyvinyl chloride or polypropylene.

2.10 Uses of the Antibodies of the Invention

The present invention provides methods of efficiently humanizing an antibody of interest. The humanized antibodies of the present invention can be used alone

or in combination with other prophylactic or therapeutic agents for treating, managing, preventing or ameliorating a disorder or one or more symptoms thereof.

The present invention provides methods for preventing, managing, treating, or ameliorating a disorder comprising administering to a subject in need thereof one or more
5 antibodies of the invention alone or in combination with one or more therapies (*e.g.*, one or more prophylactic or therapeutic agents) other than an antibody of the invention. The present invention also provides compositions comprising one or more antibodies of the invention and one or more prophylactic or therapeutic agents other than antibodies of the invention and methods of preventing, managing, treating, or ameliorating a disorder or one
10 or more symptoms thereof utilizing said compositions. Therapeutic or prophylactic agents include, but are not limited to, small molecules, synthetic drugs, peptides, polypeptides, proteins, nucleic acids (*e.g.*, DNA and RNA nucleotides including, but not limited to, antisense nucleotide sequences, triple helices, RNAi, and nucleotide sequences encoding biologically active proteins, polypeptides or peptides) antibodies, synthetic or natural
15 inorganic molecules, mimetic agents, and synthetic or natural organic molecules.

Any therapy which is known to be useful, or which has been used or is currently being used for the prevention, management, treatment, or amelioration of a disorder or one or more symptoms thereof can be used in combination with an antibody of the invention in accordance with the invention described herein. See, *e.g.*, Gilman *et al.*,
20 *Goodman and Gilman's: The Pharmacological Basis of Therapeutics*, 10th ed., McGraw-Hill, New York, 2001; *The Merck Manual of Diagnosis and Therapy*, Berkow, M.D. *et al.* (eds.), 17th Ed., Merck Sharp & Dohme Research Laboratories, Rahway, NJ, 1999; *Cecil Textbook of Medicine*, 20th Ed., Bennett and Plum (eds.), W.B. Saunders, Philadelphia, 1996 for information regarding therapies (*e.g.*, prophylactic or therapeutic agents) which
25 have been or are currently being used for preventing, treating, managing, or ameliorating a disorder or one or more symptoms thereof. Examples of such agents include, but are not limited to, immunomodulatory agents, anti-inflammatory agents (*e.g.*, adrenocorticoids, corticosteroids (*e.g.*, beclomethasone, budesonide, flunisolide, fluticasone, triamcinolone, methyprednisolone, prednisolone, prednisone, hydrocortisone), glucocorticoids, steroids,
30 non-steriodal anti-inflammatory drugs (*e.g.*, aspirin, ibuprofen, diclofenac, and COX-2 inhibitors), pain relievers, leukotrine antagonists (*e.g.*, montelukast, methyl xanthines, zafirlukast, and zileuton), beta2-agonists (*e.g.*, albuterol, biterol, fenoterol, isoetharie, metaproterenol, pirbuterol, salbutamol, terbutalin formoterol, salmeterol, and salbutamol terbutaline), anticholinergic agents (*e.g.*, ipratropium bromide and oxitropium bromide),

sulphasalazine, penicillamine, dapson, antihistamines, anti-malarial agents (*e.g.*, hydroxychloroquine), anti-viral agents, and antibiotics (*e.g.*, dactinomycin (formerly actinomycin), bleomycin, erythromycin, penicillin, mithramycin, and anthramycin (AMC)).

5 The humanized antibodies of the invention can be used directly against a particular antigen. In some embodiments, antibodies of the invention belong to a subclass or isotype that is capable of mediating the lysis of cells to which the antibody binds. In a specific embodiment, the antibodies of the invention belong to a subclass or isotype that, upon complexing with cell surface proteins, activates serum complement and/or mediates antibody dependent cellular cytotoxicity (ADCC) by activating effector cells such as natural
10 killer cells or macrophages.

The biological activities of antibodies are known to be determined, to a large extent, by the constant domains or Fc region of the antibody molecule (Uanane and Benacerraf, Textbook of Immunology, 2nd Edition, Williams & Wilkins, p. 218 (1984)). This includes their ability to activate complement and to mediate antibody-dependent
15 cellular cytotoxicity (ADCC) as effected by leukocytes. Antibodies of different classes and subclasses differ in this respect, as do antibodies from the same subclass but different species; according to the present invention, antibodies of those classes having the desired biological activity are prepared. Preparation of these antibodies involves the selection of antibody constant domains and their incorporation in the humanized antibody by known
20 technique. For example, mouse immunoglobulins of the IgG3 and IgG2a class are capable of activating serum complement upon binding to the target cells which express the cognate antigen, and therefore humanized antibodies which incorporate IgG3 and IgG2a effector functions are desirable for certain therapeutic applications.

In general, mouse antibodies of the IgG_{2a} and IgG₃ subclass and occasionally
25 IgG₁ can mediate ADCC, and antibodies of the IgG₃, IgG_{2a}, and IgM subclasses bind and activate serum complement. Complement activation generally requires the binding of at least two IgG molecules in close proximity on the target cell. However, the binding of only one IgM molecule activates serum complement.

The ability of any particular antibody to mediate lysis of the target cell by
30 complement activation and/or ADCC can be assayed. The cells of interest are grown and labeled *in vitro*; the antibody is added to the cell culture in combination with either serum complement or immune cells which may be activated by the antigen antibody complexes. Cytolysis of the target cells is detected by the release of label from the lysed cells. In fact, antibodies can be screened using the patient's own serum as a source of complement and/or

immune cells. The antibody that is capable of activating complement or mediating ADCC in the *in vitro* test can then be used therapeutically in that particular patient.

Use of IgM antibodies may be preferred for certain applications, however IgG molecules by being smaller may be more able than IgM molecules to localize to certain
5 types of infected cells.

In some embodiments, the antibodies of this invention are useful in passively immunizing patients.

The antibodies of the invention can also be used in diagnostic assays either *in vivo* or *in vitro* for detection/identification of the expression of an antigen in a subject or a
10 biological sample (*e.g.*, cells or tissues). Non-limiting examples of using an antibody, a fragment thereof, or a composition comprising an antibody or a fragment thereof in a diagnostic assay are given in U.S. Patent Nos. 6,392,020; 6,156,498; 6,136,526; 6,048,528; 6,015,555; 5,833,988; 5,811,310; 8 5,652,114; 5,604,126; 5,484,704; 5,346,687; 5,318,892; 5,273,743; 5,182,107; 5,122,447; 5,080,883; 5,057,313; 4,910,133; 4,816,402; 4,742,000;
15 4,724,213; 4,724,212; 4,624,846; 4,623,627; 4,618,486; 4,176,174 (all of which are incorporated herein by reference). Suitable diagnostic assays for the antigen and its antibodies depend on the particular antibody used. Non-limiting examples are an ELISA, sandwich assay, and steric inhibition assays. For *in vivo* diagnostic assays using the
20 antibodies of the invention, the antibodies may be conjugated to a label that can be detected by imaging techniques, such as X-ray, computed tomography (CT), ultrasound, or magnetic resonance imaging (MRI). The antibodies of the invention can also be used for the affinity purification of the antigen from recombinant cell culture or natural sources.

2.11 Administration and Formulations

The invention provides for compositions comprising antibodies of the invention for use in diagnosing, detecting, or monitoring a disorder, in preventing, treating, managing, or ameliorating of a disorder or one or more symptoms thereof, and/or in
5 research. In a specific embodiment, a composition comprises one or more antibodies of the invention. In another embodiment, a composition comprises one or more antibodies of the invention and one or more prophylactic or therapeutic agents other than antibodies of the invention. Preferably, the prophylactic or therapeutic agents known to be useful for or
10 having been or currently being used in the prevention, treatment, management, or amelioration of a disorder or one or more symptoms thereof. In accordance with these embodiments, the composition may further comprise of a carrier, diluent or excipient.

The compositions of the invention include, but are not limited to, bulk drug compositions useful in the manufacture of pharmaceutical compositions (*e.g.*, impure or non-sterile compositions) and pharmaceutical compositions (*i.e.*, compositions that are
15 suitable for administration to a subject or patient) which can be used in the preparation of unit dosage forms. Such compositions comprise a prophylactically or therapeutically effective amount of a prophylactic and/or therapeutic agent disclosed herein or a combination of those agents and a pharmaceutically acceptable carrier. Preferably, compositions of the invention are pharmaceutical compositions and comprise an effective
20 amount of one or more antibodies of the invention, a pharmaceutically acceptable carrier, and, optionally, an effective amount of another prophylactic or therapeutic agent.

The pharmaceutical composition can be formulated as an oral or non-oral dosage form, for immediate or extended release. The composition can comprise inactive ingredients ordinarily used in pharmaceutical preparation such as diluents, fillers,
25 disintegrants, sweeteners, lubricants and flavors. The pharmaceutical composition is preferably formulated for intravenous administration, either by bolus injection or sustained drip, or for release from an implanted capsule. A typical formulation for intravenous administration utilizes physiological saline as a diluent.

Fab or Fab' portions of the antibodies of the invention can also be utilized as
30 the therapeutic active ingredient. Preparation of these antibody fragments is well-known in the art.

The composition of the present invention can also include printed matter that describes clinical indications for which the antibodies can be administered as a therapeutic

agent, dosage amounts and schedules, and/or contraindications for administration of the antibodies of the invention to a patient.

The compositions of the invention include, but are not limited to, bulk drug compositions useful in the manufacture of pharmaceutical compositions (*e.g.*, impure or non-sterile compositions) and pharmaceutical compositions (*i.e.*, compositions that are suitable for administration to a subject or patient) which can be used in the preparation of unit dosage forms. Such compositions comprise a prophylactically or therapeutically effective amount of a prophylactic and/or therapeutic agent disclosed herein or a combination of those agents and a pharmaceutically acceptable carrier. Preferably, compositions of the invention are pharmaceutical compositions and comprise an effective amount of one or more antibodies of the invention, a pharmaceutically acceptable carrier, and, optionally, an effective amount of another prophylactic or therapeutic agent.

In a specific embodiment, the term “pharmaceutically acceptable” means approved by a regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly in humans. The term “carrier” refers to a diluent, adjuvant (*e.g.*, Freund’s adjuvant (complete and incomplete)), excipient, or vehicle with which the therapeutic is contained in or administered. Such pharmaceutical carriers can be sterile liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. Water is a preferred carrier when the pharmaceutical composition is administered intravenously. Saline solutions and aqueous dextrose and glycerol solutions can also be employed as liquid carriers, particularly for injectable solutions. Suitable pharmaceutical excipients include starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. The composition, if desired, can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents. These compositions can take the form of solutions, suspensions, emulsion, tablets, pills, capsules, powders, sustained-release formulations and the like.

Generally, the ingredients of compositions of the invention are supplied either separately or mixed together in unit dosage form, for example, as a dry lyophilized powder or water free concentrate in a hermetically sealed container such as an ampoule or sachette indicating the quantity of active agent. Where the composition is to be administered by infusion, it can be dispensed with an infusion bottle containing sterile

pharmaceutical grade water or saline. Where the composition is administered by injection, an ampoule of sterile water for injection or saline can be provided so that the ingredients may be mixed prior to administration.

The compositions of the invention can be formulated as neutral or salt forms.

5 Pharmaceutically acceptable salts include those formed with anions such as those derived from hydrochloric, phosphoric, acetic, oxalic, tartaric acids, etc., and those formed with cations such as those derived from sodium, potassium, ammonium, calcium, ferric hydroxides, isopropylamine, triethylamine, 2-ethylamino ethanol, histidine, procaine, etc.

Various delivery systems are known and can be used to administer one or
10 more antibodies of the invention or the combination of one or more antibodies of the invention and a prophylactic agent or therapeutic agent useful for preventing, managing, treating, or ameliorating a disorder or one or more symptoms thereof, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, recombinant cells capable of expressing the antibody or antibody fragment, receptor-mediated endocytosis (see, *e.g.*, Wu and Wu, J.
15 Biol. Chem. 262:4429-4432 (1987)), construction of a nucleic acid as part of a retroviral or other vector, etc. Methods of administering a prophylactic or therapeutic agent of the invention include, but are not limited to, parenteral administration (*e.g.*, intradermal, intramuscular, intraperitoneal, intravenous and subcutaneous), epidural administration, intratumoral administration, and mucosal administration (*e.g.*, intranasal and oral routes). In
20 addition, pulmonary administration can be employed, *e.g.*, by use of an inhaler or nebulizer, and formulation with an aerosolizing agent. See, *e.g.*, U.S. Patent Nos. 6,019,968, 5,985,320, 5,985,309, 5,934,272, 5,874,064, 5,855,913, 5,290,540, and 4,880,078; and PCT Publication Nos. WO 92/19244, WO 97/32572, WO 97/44013, WO 98/31346, and WO 99/66903, each of which is incorporated herein by reference their entireties. In one
25 embodiment, an antibody of the invention, combination therapy, or a composition of the invention is administered using Alkermes AIR™ pulmonary drug delivery technology (Alkermes, Inc., Cambridge, MA). In a specific embodiment, prophylactic or therapeutic agents of the invention are administered intramuscularly, intravenously, intratumorally, orally, intranasally, pulmonary, or subcutaneously. The prophylactic or therapeutic agents
30 may be administered by any convenient route, for example by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (*e.g.*, oral mucosa, rectal and intestinal mucosa, etc.) and may be administered together with other biologically active agents. Administration can be systemic or local.

In a specific embodiment, it may be desirable to administer the prophylactic or therapeutic agents of the invention locally to the area in need of treatment; this may be achieved by, for example, and not by way of limitation, local infusion, by injection, or by means of an implant, said implant being of a porous or non-porous material, including
5 membranes and matrices, such as sialastic membranes, polymers, fibrous matrices (*e.g.*, Tissuel[®]), or collagen matrices. In one embodiment, an effective amount of one or more antibodies of the invention antagonists is administered locally to the affected area to a subject to prevent, treat, manage, and/or ameliorate a disorder or a symptom thereof. In another embodiment, an effective amount of one or more antibodies of the invention is
10 administered locally to the affected area in combination with an effective amount of one or more therapies (*e.g.*, one or more prophylactic or therapeutic agents) other than an antibody of the invention of a subject to prevent, treat, manage, and/or ameliorate a disorder or one or more symptoms thereof.

In another embodiment, the prophylactic or therapeutic agent can be
15 delivered in a controlled release or sustained release system. In one embodiment, a pump may be used to achieve controlled or sustained release (see Langer, *supra*; Sefton, 1987, CRC Crit. Ref. Biomed. Eng. 14:20; Buchwald *et al.*, 1980, Surgery 88:507; Saudek *et al.*, 1989, N. Engl. J. Med. 321:574). In another embodiment, polymeric materials can be used to achieve controlled or sustained release of the therapies of the invention (see *e.g.*, Medical
20 Applications of Controlled Release, Langer and Wise (eds.), CRC Pres., Boca Raton, Florida (1974); Controlled Drug Bioavailability, Drug Product Design and Performance, Smolen and Ball (eds.), Wiley, New York (1984); Ranger and Peppas, 1983, J., Macromol. Sci. Rev. Macromol. Chem. 23:61; see also Levy *et al.*, 1985, Science 228:190; During *et al.*, 1989, Ann. Neurol. 25:351; Howard *et al.*, 1989, J. Neurosurg. 71:105); U.S. Patent No.
25 5,679,377; U.S. Patent No. 5,916,597; U.S. Patent No. 5,912,015; U.S. Patent No. 5,989,463; U.S. Patent No. 5,128,326; PCT Publication No. WO 99/15154; and PCT Publication No. WO 99/20253. Examples of polymers used in sustained release formulations include, but are not limited to, poly(2-hydroxy ethyl methacrylate), poly(methyl methacrylate), poly(acrylic acid), poly(ethylene-co-vinyl acetate),
30 poly(methacrylic acid), polyglycolides (PLG), polyanhydrides, poly(N-vinyl pyrrolidone), poly(vinyl alcohol), polyacrylamide, poly(ethylene glycol), polylactides (PLA), poly(lactide-co-glycolides) (PLGA), and polyorthoesters. In a preferred embodiment, the polymer used in a sustained release formulation is inert, free of leachable impurities, stable on storage, sterile, and biodegradable. In yet another embodiment, a controlled or sustained
35 release system can be placed in proximity of the prophylactic or therapeutic target, thus

requiring only a fraction of the systemic dose (see, *e.g.*, Goodson, in Medical Applications of Controlled Release, *supra*, vol. 2, pp. 115-138 (1984)).

Controlled release systems are discussed in the review by Langer (1990, Science 249:1527-1533). Any technique known to one of skill in the art can be used to produce sustained release formulations comprising one or more therapeutic agents of the invention. See, *e.g.*, U.S. Patent No. 4,526,938, PCT publication WO 91/05548, PCT publication WO 96/20698, Ning *et al.*, 1996, "Intratumoral Radioimmunotherapy of a Human Colon Cancer Xenograft Using a Sustained-Release Gel," Radiotherapy & Oncology 39:179-189, Song *et al.*, 1995, "Antibody Mediated Lung Targeting of Long-Circulating Emulsions," PDA Journal of Pharmaceutical Science & Technology 50:372-397, Cleek *et al.*, 1997, "Biodegradable Polymeric Carriers for a bFGF Antibody for Cardiovascular Application," Pro. Int'l. Symp. Control. Rel. Bioact. Mater. 24:853-854, and Lam *et al.*, 1997, "Microencapsulation of Recombinant Humanized Monoclonal Antibody for Local Delivery," Proc. Int'l. Symp. Control Rel. Bioact. Mater. 24:759-760, each of which is incorporated herein by reference in their entireties.

In a specific embodiment, where the composition of the invention is a nucleic acid encoding a prophylactic or therapeutic agent, the nucleic acid can be administered *in vivo* to promote expression of its encoded prophylactic or therapeutic agent, by constructing it as part of an appropriate nucleic acid expression vector and administering it so that it becomes intracellular, *e.g.*, by use of a retroviral vector (see U.S. Patent No. 4,980,286), or by direct injection, or by use of microparticle bombardment (*e.g.*, a gene gun; Biolistic, Dupont), or coating with lipids or cell-surface receptors or transfecting agents, or by administering it in linkage to a homeobox-like peptide which is known to enter the nucleus (see, *e.g.*, Joliot *et al.*, 1991, Proc. Natl. Acad. Sci. USA 88:1864-1868). Alternatively, a nucleic acid can be introduced intracellularly and incorporated within host cell DNA for expression by homologous recombination.

A pharmaceutical composition of the invention is formulated to be compatible with its intended route of administration. Examples of routes of administration include, but are not limited to, parenteral, *e.g.*, intravenous, intradermal, subcutaneous, oral, intranasal (*e.g.*, inhalation), transdermal (*e.g.*, topical), transmucosal, and rectal administration. In a specific embodiment, the composition is formulated in accordance with routine procedures as a pharmaceutical composition adapted for intravenous, subcutaneous, intramuscular, oral, intranasal, or topical administration to human beings. Typically, compositions for intravenous administration are solutions in sterile isotonic aqueous buffer.

Where necessary, the composition may also include a solubilizing agent and a local anesthetic such as lignocaine to ease pain at the site of the injection.

If the compositions of the invention are to be administered topically, the compositions can be formulated in the form of an ointment, cream, transdermal patch, lotion, gel, shampoo, spray, aerosol, solution, emulsion, or other form well-known to one of skill in the art. See, *e.g.*, Remington's Pharmaceutical Sciences and Introduction to Pharmaceutical Dosage Forms, 19th ed., Mack Pub. Co., Easton, PA (1995). For non-sprayable topical dosage forms, viscous to semi-solid or solid forms comprising a carrier or one or more excipients compatible with topical application and having a dynamic viscosity preferably greater than water are typically employed. Suitable formulations include, without limitation, solutions, suspensions, emulsions, creams, ointments, powders, liniments, salves, and the like, which are, if desired, sterilized or mixed with auxiliary agents (*e.g.*, preservatives, stabilizers, wetting agents, buffers, or salts) for influencing various properties, such as, for example, osmotic pressure. Other suitable topical dosage forms include sprayable aerosol preparations wherein the active ingredient, preferably in combination with a solid or liquid inert carrier, is packaged in a mixture with a pressurized volatile (*e.g.*, a gaseous propellant, such as freon) or in a squeeze bottle. Moisturizers or humectants can also be added to pharmaceutical compositions and dosage forms if desired. Examples of such additional ingredients are well-known in the art.

If the method of the invention comprises intranasal administration of a composition, the composition can be formulated in an aerosol form, spray, mist or in the form of drops. In particular, prophylactic or therapeutic agents for use according to the present invention can be conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebuliser, with the use of a suitable propellant (*e.g.*, dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, carbon dioxide or other suitable gas). In the case of a pressurized aerosol the dosage unit may be determined by providing a valve to deliver a metered amount. Capsules and cartridges (composed of, *e.g.*, gelatin) for use in an inhaler or insufflator may be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

If the method of the invention comprises oral administration, compositions can be formulated orally in the form of tablets, capsules, cachets, gelcaps, solutions, suspensions, and the like. Tablets or capsules can be prepared by conventional means with pharmaceutically acceptable excipients such as binding agents (*e.g.*, pregelatinised maize starch, polyvinylpyrrolidone, or hydroxypropyl methylcellulose); fillers (*e.g.*, lactose,

microcrystalline cellulose, or calcium hydrogen phosphate); lubricants (*e.g.*, magnesium stearate, talc, or silica); disintegrants (*e.g.*, potato starch or sodium starch glycolate); or wetting agents (*e.g.*, sodium lauryl sulphate). The tablets may be coated by methods well-known in the art. Liquid preparations for oral administration may take the form of, but not limited to, solutions, syrups or suspensions, or they may be presented as a dry product for constitution with water or other suitable vehicle before use. Such liquid preparations may be prepared by conventional means with pharmaceutically acceptable additives such as suspending agents (*e.g.*, sorbitol syrup, cellulose derivatives, or hydrogenated edible fats); emulsifying agents (*e.g.*, lecithin or acacia); non-aqueous vehicles (*e.g.*, almond oil, oily esters, ethyl alcohol, or fractionated vegetable oils); and preservatives (*e.g.*, methyl or propyl-p-hydroxybenzoates or sorbic acid). The preparations may also contain buffer salts, flavoring, coloring, and sweetening agents as appropriate. Preparations for oral administration may be suitably formulated for slow release, controlled release, or sustained release of a prophylactic or therapeutic agent(s).

The method of the invention may comprise pulmonary administration, *e.g.*, by use of an inhaler or nebulizer, of a composition formulated with an aerosolizing agent. See, *e.g.*, U.S. Patent Nos. 6,019,968, 5,985, 320, 5,985,309, 5,934,272, 5,874,064, 5,855,913, 5,290,540, and 4,880,078; and PCT Publication Nos. WO 92/19244, WO 97/32572, WO 97/44013, WO 98/31346, and WO 99/66903, each of which is incorporated herein by reference their entireties. In a specific embodiment, an antibody of the invention, combination therapy, and/or composition of the invention is administered using Alkermes AIR™ pulmonary drug delivery technology (Alkermes, Inc., Cambridge, MA).

The method of the invention may comprise administration of a composition formulated for parenteral administration by injection (*e.g.*, by bolus injection or continuous infusion). Formulations for injection may be presented in unit dosage form (*e.g.*, in ampoules or in multi-dose containers) with an added preservative. The compositions may take such forms as suspensions, solutions or emulsions in oily or aqueous vehicles, and may contain formulatory agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient may be in powder form for constitution with a suitable vehicle (*e.g.*, sterile pyrogen-free water) before use.

The methods of the invention may additionally comprise of administration of compositions formulated as depot preparations. Such long acting formulations may be administered by implantation (*e.g.*, subcutaneously or intramuscularly) or by intramuscular injection. Thus, for example, the compositions may be formulated with suitable polymeric

or hydrophobic materials (*e.g.*, as an emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives (*e.g.*, as a sparingly soluble salt).

The methods of the invention encompasses administration of compositions formulated as neutral or salt forms. Pharmaceutically acceptable salts include those formed
5 with anions such as those derived from hydrochloric, phosphoric, acetic, oxalic, tartaric acids, etc., and those formed with cations such as those derived from sodium, potassium, ammonium, calcium, ferric hydroxides, isopropylamine, triethylamine, 2-ethylamino ethanol, histidine, procaine, etc.

Generally, the ingredients of compositions are supplied either separately or
10 mixed together in unit dosage form, for example, as a dry lyophilized powder or water free concentrate in a hermetically sealed container such as an ampoule or sachette indicating the quantity of active agent. Where the mode of administration is infusion, composition can be dispensed with an infusion bottle containing sterile pharmaceutical grade water or saline. Where the mode of administration is by injection, an ampoule of sterile water for injection
15 or saline can be provided so that the ingredients may be mixed prior to administration.

In particular, the invention also provides that one or more of the prophylactic or therapeutic agents, or pharmaceutical compositions of the invention is packaged in a hermetically sealed container such as an ampoule or sachette indicating the quantity of the agent. In one embodiment, one or more of the prophylactic or therapeutic agents, or
20 pharmaceutical compositions of the invention is supplied as a dry sterilized lyophilized powder or water free concentrate in a hermetically sealed container and can be reconstituted (*e.g.*, with water or saline) to the appropriate concentration for administration to a subject. Preferably, one or more of the prophylactic or therapeutic agents or pharmaceutical compositions of the invention is supplied as a dry sterile lyophilized powder in a
25 hermetically sealed container at a unit dosage of at least 5 mg, more preferably at least 10 mg, at least 15 mg, at least 25 mg, at least 35 mg, at least 45 mg, at least 50 mg, at least 75 mg, or at least 100 mg. The lyophilized prophylactic or therapeutic agents or pharmaceutical compositions of the invention should be stored at between 2°C and 8°C in its original container and the prophylactic or therapeutic agents, or pharmaceutical
30 compositions of the invention should be administered within 1 week, preferably within 5 days, within 72 hours, within 48 hours, within 24 hours, within 12 hours, within 6 hours, within 5 hours, within 3 hours, or within 1 hour after being reconstituted. In an alternative embodiment, one or more of the prophylactic or therapeutic agents or pharmaceutical compositions of the invention is supplied in liquid form in a hermetically sealed container

indicating the quantity and concentration of the agent. Preferably, the liquid form of the administered composition is supplied in a hermetically sealed container at least 0.25 mg/ml, more preferably at least 0.5 mg/ml, at least 1 mg/ml, at least 2.5 mg/ml, at least 5 mg/ml, at least 8 mg/ml, at least 10 mg/ml, at least 15 mg/kg, at least 25 mg/ml, at least 50 mg/ml, at least 75 mg/ml or at least 100 mg/ml. The liquid form should be stored at between 2°C and 8°C in its original container.

Generally, the ingredients of the compositions of the invention are derived from a subject that is the same species origin or species reactivity as recipient of such compositions. Thus, in a preferred embodiment, human or humanized antibodies are administered to a human patient for therapy or prophylaxis.

2.11.1 Gene Therapy

In a specific embodiment, nucleic acid sequences comprising nucleotide sequences encoding an antibody of the invention or another prophylactic or therapeutic agent of the invention are administered to treat, prevent, manage, or ameliorate a disorder or one or more symptoms thereof by way of gene therapy. Gene therapy refers to therapy performed by the administration to a subject of an expressed or expressible nucleic acid. In this embodiment of the invention, the nucleic acids produce their encoded antibody or prophylactic or therapeutic agent of the invention that mediates a prophylactic or therapeutic effect.

Any of the methods for gene therapy available in the art can be used according to the present invention. For general reviews of the methods of gene therapy, see Goldspiel *et al.*, 1993, Clinical Pharmacy 12:488-505; Wu and Wu, 1991, Biotherapy 3:87-95; Tolstoshev, 1993, Ann. Rev. Pharmacol. Toxicol. 32:573-596; Mulligan, Science 260:926-932 (1993); and Morgan and Anderson, 1993, Ann. Rev. Biochem. 62:191-217; May, 1993, TIBTECH 11(5):155-215. Methods commonly known in the art of recombinant DNA technology which can be used are described in Ausubel *et al.* (eds.), Current Protocols in Molecular Biology, John Wiley & Sons, NY (1993); and Kriegler, Gene Transfer and Expression, A Laboratory Manual, Stockton Press, NY (1990).

In one embodiment, the method of the invention comprises administration of a composition comprising nucleic acids encoding antibodies or another prophylactic or therapeutic agent of the invention, said nucleic acids being part of an expression vector that expresses the antibody, another prophylactic or therapeutic agent of the invention, or fragments or chimeric proteins or heavy or light chains thereof in a suitable host. In particular, such nucleic acids have promoters, preferably heterologous promoters, operably

linked to the antibody coding region, said promoter being inducible or constitutive, and, optionally, tissue- specific. In another embodiment, nucleic acid molecules are used in which the coding sequences of an antibody or another prophylactic or therapeutic agent of the invention and any other desired sequences are flanked by regions that promote

5 homologous recombination at a desired site in the genome, thus providing for intrachromosomal expression of the antibody encoding nucleic acids (Koller and Smithies, 1989, Proc. Natl. Acad. Sci. USA 86:8932-8935; Zijlstra *et al.*, 1989, Nature 342:435-438). In specific embodiments, the expressed antibody or other prophylactic or therapeutic agent is a single chain antibody; alternatively, the nucleic acid sequences include sequences

10 encoding both the heavy and light chains, or fragments thereof, of the antibody or another prophylactic or therapeutic agent of the invention.

Delivery of the nucleic acids into a subject may be either direct, in which case the subject is directly exposed to the nucleic acid or nucleic acid-carrying vectors, or indirect, in which case, cells are first transformed with the nucleic acids *in vitro*, then

15 transplanted into the subject. These two approaches are known, respectively, as *in vivo* or *ex vivo* gene therapy.

In a specific embodiment, the nucleic acid sequences are directly administered *in vivo*, where it is expressed to produce the encoded product. This can be accomplished by any of numerous methods known in the art, *e.g.*, by constructing them as

20 part of an appropriate nucleic acid expression vector and administering it so that they become intracellular, *e.g.*, by infection using defective or attenuated retrovirals or other viral vectors (see U.S. Patent No. 4,980,286), or by direct injection of naked DNA, or by use of microparticle bombardment (*e.g.*, a gene gun; Biolistic, Dupont), or coating with lipids or cell-surface receptors or transfecting agents, encapsulation in liposomes, microparticles, or

25 microcapsules, or by administering them in linkage to a peptide which is known to enter the nucleus, by administering it in linkage to a ligand subject to receptor-mediated endocytosis (see, *e.g.*, Wu and Wu, 1987, J. Biol. Chem. 262:4429-4432) (which can be used to target cell types specifically expressing the receptors). In another embodiment, nucleic acid-ligand complexes can be formed in which the ligand comprises a fusogenic viral peptide to disrupt

30 endosomes, allowing the nucleic acid to avoid lysosomal degradation. In yet another embodiment, the nucleic acid can be targeted *in vivo* for cell specific uptake and expression, by targeting a specific receptor (see, *e.g.*, International Publication Nos. WO 92/06180; WO 92/22635; W092/20316; W093/14188; and WO 93/20221). Alternatively, the nucleic acid can be introduced intracellularly and incorporated within host cell DNA for expression, by

homologous recombination (Koller and Smithies, 1989, Proc. Natl. Acad. Sci. USA 86:8932-8935; and Zijlstra *et al.*, 1989, Nature 342:435-438).

In a specific embodiment, viral vectors that contains nucleic acid sequences encoding an antibody, another prophylactic or therapeutic agent of the invention, or
5 fragments thereof are used. For example, a retroviral vector can be used (see Miller *et al.*, 1993, Meth. Enzymol. 217:581-599). These retroviral vectors contain the components necessary for the correct packaging of the viral genome and integration into the host cell DNA. The nucleic acid sequences encoding the antibody or another prophylactic or therapeutic agent of the invention to be used in gene therapy are cloned into one or more
10 vectors, which facilitates delivery of the gene into a subject. More detail about retroviral vectors can be found in Boesen *et al.*, 1994, Biotherapy 6:291-302, which describes the use of a retroviral vector to deliver the *mdr 1* gene to hematopoietic stem cells in order to make the stem cells more resistant to chemotherapy. Other references illustrating the use of retroviral vectors in gene therapy are: Clowes *et al.*, 1994, J. Clin. Invest. 93:644-651; Klein
15 *et al.*, 1994, Blood 83:1467-1473; Salmons and Gunzberg, 1993, Human Gene Therapy 4:129-141; and Grossman and Wilson, 1993, Curr. Opin. in Genetics and Devel. 3:110-114.

Adenoviruses are other viral vectors that can be used in gene therapy. Adenoviruses are especially attractive vehicles for delivering genes to respiratory epithelia. Adenoviruses naturally infect respiratory epithelia where they cause a mild disease. Other
20 targets for adenovirus-based delivery systems are liver, the central nervous system, endothelial cells, and muscle. Adenoviruses have the advantage of being capable of infecting non-dividing cells. Kozarsky and Wilson, 1993, Current Opinion in Genetics and Development 3:499-503 present a review of adenovirus-based gene therapy. Bout *et al.*, 1994, Human Gene Therapy 5:3-10 demonstrated the use of adenovirus vectors to transfer
25 genes to the respiratory epithelia of rhesus monkeys. Other instances of the use of adenoviruses in gene therapy can be found in Rosenfeld *et al.*, 1991, Science 252:431-434; Rosenfeld *et al.*, 1992, Cell 68:143-155; Mastrangeli *et al.*, 1993, J. Clin. Invest. 91:225-234; PCT Publication W094/12649; and Wang *et al.*, 1995, Gene Therapy 2:775-783. In a preferred embodiment, adenovirus vectors are used.

30 Adeno-associated virus (AAV) has also been proposed for use in gene therapy (Walsh *et al.*, 1993, Proc. Soc. Exp. Biol. Med. 204:289-300; and U.S. Patent No. 5,436,146).

Another approach to gene therapy involves transferring a gene to cells in tissue culture by such methods as electroporation, lipofection, calcium phosphate mediated

transfection, or viral infection. Usually, the method of transfer includes the transfer of a selectable marker to the cells. The cells are then placed under selection to isolate those cells that have taken up and are expressing the transferred gene. Those cells are then delivered to a subject.

5 In this embodiment, the nucleic acid is introduced into a cell prior to administration *in vivo* of the resulting recombinant cell. Such introduction can be carried out by any method known in the art, including but not limited to transfection, electroporation, microinjection, infection with a viral or bacteriophage vector containing the nucleic acid sequences, cell fusion, chromosome-mediated gene transfer, microcell-

10 mediated gene transfer, spheroplast fusion, etc. Numerous techniques are known in the art for the introduction of foreign genes into cells (see, *e.g.*, Loeffler and Behr, 1993, Meth. Enzymol. 217:599-618; Cohen *et al.*, 1993, Meth. Enzymol. 217:618-644; Clin. Pharma. Ther. 29:69-92 (1985)) and may be used in accordance with the present invention, provided that the necessary developmental and physiological functions of the recipient cells are not

15 disrupted. The technique should provide for the stable transfer of the nucleic acid to the cell, so that the nucleic acid is expressible by the cell and preferably heritable and expressible by its cell progeny.

The resulting recombinant cells can be delivered to a subject by various methods known in the art. Recombinant blood cells (*e.g.*, hematopoietic stem or progenitor

20 cells) are preferably administered intravenously. The amount of cells envisioned for use depends on the several factors including, but not limited to, the desired effects and the patient state, and can be determined by one skilled in the art.

Cells into which a nucleic acid can be introduced for purposes of gene therapy encompass any desired, available cell type, and include but are not limited to

25 epithelial cells, endothelial cells, keratinocytes, fibroblasts, muscle cells, hepatocytes; blood cells such as T lymphocytes, B lymphocytes, monocytes, macrophages, neutrophils, eosinophils, mast cells, megakaryocytes, granulocytes; various stem or progenitor cells, in particular hematopoietic stem or progenitor cells (*e.g.*, as obtained from bone marrow, umbilical cord blood, peripheral blood, fetal liver, etc.). In a preferred embodiment, the cell

30 used for gene therapy is autologous to the subject.

In an embodiment in which recombinant cells are used in gene therapy, nucleic acid sequences encoding an antibody or fragment thereof are introduced into the cells such that they are expressible by the cells or their progeny, and the recombinant cells are then administered *in vivo* for therapeutic effect. In a specific embodiment, stem or

progenitor cells are used. Any stem and/or progenitor cells which can be isolated and maintained *in vitro* can potentially be used in accordance with this embodiment of the present invention (see *e.g.*, PCT Publication WO 94/08598; Stemple and Anderson, 1992, Cell 71:973-985; Rheinwald, 1980, Meth. Cell Bio. 21A:229; and Pittelkow and Scott, 5 1986, Mayo Clinic Proc. 61:771).

In a specific embodiment, the nucleic acid to be introduced for purposes of gene therapy comprises an inducible promoter operably linked to the coding region, such that expression of the nucleic acid is controllable by controlling the presence or absence of the appropriate inducer of transcription.

10 2.12 Dosage and Frequency of Administration

The amount of a prophylactic or therapeutic agent or a composition of the present invention which will be effective in the treatment, management, prevention, or amelioration of a disorder or one or more symptoms thereof can be determined by standard clinical. The frequency and dosage will vary according to factors specific for each patient 15 depending on the specific therapy or therapies (*e.g.*, the specific therapeutic or prophylactic agent or agents) administered, the severity of the disorder, disease, or condition, the route of administration, as well as age, body, weight, response, the patient's immune status, and the past medical history of the patient. For example, the dosage of a prophylactic or therapeutic agent or a composition of the invention which will be effective in the treatment, prevention, 20 management, or amelioration of a disorder or one or more symptoms thereof can be determined by administering the composition to an animal model such as, *e.g.*, the animal models disclosed herein or known to those skilled in the art. In addition, *in vitro* assays may optionally be employed to help identify optimal dosage ranges. Suitable regimens can be selected by one skilled in the art by considering such factors and by following, for example, 25 dosages reported in the literature and recommended in the *Physician's Desk Reference* (57th ed., 2003).

The toxicity and/or efficacy of the prophylactic and/or therapeutic protocols of the instant invention can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD₅₀ (the dose lethal to 50% of 30 the population) and the ED₅₀ (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio LD₅₀/ED₅₀. Therapies that exhibit large therapeutic indices are preferred. While therapies that exhibit toxic side effects may be used, care should be taken

to design a delivery system that targets such agents to the site of affected tissue in order to minimize potential damage to uninfected cells and, thereby, reduce side effects.

The data obtained from the cell culture assays and animal studies can be used in formulating a range of dosage of the prophylactic and/or therapeutic agents for use in humans. The dosage of such agents lies preferably within a range of circulating concentrations that include the ED₅₀ with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilized. For any therapy used in the method of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. A dose may be formulated in animal models to achieve a circulating plasma concentration range that includes the IC₅₀ (*i.e.*, the concentration of the test compound that achieves a half-maximal inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma may be measured, for example, by high performance liquid chromatography.

For peptides, polypeptides, proteins, fusion proteins, and antibodies, the dosage administered to a patient is typically 0.01 mg/kg to 100 mg/kg of the patient's body weight. Preferably, the dosage administered to a patient is between 0.1 mg/kg and 20 mg/kg of the patient's body weight, more preferably 1 mg/kg to 10 mg/kg of the patient's body weight. Generally, human and humanized antibodies have a longer half-life within the human body than antibodies from other species due to the immune response to the foreign polypeptides. Thus, lower dosages of human antibodies and less frequent administration is often possible.

Exemplary doses of a small molecule include milligram or microgram amounts of the small molecule per kilogram of subject or sample weight (*e.g.*, about 1 microgram per kilogram to about 500 milligrams per kilogram, about 100 micrograms per kilogram to about 5 milligrams per kilogram, or about 1 microgram per kilogram to about 50 micrograms per kilogram).

The dosages of prophylactic or therapeutically agents are described in the Physicians' Desk Reference (56th ed., 2002).

2.13 Biological Assays

Antibodies of the present invention or fragments thereof may be characterized in a variety of ways well-known to one of skill in the art. In particular, antibodies of the invention or fragments thereof may be assayed for the ability to

immunospecifically bind to an antigen. Such an assay may be performed in solution (*e.g.*, Houghten, 1992, *Bio/Techniques* 13:412 421), on beads (Lam, 1991, *Nature* 354:82 84), on chips (Fodor, 1993, *Nature* 364:555 556), on bacteria (U.S. Patent No. 5,223,409), on spores (U.S. Patent Nos. 5,571,698; 5,403,484; and 5,223,409), on plasmids (Cull et al., 1992, Proc. Natl. Acad. Sci. USA 89:1865 1869) or on phage (Scott and Smith, 1990, *Science* 249:386 390; Cwirla et al., 1990, *Proc. Natl. Acad. Sci. USA* 87:6378 6382; and Felici, 1991, *J. Mol. Biol.* 222:301 310) (each of these references is incorporated herein in its entirety by reference). Antibodies or fragments thereof that have been identified can then be assayed for specificity and affinity.

10 The antibodies of the invention or fragments thereof may be assayed for immunospecific binding to a specific antigen and cross-reactivity with other antigens by any method known in the art. Immunoassays which can be used to analyze immunospecific binding and cross-reactivity include, but are not limited to, competitive and non-competitive assay systems using techniques such as western blots, radioimmunoassays, ELISA (enzyme
15 linked immunosorbent assay), “sandwich” immunoassays, immunoprecipitation assays, precipitin reactions, gel diffusion precipitin reactions, immunodiffusion assays, agglutination assays, complement-fixation assays, immunoradiometric assays, fluorescent immunoassays, protein A immunoassays, to name but a few. Such assays are routine and well-known in the art (see, *e.g.*, Ausubel et al., eds., 1994, *Current Protocols in Molecular*
20 Biology, Vol. 1, John Wiley & Sons, Inc., New York, which is incorporated by reference herein in its entirety). Exemplary immunoassays are described briefly in Section 5.6.

 The antibodies of the invention or fragments thereof can also be assayed for their ability to inhibit the binding of an antigen to its host cell receptor using techniques known to those of skill in the art. For example, cells expressing a receptor can be contacted
25 with a ligand for that receptor in the presence or absence of an antibody or fragment thereof that is an antagonist of the ligand and the ability of the antibody or fragment thereof to inhibit the ligand’s binding can measured by, for example, flow cytometry or a scintillation assay. The ligand or the antibody or antibody fragment can be labeled with a detectable compound such as a radioactive label (*e.g.*, ³²P, ³⁵S, and ¹²⁵I) or a fluorescent label (*e.g.*,
30 fluorescein isothiocyanate, rhodamine, phycoerythrin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine) to enable detection of an interaction between the ligand and its receptor. Alternatively, the ability of antibodies or fragments thereof to inhibit a ligand from binding to its receptor can be determined in cell-free assays. For example, a ligand can be contacted with an antibody or fragment thereof that is an antagonist of the

ligand and the ability of the antibody or antibody fragment to inhibit the ligand from binding to its receptor can be determined. Preferably, the antibody or the antibody fragment that is an antagonist of the ligand is immobilized on a solid support and the ligand is labeled with a detectable compound. Alternatively, the ligand is immobilized on a solid support and the antibody or fragment thereof is labeled with a detectable compound. A ligand may be partially or completely purified (*e.g.*, partially or completely free of other polypeptides) or part of a cell lysate. Alternatively, a ligand can be biotinylated using techniques well known to those of skill in the art (*e.g.*, biotinylation kit, Pierce Chemicals; Rockford, IL).

An antibody or a fragment thereof constructed and/or identified in accordance with the present invention can be tested *in vitro* and/or *in vivo* for its ability to modulate the biological activity of cells. Such ability can be assessed by, *e.g.*, detecting the expression of antigens and genes; detecting the proliferation of cells; detecting the activation of signaling molecules (*e.g.*, signal transduction factors and kinases); detecting the effector function of cells; or detecting the differentiation of cells. Techniques known to those of skill in the art can be used for measuring these activities. For example, cellular proliferation can be assayed by ³H-thymidine incorporation assays and trypan blue cell counts. Antigen expression can be assayed, for example, by immunoassays including, but are not limited to, competitive and non-competitive assay systems using techniques such as western blots, immunohistochemistry radioimmunoassays, ELISA (enzyme linked immunosorbent assay), "sandwich" immunoassays, immunoprecipitation assays, precipitin reactions, gel diffusion precipitin reactions, immunodiffusion assays, agglutination assays, complement-fixation assays, immunoradiometric assays, fluorescent immunoassays, protein A immunoassays, and FACS analysis. The activation of signaling molecules can be assayed, for example, by kinase assays and electrophoretic shift assays (EMSAs).

The antibodies, fragments thereof, or compositions of the invention are preferably tested *in vitro* and then *in vivo* for the desired therapeutic or prophylactic activity prior to use in humans. For example, assays which can be used to determine whether administration of a specific pharmaceutical composition is indicated include cell culture assays in which a patient tissue sample is grown in culture and exposed to, or otherwise contacted with, a pharmaceutical composition, and the effect of such composition upon the tissue sample is observed. The tissue sample can be obtained by biopsy from the patient. This test allows the identification of the therapeutically most effective therapy (*e.g.*, prophylactic or therapeutic agent) for each individual patient. In various specific embodiments, *in vitro* assays can be carried out with representative cells of cell types

involved a particular disorder to determine if a pharmaceutical composition of the invention has a desired effect upon such cell types. For example, *in vitro* assay can be carried out with cell lines.

5 The effect of an antibody, a fragment thereof, or a composition of the invention on peripheral blood lymphocyte counts can be monitored/assessed using standard techniques known to one of skill in the art. Peripheral blood lymphocytes counts in a subject can be determined by, *e.g.*, obtaining a sample of peripheral blood from said subject, separating the lymphocytes from other components of peripheral blood such as plasma using, *e.g.*, Ficoll-Hypaque (Pharmacia) gradient centrifugation, and counting the
10 lymphocytes using trypan blue. Peripheral blood T-cell counts in subject can be determined by, *e.g.*, separating the lymphocytes from other components of peripheral blood such as plasma using, *e.g.*, a use of Ficoll-Hypaque (Pharmacia) gradient centrifugation, labeling the T-cells with an antibody directed to a T-cell antigen which is conjugated to FITC or phycoerythrin, and measuring the number of T-cells by FACS.

15 The antibodies, fragments, or compositions of the invention used to treat, manage, prevent, or ameliorate a viral infection or one or more symptoms thereof can be tested for their ability to inhibit viral replication or reduce viral load in *in vitro* assays. For example, viral replication can be assayed by a plaque assay such as described, *e.g.*, by Johnson et al., 1997, Journal of Infectious Diseases 176:1215-1224 176:1215-1224. The
20 antibodies or fragments thereof administered according to the methods of the invention can also be assayed for their ability to inhibit or downregulate the expression of viral polypeptides. Techniques known to those of skill in the art, including, but not limited to, western blot analysis, northern blot analysis, and RT-PCR can be used to measure the expression of viral polypeptides.

25 The antibodies, fragments, or compositions of the invention used to treat, manage, prevent, or ameliorate a bacterial infection or one or more symptoms thereof can be tested in *in vitro* assays that are well-known in the art. *In vitro* assays known in the art can also be used to test the existence or development of resistance of bacteria to a therapy. Such
30 *in vitro* assays are described in Gales et al., 2002, Diag. Microbiol. Infect. Dis. 44(3):301-311; Hicks et al., 2002, Clin. Microbiol. Infect. 8(11): 753-757; and Nicholson et al., 2002, Diagn. Microbiol. Infect. Dis. 44(1): 101-107.

The antibodies, fragments, or compositions of the invention used to treat, manage, prevent, or ameliorate a fungal infection or one or more symptoms thereof can be tested for anti-fungal activity against different species of fungus. Any of the standard anti-

fungus assays well-known in the art can be used to assess the anti-fungal activity of a therapy. The anti-fungal effect on different species of fungus can be tested. The tests recommended by the National Committee for Clinical Laboratories (NCCLS) (See National Committee for Clinical Laboratories Standards. 1995, Proposed Standard M27T. Villanova, Pa., all of which is incorporated herein by reference in its entirety) and other methods known to those skilled in the art (Pfaller et al., 1993, Infectious Dis. Clin. N. Am. 7: 435-444) can be used to assess the anti-fungal effect of a therapy. The antifungal properties of a therapy may also be determined from a fungal lysis assay, as well as by other methods, including, inter alia, growth inhibition assays, fluorescence-based fungal viability assays, flow cytometry analyses, and other standard assays known to those skilled in the art.

For example, the anti-fungal activity of a therapy can be tested using macrodilution methods and/or microdilution methods using protocols well-known to those skilled in the art (see, e.g., Clancy et al., 1997 Journal of Clinical Microbiology, 35(11): 2878-82; Ryder et al., 1998, Antimicrobial Agents and Chemotherapy, 42(5): 1057-61; U.S. 5,521,153; U.S. 5,883,120, U.S. 5,521,169, all of which are incorporated by reference in their entirety). Briefly, a fungal strain is cultured in an appropriate liquid media, and grown at an appropriate temperature, depending on the particular fungal strain used for a determined amount of time, which is also depends on the particular fungal strain used. An inoculum is then prepared photometrically and the turbidity of the suspension is matched to that of a standard, e.g., a McFarland standard. The effect of a therapy on the turbidity of the inoculum is determined visually or spectrophotometrically. The minimal inhibitory concentration ("MIC") of the therapy is determined, which is defined as the lowest concentration of the lead compound which prevents visible growth of an inoculum as measured by determining the culture turbidity.

The anti-fungal activity of a therapy can also be determined utilizing colorimetric based assays well-known to one of skill in the art. One exemplary colorimetric assay that can be used to assess the anti-fungal activity of a therapy is described by Pfaller et al. (1994, Journal of Clinical Microbiology, 32(8): 1993-6, which is incorporated herein by reference in its entirety; also see Tiballi et al., 1995, Journal of Clinical Microbiology, 33(4): 915-7). This assay employs a colorimetric endpoint using an oxidation-reduction indicator (Alamar Biosciences, Inc., Sacramento CA).

The anti-fungal activity of a therapy can also be determined utilizing photometric assays well-known to one of skill in the art (see, e.g., Clancy et al., 1997 Journal of Clinical Microbiology, 35(11): 2878-82; Jahn et al., 1995, Journal of Clinical

Microbiology, 33(3): 661-667, each of which is incorporated herein by reference in its entirety). This photometric assay is based on quantifying mitochondrial respiration by viable fungi through the reduction of 3-(4,5-dimethyl-2thiazolyl)-2,5,-diphenyl-2H-tetrazolium bromide (MTT) to formazan. MIC's determined by this assay are defined as the
5 highest concentration of the test therapy associated with the first precipitous drop in optical density. In some embodiments, the therapy is assayed for anti-fungal activity using macrodilution, microdilution and MTT assays in parallel.

Further, any *in vitro* assays known to those skilled in the art can be used to evaluate the prophylactic and/or therapeutic utility of an antibody therapy disclosed herein
10 for a particular disorder or one or more symptoms thereof.

The antibodies, compositions, or combination therapies of the invention can be tested in suitable animal model systems prior to use in humans. Such animal model systems include, but are not limited to, rats, mice, chicken, cows, monkeys, pigs, dogs, rabbits, etc. Any animal system well-known in the art may be used. Several aspects of the
15 procedure may vary; said aspects include, but are not limited to, the temporal regime of administering the therapies (*e.g.*, prophylactic and/or therapeutic agents) whether such therapies are administered separately or as an admixture, and the frequency of administration of the therapies.

Animal models can be used to assess the efficacy of the antibodies,
20 fragments thereof, or compositions of the invention for treating, managing, preventing, or ameliorating a particular disorder or one or more symptom thereof.

The administration of antibodies, compositions, or combination therapies according to the methods of the invention can be tested for their ability to decrease the time course of a particular disorder by at least 25%, preferably at least 50%, at least 60%, at least
25 75%, at least 85%, at least 95%, or at least 99%. The antibodies, compositions, or combination therapies of the invention can also be tested for their ability to increase the survival period of humans suffering from a particular disorder by at least 25%, preferably at least 50%, at least 60%, at least 75%, at least 85%, at least 95%, or at least 99%. Further, antibodies, compositions, or combination therapies of the invention can be tested for their
30 ability reduce the hospitalization period of humans suffering from viral respiratory infection by at least 60%, preferably at least 75%, at least 85%, at least 95%, or at least 99%. Techniques known to those of skill in the art can be used to analyze the function of the antibodies, compositions, or combination therapies of the invention *in vivo*.

Further, any *in vivo* assays known to those skilled in the art can be used to evaluate the prophylactic and/or therapeutic utility of an antibody, a fragment thereof, a composition, a combination therapy disclosed herein for a particular disorder or one or more symptoms thereof.

5 The toxicity and/or efficacy of the prophylactic and/or therapeutic protocols of the instant invention can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, e.g., for determining the LD50 (the dose lethal to 50% of the population) and the ED50 (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be
10 expressed as the ratio LD50/ED50. Therapies that exhibit large therapeutic indices are preferred. While therapies that exhibit toxic side effects may be used, care should be taken to design a delivery system that targets such agents to the site of affected tissue in order to minimize potential damage to uninfected cells and, thereby, reduce side effects.

 The data obtained from the cell culture assays and animal studies can be used
15 in formulating a range of dosage of the prophylactic and/or therapeutic agents for use in humans. The dosage of such agents lies preferably within a range of circulating concentrations that include the ED50 with little or no toxicity. The dosage may vary within this range depending upon the dosage form employed and the route of administration utilized. For any therapy used in the method of the invention, the therapeutically effective
20 dose can be estimated initially from cell culture assays. A dose may be formulated in animal models to achieve a circulating plasma concentration range that includes the IC50 (i.e., the concentration of the test compound that achieves a half-maximal inhibition of symptoms) as determined in cell culture. Such information can be used to more accurately determine useful doses in humans. Levels in plasma may be measured, for example, by
25 high performance liquid chromatography.

2.14 Kits

 The invention provides kits comprising sub-banks of antibody framework regions of a species of interest. The invention also provides kits comprising sub-banks of CDRs of a species of interest. The invention also provides kits comprising combinatorial
30 sub-libraries that comprises plurality of nucleic acid sequences comprising nucleotide sequences, each nucleotide sequence encoding one framework region (e.g., FR1) in frame fused to one corresponding CDR (e.g., CDR1). The invention further provides kits comprising combinatorial libraries that comprises plurality of nucleic acid sequences

comprising nucleotide sequences, each nucleotide sequence encoding the framework regions and CDRs fused in-frame (*e.g.*, FR1+CDR1+FR2+CDR2+FR3+CDR3+FR4).

In some preferred embodiments, the invention provides kits comprising sub-banks of human immunoglobulin framework regions, sub-banks of CDRs, combinatorial sub-libraries, and/or combinatorial libraries. In one embodiment, the invention provides a kit comprising a framework region sub-bank for variable light chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Kabat system. In another embodiment, the invention provides a kit comprising a framework region sub-bank for variable light chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Chothia system. In another embodiment, the invention provides a kit comprising a framework region sub-bank for variable heavy chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Kabat system. In another embodiment, the invention provides a kit comprising a framework region sub-bank for variable heavy chain framework region 1, 2, 3, and/or 4, wherein the framework region is defined according to the Chothia system. In yet another embodiment, the invention provides a kit comprising sub-banks of both the light chain and the heavy chain frameworks.

The invention also provides a pharmaceutical pack or kit comprising one or more containers filled with a humanized antibody of the invention. The pharmaceutical pack or kit may further comprises one or more other prophylactic or therapeutic agents useful for the treatment of a particular disease. The invention also provides a pharmaceutical pack or kit comprising one or more containers filled with one or more of the ingredients of the pharmaceutical compositions of the invention. Optionally associated with such container(s) can be a notice in the form prescribed by a governmental agency regulating the manufacture, use or sale of pharmaceuticals or biological products, which notice reflects approval by the agency of manufacture, use or sale for human administration.

2.15 Article of Manufacture

The present invention also encompasses a finished packaged and labeled pharmaceutical product. This article of manufacture includes the appropriate unit dosage form in an appropriate vessel or container such as a glass vial or other container that is hermetically sealed. In the case of dosage forms suitable for parenteral administration the active ingredient is sterile and suitable for administration as a particulate free solution. In other words, the invention encompasses both parenteral solutions and lyophilized powders, each being sterile, and the latter being suitable for reconstitution prior to injection.

Alternatively, the unit dosage form may be a solid suitable for oral, transdermal, topical or mucosal delivery.

In a preferred embodiment, the unit dosage form is suitable for intravenous, intramuscular or subcutaneous delivery. Thus, the invention encompasses solutions,
5 preferably sterile, suitable for each delivery route.

As with any pharmaceutical product, the packaging material and container are designed to protect the stability of the product during storage and shipment. Further, the products of the invention include instructions for use or other informational material that advise the physician, technician or patient on how to appropriately prevent or treat the
10 disease or disorder in question. In other words, the article of manufacture includes instruction means indicating or suggesting a dosing regimen including, but not limited to, actual doses, monitoring procedures (such as methods for monitoring mean absolute lymphocyte counts, tumor cell counts, and tumor size) and other monitoring information.

More specifically, the invention provides an article of manufacture
15 comprising packaging material, such as a box, bottle, tube, vial, container, sprayer, insufflator, intravenous (i.v.) bag, envelope and the like; and at least one unit dosage form of a pharmaceutical agent contained within said packaging material. The invention further provides an article of manufacture comprising packaging material, such as a box, bottle, tube, vial, container, sprayer, insufflator, intravenous (i.v.) bag, envelope and the like; and at
20 least one unit dosage form of each pharmaceutical agent contained within said packaging material.

In a specific embodiment, an article of manufacture comprises packaging material and a pharmaceutical agent and instructions contained within said packaging material, wherein said pharmaceutical agent is a humanized antibody and a
25 pharmaceutically acceptable carrier, and said instructions indicate a dosing regimen for preventing, treating or managing a subject with a particular disease. In another embodiment, an article of manufacture comprises packaging material and a pharmaceutical agent and instructions contained within said packaging material, wherein said pharmaceutical agent is a humanized antibody, a prophylactic or therapeutic agent other
30 than the humanized antibody and a pharmaceutically acceptable carrier, and said instructions indicate a dosing regimen for preventing, treating or managing a subject with a particular disease. In another embodiment, an article of manufacture comprises packaging material and two pharmaceutical agents and instructions contained within said packaging material, wherein said first pharmaceutical agent is a humanized antibody and a

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pharmaceutically acceptable carrier and said second pharmaceutical agent is a prophylactic or therapeutic agent other than the humanized antibody, and said instructions indicate a dosing regimen for preventing, treating or managing a subject with a particular disease.

5 The present invention provides that the adverse effects that may be reduced or avoided by the methods of the invention are indicated in informational material enclosed in an article of manufacture for use in preventing, treating or ameliorating one or more symptoms associated with a disease. Adverse effects that may be reduced or avoided by the methods of the invention include but are not limited to vital sign abnormalities (*e.g.*, fever, tachycardia, bradycardia, hypertension, hypotension), hematological events (*e.g.*, anemia, lymphopenia, leukopenia, thrombocytopenia), headache, chills, dizziness, nausea, asthenia, back pain, chest pain (*e.g.*, chest pressure), diarrhea, myalgia, pain, pruritus, psoriasis, rhinitis, sweating, injection site reaction, and vasodilatation. Since some of the therapies may be immunosuppressive, prolonged immunosuppression may increase the risk of infection, including opportunistic infections. Prolonged and sustained immunosuppression may also result in an increased risk of developing certain types of cancer.

Further, the information material enclosed in an article of manufacture can indicate that foreign proteins may also result in allergic reactions, including anaphylaxis, or cytosine release syndrome. The information material should indicate that allergic reactions may exhibit only as mild pruritic rashes or they may be severe such as erythroderma, Stevens Johnson syndrome, vasculitis, or anaphylaxis. The information material should also indicate that anaphylactic reactions (anaphylaxis) are serious and occasionally fatal hypersensitivity reactions. Allergic reactions including anaphylaxis may occur when any foreign protein is injected into the body. They may range from mild manifestations such as urticaria or rash to lethal systemic reactions. Anaphylactic reactions occur soon after exposure, usually within 10 minutes. Patients may experience paresthesia, hypotension, laryngeal edema, mental status changes, facial or pharyngeal angioedema, airway obstruction, bronchospasm, urticaria and pruritus, serum sickness, arthritis, allergic nephritis, glomerulonephritis, temporal arthritis, or eosinophilia.

The information material can also indicate that cytokine release syndrome is an acute clinical syndrome, temporally associated with the administration of certain activating anti T cell antibodies. Cytokine release syndrome has been attributed to the release of cytokines by activated lymphocytes or monocytes. The clinical manifestations for cytokine release syndrome have ranged from a more frequently reported mild, self limited, "flu like" illness to a less frequently reported severe, life threatening, shock like reaction,

which may include serious cardiovascular, pulmonary and central nervous system manifestations. The syndrome typically begins approximately 30 to 60 minutes after administration (but may occur later) and may persist for several hours. The frequency and severity of this symptom complex is usually greatest with the first dose. With each successive dose, both the incidence and severity of the syndrome tend to diminish. Increasing the amount of a dose or resuming treatment after a hiatus may result in a reappearance of the syndrome. As mentioned above, the invention encompasses methods of treatment and prevention that avoid or reduce one or more of the adverse effects discussed herein.

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2.16 Exemplary Embodiments

1. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence encoding the humanized heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and each heavy chain framework region is from a sub-bank of human heavy chain framework regions.

2. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized light chain variable region, said first nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and each light chain framework region is from a sub-bank of human light chain framework regions.

3. The nucleic acid sequence of embodiment 1 further comprising a second nucleotide sequence encoding a donor light chain variable region.

4. The nucleic acid sequence of embodiment 1 further comprising a second
5 nucleotide sequence encoding a humanized light chain variable region, said second
nucleotide sequence encoding the humanized light chain variable region produced by fusing
together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid
sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain
framework region 2, a nucleic acid sequenced encoding a light chain CDR2, a nucleic acid
10 sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a
light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4,
wherein the CDRs are derived from a donor antibody light chain variable region and each
light chain framework region is from a sub-bank of human light chain framework regions.

15 5. The nucleic acid sequence of embodiment 2 further comprising a second
nucleotide sequence encoding a donor heavy chain variable region.

6. The nucleic acid sequence of embodiment 1, wherein one or more of the
CDRs derived from the donor antibody heavy chain variable region contains one or more
20 mutations relative to the nucleic acid sequence encoding the corresponding CDR in the
donor antibody.

7. The nucleic acid sequence of embodiment 2, wherein one or more of the
CDRs derived from the donor antibody light chain variable region contains one or more
25 mutations relative to the nucleic acid sequence encoding the corresponding CDR in the
donor antibody.

8. The nucleic acid sequence of embodiment 4, wherein one or more of the
CDRs derived from the donor antibody light chain variable region contains one or more
30 mutations relative to the nucleic acid sequence encoding the corresponding CDR in the
donor antibody.

9. A nucleic acid sequence comprising a first nucleotide sequence encoding a
humanized heavy chain variable region, said first nucleotide acid sequence encoding the
35 humanized heavy chain variable region produced by fusing together a nucleic acid sequence

encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a
5 nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

10 10. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized light chain variable region, said first nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid
15 sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human
20 light chain framework regions.

11. The nucleic acid of embodiment 9 further comprising a second nucleotide sequence encoding a donor light chain variable region.

25 12. The nucleic acid sequence of embodiment 9 further comprising a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain
30 framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework
35 regions.

13. The nucleic acid sequence of embodiment 9 further comprising a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence encoding the humanized light chain variable region produced by fusing
5 together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4,
10 wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.

14. The nucleic acid sequence of embodiment 10 further comprising a second
15 nucleotide sequence encoding a donor heavy chain variable region.

15. The nucleic acid sequence of embodiment 10 further comprising a second nucleotide sequence encoding a humanized heavy chain variable region, said second nucleotide sequence encoding the humanized heavy chain variable region produced by
20 fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic
25 acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

16. A cell engineered to contain the nucleic acid sequence of embodiment 1.
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17. A cell engineered to contain the nucleic acid sequence of embodiment 2.

18. The cell of embodiment 16 further engineered to contain the nucleic acid sequence of embodiment 2.
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19. A cell engineered to contain the nucleic acid of embodiment 3.
20. A cell engineered to contain the nucleic acid of embodiment 4.
- 5 21. A cell engineered to contain the nucleic acid of embodiment 5.
22. A cell engineered to contain the nucleic acid sequence of embodiment 9.
23. A cell engineered to contain the nucleic acid sequence of embodiment 10.
- 10 24. The cell of embodiment 22 further engineered to contain the nucleic acid sequence of embodiment 10.
25. A cell engineered to contain the nucleic acid sequence of embodiment 11.
- 15 26. A cell engineered to contain the nucleic acid sequence of embodiment 12.
27. A cell engineered to contain the nucleic acid sequence of embodiment 13.
- 20 28. A cell engineered to contain the nucleic acid sequence of embodiment 14.
29. A cell engineered to contain the nucleic acid sequence of embodiment 15.
30. A cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.
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31. A cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a humanized light chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide
5 sequence encoding a humanized light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain
10 CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions.

32. A cell comprising a nucleic acid sequence comprising a first nucleotide
15 sequence encoding a humanized heavy chain variable region and a second nucleotide sequence encoding a humanized light chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a
20 nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a humanized light
25 chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence
30 encoding a light chain framework region 4, wherein the CDRs of the heavy chain variable region are derived from a donor antibody heavy chain variable region, the CDRs of the light chain variable region are derived from a donor light chain variable region, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions, and at least one light chain framework region is from a sub-bank of human light chain
35 framework regions.

33. A cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

34. A cell comprising a first nucleic acid sequence comprising a first nucleotide sequence encoding a humanized light chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.

35. A cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region and a second nucleotide sequence encoding a humanized light chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a

nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a humanized light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions, and at least one light chain framework region is from a sub-bank of human light chain framework regions.

36. A cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region and a second nucleotide sequence encoding a humanize light chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4; and (ii) a second nucleotide sequence encoding a humanized light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that

immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions, and at least one light chain framework region is from a sub-bank of human light chain framework regions.

5 37. A cell comprising a nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region and a second nucleotide sequence encoding a humanized light chain variable region, said cell produced by the process comprising introducing into a cell a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region synthesized by
10 fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain
15 framework region 4; and (ii) a second nucleotide sequence encoding a humanized light chain variable region synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework
20 region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework
25 region is from a sub-bank of human heavy chain framework regions, and at least one light chain framework region is from a sub-bank of human light chain framework regions.

38. The cell of embodiment 30 further comprising a second nucleic acid sequence comprising a second nucleotide sequence encoding a humanized light chain
30 variable region.

39. The cell of embodiment 30 further comprising a second nucleic acid sequence comprising a second nucleotide sequence encoding a light chain variable region.

40. The cell of embodiment 31 further comprising a second nucleic acid sequence comprising a second nucleotide sequence encoding a heavy chain variable region.

41. The cell of embodiment 33 further comprising a second nucleic acid sequence comprising a second nucleotide sequence encoding a humanized light chain variable region.

42. The cell of embodiment 33 further comprising a second nucleic acid sequence comprising a second nucleotide sequence encoding a light chain variable region.

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43. The cell of embodiment 34 further comprising a second nucleic acid sequence comprising a second nucleotide sequence encoding a heavy chain variable region.

44. A cell containing nucleic acid sequences encoding a humanized antibody that immunospecifically binds to an antigen, said cell produced by the process comprising:

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(a) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions; and

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(b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a light

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chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework region.

45. A cell containing nucleic acid sequences encoding a humanized antibody that immunospecifically binds to an antigen, said cell produced by the process comprising:
- (a) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions; and
 - (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain

framework region is from a sub-bank of human light chain framework region.

46. A cell containing nucleic acid sequences encoding a humanized antibody that immunospecifically binds to an antigen, said cell produced by the process comprising:

- 5 (a) introducing into a cell a nucleic acid sequence comprising a nucleotide acid sequence encoding a heavy chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions; and
- 10 15 20 (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.
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47. A cell containing nucleic acid sequences encoding a humanized antibody that immunospecifically binds to an antigen, said cell produced by the process comprising:

- 5 (a) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a heavy chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions; and
- 10 (b) introducing into a cell a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.
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48. A method of producing a humanized heavy chain variable region, said method comprising expressing the nucleotide sequence encoding the humanized heavy chain variable region in the cell of embodiment 30 or 33.

49. A method of producing a humanized light chain variable region, said method comprising expressing the nucleotide sequence encoding the humanized light chain variable region in the cell of embodiment 31 or 34.

5 50. A method of producing a humanized antibody, said method comprising expressing the nucleic acid sequence comprising the first nucleotide sequence encoding the humanized heavy chain variable region and the second nucleotide sequence encoding the humanized light chain variable region in the cell of embodiment 32, 35, 36 or 37.

10 51. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising expressing the nucleic acid sequences encoding the humanized antibody contained in the cell of embodiment 44, 45, 46 or 47.

15 52. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of heavy chain framework regions;
- (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions;
- 30 (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized variable light chain variable region; and
- (d) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

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53. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of heavy chain framework regions;
- (b) synthesizing a nucleic acid sequence comprising a nucleotide
5 sequence encoding a humanized heavy chain variable region, said
nucleotide sequence produced by fusing together a nucleic acid
sequence encoding a heavy chain framework region 1, a nucleic acid
sequence encoding a heavy chain CDR1, a nucleic acid sequence
encoding a heavy chain framework region 2, a nucleic acid sequence
10 encoding heavy chain CDR2, a nucleic acid sequence encoding a
heavy chain framework region 3, a nucleic acid sequence encoding a
heavy chain CDR3, and a nucleic acid sequence encoding a heavy
chain framework region 4, wherein at least one CDR is from a sub-
bank of heavy chain CDRs derived from donor antibodies that
15 immunospecifically bind to an antigen and at least one heavy chain
framework region is from a sub-bank of human heavy chain
framework regions;
- (c) introducing the nucleic acid sequence into a cell containing a nucleic
acid sequence comprising a nucleotide sequence encoding a
20 humanized variable light chain variable region; and
- (d) expressing the nucleotide sequences encoding the humanized heavy
chain variable region and the humanized light chain variable region.

54. A method of producing a humanized antibody that immunospecifically binds
25 to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- (b) synthesizing a nucleic acid sequence comprising a nucleotide
sequence encoding a humanized light chain variable region, said
nucleotide sequence produced by fusing together a nucleic acid
30 sequence encoding a light chain framework region 1, a nucleic acid
sequence encoding a light chain CDR1, a nucleic acid sequence
encoding a light chain framework region 2, a nucleic acid sequence
encoding a light chain CDR2, a nucleic acid sequence encoding a
light chain framework region 3, a nucleic acid sequence encoding a
35 light chain CDR3, and a nucleic acid sequence encoding a light chain

framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions;

- 5 (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized variable heavy chain variable region; and
- (d) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

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55. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- 15 (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that
- 20 immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a
- 30 humanized variable heavy chain variable region; and
- (d) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

56. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

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- (a) generating sub-banks of light chain framework regions;
- (b) generating sub-banks of heavy chain framework regions;
- (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions;
- (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (e) introducing the nucleic acid sequences into a cell; and
- (f) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

57. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;

- (b) generating sub-banks of heavy chain framework regions;
- (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions;
- (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (e) introducing the nucleic acid sequences into a cell; and
- (f) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

58. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;

- (b) generating sub-banks of heavy chain framework regions;
- (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions;
- (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (e) introducing the nucleic acid sequences into a cell; and
- (f) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

59. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;

- (b) generating sub-banks of heavy chain framework regions;
- (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions;
- (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (e) introducing the nucleic acid sequences into a cell; and
- (f) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

60. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- (b) generating sub-banks of heavy chain framework regions;
- (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region, said
 5 first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a
 10 heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence produced by fusing together a nucleic acid
 15 sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a
 20 light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework region
 25 is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (d) introducing the nucleic acid sequence into a cell; and
- (e) expressing the nucleotide sequences encoding the humanized heavy
 30 chain variable region and the humanized light chain variable region.

61. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- (b) generating sub-banks of heavy chain framework regions;

- 5 (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- 10 (d) introducing the nucleic acid sequence into a cell; and
- 15 (e) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.
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62. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- (b) generating sub-banks of heavy chain framework regions;

- 5 (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- 10 (d) introducing the nucleic acid sequence into a cell; and
- 15 (e) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.
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63. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- (b) generating sub-banks of heavy chain framework regions;

- 5 (c) synthesizing a nucleic acid sequence comprising: (i) a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- 20 (d) introducing the nucleic acid sequence into a cell; and
- 25 (e) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.
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64. The method of embodiment 52, 53, 54 or 55 further comprising (e) screening for a humanized antibody that immunospecifically binds to the antigen.

65. The method of embodiment 56, 57, 58 or 59 further comprising (g) screening for a humanized antibody that immunospecifically binds to the antigen.

66. The method of embodiment 60, 61, 62 or 63 further comprising (f) screening
5 for a humanized antibody that immunospecifically binds to the antigen.

67. A humanized antibody produced by the method of embodiment 48.

68. A humanized antibody produced by the method of embodiment 49.

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69. A humanized antibody produced by the method of embodiment 50.

70. A humanized antibody produced by the method of embodiment 51.

15 71. A humanized antibody produced by the method of any one of embodiments
52-63.

72. A humanized antibody produced by the method of embodiment 64.

20 73. A humanized antibody produced by the method of embodiment 65.

74. A humanized antibody produced by the method of embodiment 66.

25 75. A composition comprising the humanized antibody of embodiment 67, and a
carrier, diluent or excipient.

76. A composition comprising the humanized antibody of embodiment 68, and a
carrier, diluent or excipient.

30 77. A composition comprising the humanized antibody of embodiment 69, and a
carrier, diluent or excipient.

78. A composition comprising the humanized antibody of embodiment 70, and a
carrier, diluent or excipient.

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79. A composition comprising the humanized antibody of embodiment 71, and a carrier, diluent or excipient.

80. A composition comprising the humanized antibody of embodiment 72, and a carrier, diluent or excipient.

81. A composition comprising the humanized antibody of embodiment 73, and a carrier, diluent or excipient.

82. A plurality of nucleic acid sequences comprising nucleotide sequences encoding humanized heavy chain variable regions, said nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

83. A plurality of nucleic acid sequences comprising nucleotide sequences encoding humanized heavy chain variable regions, said nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

84. A plurality of nucleic acid sequences comprising nucleotide sequences encoding humanized light chain variable regions, said nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid

sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a
5 nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions.

85. A plurality of nucleic acid sequences comprising nucleotide sequences
10 encoding humanized light chain variable regions, said nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a
15 light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.

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86. A plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding humanized heavy chain variable regions, said first set of nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid
25 sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable
30 regions, said second set of nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a
35 nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a

light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

87. A plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding humanized heavy chain variable regions, said first set of nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable regions, said second set of nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

88. A plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding humanized heavy chain variable regions, said first set of nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid

sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable regions, said second set of nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

89. A plurality of nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding humanized heavy chain variable regions, said first set of nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable regions, said second set of nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind

to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

5 90. A population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of humanized heavy chain variable regions, said cells produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding humanized heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework
10 region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy
15 chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

 91. A population of cells comprising nucleic acid sequences comprising nucleotide acid sequences encoding a plurality of humanized heavy chain variable regions,
20 said cells produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding humanized heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy
25 chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework
30 regions.

 92. A population of cells comprising nucleic sequences comprising nucleotide sequences encoding a plurality of humanized light chain variable regions, said cells produced by the process comprising introducing into cells nucleic acid sequences
35 comprising nucleotide sequences encoding humanized light chain variable regions each

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synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions.

10 93. A population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of humanized light chain variable regions, said cells produced by the process comprising introducing into cells nucleic acid sequences comprising nucleotide sequences encoding humanized light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework
15 region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs
20 derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.

 94. The cells of embodiment 90, wherein the cells further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region.

25

 95. The cells of embodiment 91, wherein the cells further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region.

 96. The cells of embodiment 92, wherein the cells further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a light chain variable region.

30

 97. The cells of embodiment 93, wherein the cells further comprise a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region.

35

98. A population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of humanized heavy chain variable regions and a plurality of humanized light chain variable regions, said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of
5 nucleotide sequences encoding humanized heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence
10 encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence
15 encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one
20 heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

99. A population of cells comprising nucleic acid sequences comprising
25 nucleotide sequences encoding a plurality of humanized heavy chain variable regions and a plurality of humanized light chain variable regions, said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding humanized heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a
30 nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light
35 chain variable regions each synthesized by fusing together a nucleic acid sequence encoding

a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, the light chain variable region CDRs are derived from a donor antibody light chain variable region, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

100. A population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of humanized heavy chain variable regions and a plurality of humanized light chain variable regions, said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of nucleotide sequences encoding humanized heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the heavy chain variable region CDRs are derived from a donor antibody heavy chain variable region, at least one light chain variable region CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

101. A population of cells comprising nucleic acid sequences comprising nucleotide sequences encoding a plurality of humanized heavy chain variable regions and a plurality of humanized light chain variable regions, said cells each produced by the process comprising introducing into cells nucleic acid sequences comprising: (i) a first set of
5 nucleotide sequences encoding humanized heavy chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence
10 encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, and (ii) a second set of nucleotide sequences encoding humanized light chain variable regions each synthesized by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence
15 encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one heavy chain variable region CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one light chain variable region CDR is from
20 a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen, at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions and at least one light chain framework region is from a sub-bank of human light chain framework regions.

25 102. A method of identifying a humanized antibody that immunospecifically binds to an antigen, said method comprising expressing the nucleic acid sequences in the cells of embodiment 94, 95, 96 or 97 and screening for a humanized antibody that has an affinity of $1 \times 10^6 \text{ M}^{-1}$ or above for said antigen.

30 103. A method of identifying a humanized antibody that immunospecifically binds to an antigen, said method comprising expressing the nucleic acid sequences in the cells of embodiment 98, 99, 100 or 101 and screening for a humanized antibody that has an affinity of $1 \times 10^6 \text{ M}^{-1}$ or above for said antigen.

35 104. A humanized antibody identified by the method of embodiment 102.

105. A humanized antibody identified by the method of embodiment 103.

106. A composition comprising the humanized antibody of embodiment 104, and
5 a carrier, diluent or excipient.

107. A composition comprising the humanized antibody of embodiment 105, and
a carrier, diluent or excipient.

10

5.0 EXAMPLE

Reagents

All chemicals were of analytical grade. Restriction enzymes and DNA-modifying
enzymes were purchased from New England Biolabs, Inc. (Beverly, MA). *pfu* DNA
15 polymerase and oligonucleotides were purchased from Invitrogen (Carlsbad, CA). Human
EphA2-Fc fusion protein (consisting of human EphA2 fused with the Fc portion of a human
IgG1 (Carles-Kinch *et al.* Cancer Res. 62: 2840-2847 (2002)) was expressed in human
embryonic kidney (HEK) 293 cells and purified by protein G affinity chromatography using
standard protocols. Streptavidin magnetic beads were purchased from Dynal (Lake Success,
20 NY). Human EphA2-Fc biotinylation was carried out using an EZ-Link Sulfo-NHS-LC-
Biotinylation Kit according to the manufacturer's instructions (Pierce, Rockford, IL).

5.1- Cloning and sequencing of the parental monoclonal antibody

A murine hybridoma cell line (B233) secreting a monoclonal antibody (mAb) raised
25 against the human receptor tyrosine kinase EphA2 (Kinch *et al.* Clin. Exp. Metastasis.
20:59-68 (2003)) was acquired by MedImmune, Inc. This mouse mAb is referred to as
mAb B233 thereafter. Cloning and sequencing of the variable heavy (V_H) and light (V_L)
genes of mAb B233 were carried out after isolation and purification of the messenger RNA
from B233 using a Straight A's mRNA Purification kit (Novagen, Madison, WI) according
30 to the manufacturer's instructions. cDNA was synthesized with a First Strand cDNA
synthesis kit (Novagen, Madison, WI) as recommended by the manufacturer. Amplification
of both V_H and V_L genes was carried out using the IgGV_H and IgkV_L oligonucleotides from
the Mouse Ig-Primer Set (Novagen, Madison, WI) as suggested by the manufacturer. DNA
fragments resulting from productive amplifications were cloned into pSTBlue-1 using the

Perfectly Blunt Cloning Kit (Novagen, Madison, WI). Multiple V_H and V_L clones were then sequenced by the dideoxy chain termination method (Sanger *et al.*, Proc. Natl. Acad. Sci. USA. 74: 5463-5467 (1977)) using a ABI3000 sequencer (Applied Biosystems, Foster City, CA). The consensus sequences of mAb B233 V_L (V_L-233) and V_H (V_H-233) genes are
 5 shown in Figure 1.

5.2- Selection of the human frameworks

Human framework genes were selected from the publicly available pool of antibody germline genes. More precisely, this included 46 human germline kappa chain
 10 genes (A1, A10, A11, A14, A17, A18, A19, A2, A20, A23, A26, A27, A3, A30, A5, A7, B2, B3, L1, L10, L11, L12, L14, L15, L16, L18, L19, L2, L20, L22, L23, L24, L25, L4/18a, L5, L6, L8, L9, O1, O11, O12, O14, O18, O2, O4 and O8; K.F. Schable, *et al.*, Biol. Chem. Hoppe Seyler 374: 1001-1022, (1993); J. Brensing-Kuppers, *et al.*, Gene 191:173-
 15 181(1997)) for the 1st, 2nd and 3rd frameworks and 5 human germline J sequences for the 4th framework (Jk1, Jk2, Jk3, Jk4 and Jk5; P.A. Hieter, *et al.*, J. Biol. Chem. 257:1516-1522 (1982)). The heavy chain portion of the library included 44 human germline heavy chain sequences (VH1-18, VH1-2, VH1-24, VH1-3, VH1-45, VH1-46, VH1-58, VH1-69, VH1-8, VH2-26, VH2-5, VH2-70, VH3-11, VH3-13, VH3-15, VH3-16, VH3-20, VH3-21, VH3-23, VH3-30, VH3-33, VH3-35, VH3-38, VH3-43, VH3-48, VH3-49, VH3-53, VH3-64, VH3-
 20 66, VH3-7, VH3-72, VH3-73, VH3-74, VH3-9, VH4-28, VH4-31, VH4-34, VH4-39, VH4-4, VH4-59, VH4-61, VH5-51, VH6-1 and VH7-8; F. Matsuda, *et al.*, J. Exp. Med. 188:1973-1975 (1998)) for the 1st, 2nd and 3rd frameworks and 6 human germline J sequences for the 4th framework (JH1, JH2, JH3, JH4, JH5 and JH6; J.V. Ravetch, *et al.*, Cell 27(3 Pt 2): 583-591 (1981)).

25

5.3- Construction of the framework-shuffled libraries

5.3.1- Description of the libraries

Three main framework-shuffled libraries (library A, B and C) were constructed. Library A included a light chain framework shuffled sub-library (V_L sub1) paired with the heavy chain of
 30 mAb B233 (V_H-233). Library B included a heavy chain framework shuffled sub-library (V_H sub1) paired with the fixed framework shuffled light chains V_L-12C8 and V_L-8G7 (see §5.4.1.1, §5.4.1.2 and §5.4.1.3). Library C included a light chain framework shuffled sub-library (V_L sub2) paired with a heavy chain framework shuffled sub-library (V_H sub2).

The construction of the framework shuffled V_H and V_L sub-libraries was carried out using the oligonucleotides shown in Tables 1-7 and 11. More precisely, the oligonucleotides described in Tables 1-7 and 11 encode the complete sequences of all known human framework germline genes for the light (κ) and heavy chains, Kabat definition. The oligonucleotides described in Tables 64 and 65 encode part of the CDRs of mAb B233 and are overlapping with the corresponding human germline frameworks. With respect to Table 64, with the exception of AL1-13 and DL1Ü-4Ü, each oligonucleotide encodes portions of one CDR of mAb B233 (underlined) and of one human germline light chain framework (Kabat definition; Kabat *et al.*, Sequences of Proteins of Immunological Interest, U.S. Public Health Service, National Institutes of Health, Washington, DC, 1991). CDRL1, L2 and L3 are encoded by AL1Ü-10Ü/BL1-10, BL1Ü-16Ü/CL1-11 and CL1Ü-12Ü/DL1-4, respectively. Oligonucleotides AL1-13 contain a M13 gene 3 leader overlapping sequence (bold) and oligonucleotides DL1Ü-4Ü contain a Cκ overlapping sequence (bold). With respect to table 65, with the exception of AH1-10 and DH1Ü-3Ü, each oligonucleotide encodes portions of one CDR of mAb B233 (underlined) and of one human germline heavy chain framework (Kabat definition). CDRH1, H2 and H3 are encoded by AH1Ü-17Ü/BH1-17, BH1Ü-16Ü/CH1-15 and CH1Ü-13Ü/DH1-3, respectively. Oligonucleotides AH1-10 contain a M13 gene 3 leader overlapping sequence (bold) whereas oligonucleotides DH1Ü-3Ü contain a Cκ₁ overlapping sequence (bold). (K=G or T, M=A or C, R=A or G, S=C or G, W=A or T and Y=C or T).

Table 64. Oligonucleotides used for the fusion of mAb B233 light chain CDRs with human germline light chain frameworks.

25	1589	AL1	5' -GGTCGTTCCATTTTACTCCCCTCCGATGTTGTGATGACWCAGTCT-3'
	1590	AL2	5' -GGTCGTTCCATTTTACTCCCCTCCGACATCCAGATGAYCCAGTCT-3'
	1591	AL3	5' -GGTCGTTCCATTTTACTCCCCTCCGCCATCCAGWTGACCCAGTCT-3'
	1592	AL4	5' -GGTCGTTCCATTTTACTCCCCTCCGAAATAGTGATGAYGCAGTCT-3'
	1593	AL5	5' -GGTCGTTCCATTTTACTCCCCTCCGAAATTGTGTTGACRCAGTCT-3'
	1594	AL6	5' -GGTCGTTCCATTTTACTCCCCTCCGAKATTGTGATGACCCAGACT-3'
30	1595	AL7	5' -GGTCGTTCCATTTTACTCCCCTCCGAAATTGTRMTGACWCAGTCT-3'
	1596	AL8	5' -GGTCGTTCCATTTTACTCCCCTCCGAYATYGTGATGACYCAGTCT-3'
	1597	AL9	5' -GGTCGTTCCATTTTACTCCCCTCCGAAACGACACTCACGCAGTCT-3'
	1598	AL10	5' -GGTCGTTCCATTTTACTCCCCTCCGACATCCAGTTGACCCAGTCT-3'
	1599	AL11	5' -GGTCGTTCCATTTTACTCCCCTCCAACATCCAGATGACCCAGTCT-3'
35	1600	AL12	5' -GGTCGTTCCATTTTACTCCCCTCCGCCATCCGGATGACCCAGTCT-3'
	1601	AL13	5' -GGTCGTTCCATTTTACTCCCCTCCGTCATCTGGATGACCCAGTCT-3'
	1602	AL1Ü	5' -TAATACTTTGGCTGGCCCTGCAGGAGATGGAGGCCGGC-3'
	1603	AL2Ü	5' -TAATACTTTGGCTGGCCCTGCAGGAGAGGGTGRCCTCTTTC-3'
	1604	AL3Ü	5' -TAATACTTTGGCTGGCCCTACAAGTATGGTGACTCTGTC-3'
40	1605	AL4Ü	5' -TAATACTTTGGCTGGCCCTGAAGGAGATGGAGGCCGGCTG-3'
	1606	AL5Ü	5' -TAATACTTTGGCTGGCCCTGCAGGAGATGGAGGCCTGCTC-3'
	1607	AL6Ü	5' -TAATACTTTGGCTGGCCCTGCAGGAGATGTTGACTTTGTC-3'
	1608	AL7Ü	5' -TAATACTTTGGCTGGCCCTGCAGGTGATGGTGACTTTCTC-3'
	1609	AL8Ü	5' -TAATACTTTGGCTGGCCCTGCAGTTGATGGTGCCCTCTC-3'

1610	AL9Ü	5' -TAATACTTTGGCTGGCCCTGCAAGTGATGGTGACTCTGTC-3'
1611	AL10Ü	5' -TAATACTTTGGCTGGCCCTGCAAATGATACTGACTCTGTC-3'
1612	BL1	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGYTTTCAGCAGAGGCCAGGC-3'
1613	BL2	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTACCTGCAGAAGCCAGGS-3'
5	1614	BL3 5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTATCRGCAGAAACCAGGG-3'
1615	BL4	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTACCARCAGAAACCAGGA-3'
1616	BL5	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTACCARCAGAAACCTGGC-3'
1617	BL6	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTAYCWGCAGAAACCWGGG-3'
1618	BL7	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTATCAGCARAAACCWGGS-3'
10	1619	BL8 5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTAYCAGCARAAACCAG-3'
1620	BL9	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTTTCTGCAGAAAGCCAGG-3'
1621	BL10	5' -CCAGCCAAAGTATTAGCAACAACCTACACTGGTTTTCAGCAGAAACCAGGG-3'
1622	BL1Ü	5' -GATGGACTGGAAAACATAATAGATCAGGAGCTGTGGAG-3'
1623	BL2Ü	5' -GATGGACTGGAAAACATAATAGATCAGGAGCTTAGGRGC-3'
15	1624	BL3Ü 5' -GATGGACTGGAAAACATAATAGATGAGGAGCCTGGGMGC-3'
1625	BL4Ü	5' -GATGGACTGGAAAACATARTAGATCAGGMGCTTAGGGGC-3'
1626	BL5Ü	5' -GATGGACTGGAAAACATAATAGATCAGGWGCTTAGGRAC-3'
1627	BL6Ü	5' -GATGGACTGGAAAACATAATAGATGAAGAGCTTAGGGGC-3'
1628	BL7Ü	5' -GATGGACTGGAAAACATAATAAATTAGGAGTCTTGGAGG-3'
20	1629	BL8Ü 5' -GATGGACTGGAAAACATAGTAAATGAGCAGCTTAGGAGG-3'
1630	BL9Ü	5' -GATGGACTGGAAAACATAATAGATCAGGAGTGTGGAGAC-3'
1631	BL10Ü	5' -GATGGACTGGAAAACATAATAGATCAGGAGCTCAGGGGC-3'
1632	BL11Ü	5' -GATGGACTGGAAAACATAATAGATCAGGGACTTAGGGGC-3'
1633	BL12Ü	5' -GATGGACTGGAAAACATAATAGAGGAAGAGCTTAGGGGA-3'
25	1634	BL13Ü 5' -GATGGACTGGAAAACATACTTGATGAGGAGCTTTGGAGA-3'
1635	BL14Ü	5' -GATGGACTGGAAAACATAATAAATTAGGCGCCTTGGAGA-3'
1636	BL15Ü	5' -GATGGACTGGAAAACATACTTGATGAGGAGCTTTGGGGC-3'
1637	BL16Ü	5' -GATGGACTGGAAAACATATTGAATAATGAAAATAGCAGC-3'
1638	CL1	5' -GTTTTCCAGTCCATCTCTGGGGTCCCAGACAGATTCAGY-3'
30	1639	CL2 5' -GTTTTCCAGTCCATCTCTGGGGTCCCATCAAGGTTTCAGY-3'
1744	CL3	5' -GTTTTCCAGTCCATCTCTGGYATCCCAGCCAGGTTTCAGT-3'
1745	CL4	5' -GTTTTCCAGTCCATCTCTGGRGTCCWGCAGGTTTCAGT-3'
1746	CL5	5' -GTTTTCCAGTCCATCTCTAGCATCCCAGCCAGGTTTCAGT-3'
1747	CL6	5' -GTTTTCCAGTCCATCTCTGGGGTCCCCTCGAGGTTTCAGT-3'
35	1748	CL7 5' -GTTTTCCAGTCCATCTCTGGAATCCCACCTCGATTCAGT-3'
1749	CL8	5' -GTTTTCCAGTCCATCTCTGGGGTCCCTGACCGATTCAGT-3'
1750	CL9	5' -GTTTTCCAGTCCATCTCTGGCATCCCAGACAGGTTTCAGT-3'
1751	CL10	5' -GTTTTCCAGTCCATCTCTGGGGTCTCATCGAGGTTTCAGT-3'
1752	CL11	5' -GTTTTCCAGTCCATCTCTGGAGTGCCAGATAGGTTTCAGT-3'
40	1753	CL1Ü 5' -CCAGCTGTTACTCTGTTGKCAGTAATAAACCCCAACATC-3'
1754	CL2Ü	5' -CCAGCTGTTACTCTGTTGACAGTAATAYGTTGCAGCATC-3'
1755	CL3Ü	5' -CCAGCTGTTACTCTGTTGACMGTAATAAGTTGCAACATC-3'
1756	CL4Ü	5' -CCAGCTGTTACTCTGTTGRCAGTAATAAGTTGCAAAATC-3'
1757	CL5Ü	5' -CCAGCTGTTACTCTGTTGACAGTAATAARCTGCAAAATC-3'
45	1758	CL6Ü 5' -CCAGCTGTTACTCTGTTGACARTAGTAAGTTGCAAAATC-3'
1759	CL7Ü	5' -CCAGCTGTTACTCTGTTGGCAGTAATAAACTCCAAMATC-3'
1760	CL8Ü	5' -CCAGCTGTTACTCTGTTGGCAGTAATAAACCCCGACATC-3'
1761	CL9Ü	5' -CCAGCTGTTACTCTGTTGACAGAAGTAATATGCAGCATC-3'
1762	CL10Ü	5' -CCAGCTGTTACTCTGTTGACAGTAATATGTTGCAATATC-3'
50	1763	CL11Ü 5' -CCAGCTGTTACTCTGTTGACAGTAATACTGCAAAATC-3'
1764	CL12Ü	5' -CCAGCTGTTACTCTGTTGACAGTAATAAACTGCCACATC-3'
1765	DL1	5' -CAGAGTAACAGCTGGCCGCTCACGTTYGGCCARGGGACCAAGSTG-3'
1766	DL2	5' -CAGAGTAACAGCTGGCCGCTCACGTTTCGGCCAAGGGACACGACTG-3'
1767	DL3	5' -CAGAGTAACAGCTGGCCGCTCACGTTTCGGCCCTGGGACCAAAGTG-3'
55	1768	DL4 5' -CAGAGTAACAGCTGGCCGCTCACGTTTCGGCGGAGGGACCAAGGTG-3'
1769	DL1Ü	5' -GATGAAGACAGATGGTGCAGCCACAGTACGTTTGATYTCCACCTTGG-3'
1770	DL2Ü	5' -GATGAAGACAGATGGTGCAGCCACAGTACGTTTGATCTCCAGCTTGG-3'
1771	DL3Ü	5' -GATGAAGACAGATGGTGCAGCCACAGTACGTTTGATATCCACTTTGG-3'
1772	DL4Ü	5' -GATGAAGACAGATGGTGCAGCCACAGTACGTTTAAATCTCCAGTCGTG-3'

Table 65. Oligonucleotides used for the fusion of mAb B233 heavy chain CDRs with human germline light chain frameworks.

1640	AH1	5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGGTCAGCTGGTGCAGTCT-3'
1641	AH2	5' -GCTGGTGGTGCCGTTCTATAGCCATAGCGAGGTGCAGCTGKTGGAGTCT-3'
65	1642	AH3 5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGSTGCAGCTGCAGGAGTCG-3'
1643	AH4	5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGGTCACCTTGARGGAGTCT-3'
1644	AH5	5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCARATGCAGCTGGTGCAGTCT-3'

1645	AH6 5' -GCTGGTGGTGCCGTTCTATAGCCATAGCGARGTGCAGCTGGTGSAGTC-3'
1646	AH7 5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGATCACCTTGAAGGAGTCT-3'
1647	AH8 5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGGTSCAGCTGGTRSAGTCT-3'
1648	AH9 5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGGTACAGCTGCAGCAGTCA-3'
5 1649	AH10 5' -GCTGGTGGTGCCGTTCTATAGCCATAGCCAGGTGCAGCTACAGCAGTGG-3'
1650	AH1Ü 5' -GTTTCATGGAGTAATCRGTGAAGGTGTATCCAGAAGC-3'
1651	AH2Ü 5' -GTTTCATGGAGTAATCGCTGAGTGAGAACCCAGAGAM-3'
1652	AH3Ü 5' -GTTTCATGGAGTAATCACTGAARGTGAATCCAGAGGC-3'
1653	AH4Ü 5' -GTTTCATGGAGTAATCACTGACGGTGAAYCCAGAGGC-3'
10 1654	AH5Ü 5' -GTTTCATGGAGTAATCGCTGAYGGAGCCACCAGAGAC-3'
1655	AH6Ü 5' -GTTTCATGGAGTAATCRGTAAAGGTGWAWCCAGAAGC-3'
1656	AH7Ü 5' -GTTTCATGGAGTAATCACTRAAGGTGAAYCCAGAGGC-3'
1657	AH8Ü 5' -GTTTCATGGAGTAATCGGTAAARCTGTAWCCAGAASC-3'
1658	AH9Ü 5' -GTTTCATGGAGTAATCAYCAAAGGTGAATCCAGARGC-3'
15 1659	AH10Ü 5' -GTTTCATGGAGTAATCRCTRAAGGTGAATCCAGASGC-3'
1660	AH11Ü 5' -GTTTCATGGAGTAATCGGTGAAGGTGTATCCRGAWGC-3'
1661	AH12Ü 5' -GTTTCATGGAGTAATCACTGAAGGACCCACCATAGAC-3'
1662	AH13Ü 5' -GTTTCATGGAGTAATCACTGATGGAGCCACCAGAGAC-3'
1663	AH14Ü 5' -GTTTCATGGAGTAATCGCTGATGGAGTAACCAGAGAC-3'
20 1664	AH15Ü 5' -GTTTCATGGAGTAATCAGTGAGGGTGTATCCGGAAAC-3'
1665	AH16Ü 5' -GTTTCATGGAGTAATCGCTGAAGGTGCCTCCAGAAGC-3'
1666	AH17Ü 5' -GTTTCATGGAGTAATCAGAGACACTGTCCCCGGAGAT-3'
1667	BH1 5' -GATTACTCCATGAACCTGGGTGCGACAGGCYCCTGGA-3'
1668	BH2 5' -GATTACTCCATGAACCTGGGTGCGMCAGGCCCCCGGA-3'
25 1669	BH3 5' -GATTACTCCATGAACCTGGATCCGTCAGCCCCCAGGR-3'
1670	BH4 5' -GATTACTCCATGAACCTGGRTCCGCCAGGCTCCAGGG-3'
1671	BH5 5' -GATTACTCCATGAACCTGGATCCGSCAGCCCCCAGGG-3'
1672	BH6 5' -GATTACTCCATGAACCTGGGTCCGSCAAGCTCCAGGG-3'
1673	BH7 5' -GATTACTCCATGAACCTGGGTCCRTCARGCTCCRGGR-3'
30 1674	BH8 5' -GATTACTCCATGAACCTGGGTSCGMCARGCYACWGGA-3'
1675	BH9 5' -GATTACTCCATGAACCTGGKTCCGCCAGGCTCCAGGS-3'
1676	BH10 5' -GATTACTCCATGAACCTGGATCAGGCAGTCCCCATCG-3'
1677	BH11 5' -GATTACTCCATGAACCTGGGCCCGCAAGGCTCCAGGA-3'
1678	BH12 5' -GATTACTCCATGAACCTGGATCCGCCAGCACCAGGG-3'
35 1679	BH13 5' -GATTACTCCATGAACCTGGGTCCGCCAGGCTTCCGGG-3'
1680	BH14 5' -GATTACTCCATGAACCTGGGTGCGCCAGATGCCCGGG-3'
1681	BH15 5' -GATTACTCCATGAACCTGGGTGCGACAGGCTCGTGGA-3'
1682	BH16 5' -GATTACTCCATGAACCTGGATCCGGCAGCCCCGCCGGG-3'
1683	BH17 5' -GATTACTCCATGAACCTGGGTGCCACAGGCCCCCTGGA-3'
40 1684	BH1Ü 5' -TGTTGTAATCATTAGCTTTGTTTCTAATAAATCCCATCCACTCAAGCCYTTG-3'
1685	BH2Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATCCCATCCACTCAAGCSCTT-3'
1686	BH3Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAAWAGACCCACTCCAGCCCCTT-3'
1687	BH4Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAAACCAATCCACTCCAGKCCCTT-3'
1688	BH5Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATGAGACCCACTCCAGRCCCTT-3'
45 1689	BH6Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAAGCCAACCCACTCCAGCCCCTT-3'
1690	BH7Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAAKGCCACCCACTCCAGCCCCTT-3'
1691	BH8Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATCCCAGCCACTCAAGGCCCTC-3'
1692	BH9Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAACCCCATCCACTCCAGGCCCTT-3'
1693	BH10Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATGARACCCACWCCAGCCCCTT-3'
50 1694	BH11Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAAMGAKACCCACTCCAGMCCCTT-3'
1695	BH12Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAAYCCMATCCACTCMAGCCCCTT-3'
1696	1BH13Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATCCTATCCACTCAAGGCGTTG-3'
1697	BH14Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATGCAAGCCACTCCAGGGCCTT-3'
1698	BH15Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAATGAAACATATCCAGTCCCTT-3'
55 1699	BH16Ü 5' -TGTTGTGTAATCATTAGCTTTGTTTCTAATAAACGATACCCACTCCAGCCCCTT-3'
1700	CH1 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGAGTCACCATGACCAGGRAC-3'
1701	CH2 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGGCTCACCATCWCCAAGGAC-3'
1702	CH3 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGAGTYACCATATCAGTAGAC-3'
1703	CH4 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGATTACCATCTCCAGRGAC-3'
60 1704	CH5 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGATTCACCATCTCMAGAGA-3'
1705	CH6 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTMGGTTCACCATCTCCAGAGA-3'
1706	CH7 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGATTCAATCTCCAGAGA-3'
1707	CH8 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGAGTCACCATRTCMGTAGAC-3'
1708	CH9 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGRGTACCATKACCAGGGAC-3'
65 1709	CH10 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCAGGTCACCATCTCAGCCGAC-3'
1710	CH11 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGAATAACCATCAACCCAGAC-3'
1711	CH12 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTCGGTTTGTCTTCTCCATGGAC-3'
1712	CH13 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGAGTCACCATGACCCAGGAC-3'
1713	CH14 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGAGTCACGATTACCGCGGAC-3'
70 1714	CH15 5' -GCTAATGATTACACAACAGAGTACAGTGCATCTGTGAAGGGTAGAGTCACCATGACCACAGAC-3'
1715	CH1Ü 5' -GTCCATAGCATGATACCTAGGGTATCTAGYACAGTAATACACGGC-3'

	1716	CH2Ü 5' -GTCCATAGCATGATACCTAGGGTATCTCGCACAGTAATACAYGGC-3'
	1717	CH3Ü 5' -GTCCATAGCATGATACCTAGGGTATCTYGCACAGTAATACACAGC-3'
	1718	CH4Ü 5' -GTCCATAGCATGATACCTAGGGTATGYYGCACAGTAATACACGGC-3'
	1719	CH5Ü 5' -GTCCATAGCATGATACCTAGGGTACCGTGCACARTAATAYGTGGC-3'
5	1720	CH6Ü 5' -GTCCATAGCATGATACCTAGGGTATCTGGCACAGTAATACACGGC-3'
	1721	CH7Ü 5' -GTCCATAGCATGATACCTAGGGTATGTGGTACAGTAATACACGGC-3'
	1722	CH8Ü 5' -GTCCATAGCATGATACCTAGGGTATCTCGCACAGTGATACAAGGC-3'
	1723	CH9Ü 5' -GTCCATAGCATGATACCTAGGGTATTTTGCACAGTAATACAAGGC-3'
	1724	CH10Ü 5' -GTCCATAGCATGATACCTAGGGTATCTTGCACAGTAATACATGGC-3'
10	1725	CH11Ü 5' -GTCCATAGCATGATACCTAGGGTAGTGTGCACAGTAATATGTGGC-3'
	1726	CH12Ü 5' -GTCCATAGCATGATACCTAGGGTATTTTCGCACAGTAATATACGGC-3'
	1727	CH13Ü 5' -GTCCATAGCATGATACCTAGGGTATCTCACACAGTAATACACAGC-3'
	1728	DH1 5' -CCTAGGTATCATGCTATGGACTCCTGGGGCCARGGMACCCTGGTC-3'
	1729	DH2 5' -CCTAGGTATCATGCTATGGACTCCTGGGGSCAAGGGACMAYGGTC-3'
15	1730	DH3 5' -CCTAGGTATCATGCTATGGACTCCTGGGGCCGTGGCACCCCTGGTC-3'
	1731	DH1Ü 5' -GGAAGACCGATGGGCCCTTGGTGGAGGCTGAGGAGACRGTGACCAGGGT-3'
	1732	DH2Ü 5' -GGAAGACCGATGGGCCCTTGGTGGAGGCTGARGAGACGGTGACCRTKGT-3'
	1733	DH3Ü 5' -GGAAGACCGATGGGCCCTTGGTGGAGGCTGAGGAGACGGTGACCAGGGT-3'

20 5.3.2- Construction of the V_H and V_L sub-libraries

V_L sub1 sub-library was assembled sequentially using the polymerase chain reaction (PCR) by overlap extension. Ho *et al.*, Gene 77:51-59 (1989). More precisely, so-called “intermediate” PCRs were carried out to synthesize each individual human germline framework fused in frame with a portion of the corresponding donor CDRs using the following oligonucleotide combinations:

25 AL1-13/AL1Ü-10Ü/1-46, BL1-10/BL1Ü-16Ü/47-92, CL1-11/CL1Ü-12Ü/93-138 and DL1-4/DL1Ü-4Ü/139-143 for the 1st, 2nd, 3rd and 4th frameworks, respectively. This was carried out using *pfu* DNA polymerase (PCR SuperMix, Invitrogen) in 100 µl volume and approximately 5 pmol of oligonucleotides AL1-13, AL1Ü-10Ü, BL1-10, BL1Ü-16Ü, CL1-11, CL1Ü-12Ü, DL1-4 and DL1Ü-4Ü and approximately 100 pmol of oligonucleotides 1-143. The PCR program

30 consisted of 5 min at 95°C; 1 min at 94°C, 1 min at 45°C, 1 min at 72°C for 30 cycles then 8 min at 72°C. A second PCR (“assembly PCR”) was then carried out using *pfu* DNA polymerase (PCR SuperMix, Invitrogen), 0.5-2 µl of each of the “intermediate” PCRs, 25 pmol of each of the oligonucleotides DL1Ü, DL2Ü, DL3Ü, DL4Ü (see Table 64) and 100 pmol of the biotinylated oligonucleotide 5'-GGTCGTTCCATTTTACTCCCAC-3' (SEQ ID NO. 1734) in a 100 µl reaction

35 volume. The assembly PCR program consisted of 5 min at 95°C; 30 s at 94°C, 30 s at 50°C, 45 s at 72°C for 30 cycles then 8 min at 72°C.

V_H sub1, V_H sub2 and V_L sub2 framework-shuffled sub-libraries were also synthesized using the PCR by overlap extension. Ho *et al.*, Gene 77:51-59 (1989). This total *in vitro* synthesis of the framework shuffled V_H and V_L genes was done essentially as described H. Wu *et al.*,

40 Methods Mol. Biol. 207: 213-233 (2003). Briefly, a first so-called “fusion PCR” was carried out using *pfu* DNA polymerase (PCR SuperMix, Invitrogen). Construction of V_H sub1 was carried out using approximately 3-10 pmol of each of the oligonucleotides described in Tables 5, 6, 7, 11 and 65 in a 100 µl reaction volume. Construction of V_H sub2 was carried out using approximately 0.5

pmol of each of the oligonucleotides described in Tables 5, 6, 7, 11 and 65 in a 100 µl reaction volume. Construction of V_L sub2 was carried out using approximately 0.5 pmol of each of the oligonucleotides described in Tables 1, 2, 3, 4, and 64 in a 100 µl reaction volume. For each V_H sub1, V_H sub2 and V_L sub2 sub-library, the fusion PCR program consisted of 1 min at 95°C; 20 s at 94°C, 30 s at 50°C, 30 s at 72°C for 5 cycles; 20 s at 94°C, 30 s at 55°C, 30 s at 72°C for 25 cycles then 7 min at 72°C. A second so-called "synthesis PCR" then followed. More precisely, V_H sub1 and V_H sub2 sub-libraries were synthesized using *pfu* DNA polymerase (PCR SuperMix, Invitrogen), 2-3 µl of the corresponding "fusion PCR", 30 pmol of each of the oligonucleotides DH1Ü, DH2Ü, DH3Ü (see Table 65) and 100 pmol of the biotinylated oligonucleotide 5'-GCTGGTGGTGCCGTTCTATAGCC-3' (SEQ ID NO. 1735) in a 100 µl reaction volume. V_L sub2 sub-library was synthesized using *pfu* DNA polymerase (PCR SuperMix, Invitrogen), 3 µl of the corresponding "fusion PCR", 25 pmol of each of the oligonucleotides DL1Ü, DL2Ü, DL3Ü, DL4Ü (see Table 64) and 100 pmol of the biotinylated oligonucleotide 5'-GGTCGTTCCATTTTACTCCCAC-3' (SEQ ID NO. 1734) in a 100 µl reaction volume. For each V_H sub1, V_H sub2 and V_L sub2 sub-library, the synthesis PCR program consisted of 5 min at 94°C; 1 min at 94°C, 1 min at 45°C, 1 min at 72°C for 30 cycles then 8 min at 72°C.

5.3.3- Synthesis of the V_L-12C8 and V_L-8G7 genes

V_L-12C8 and V_L-8G7 light chain genes, used in the context of library B (V_L-12C8+V_L-8G7+V_H sub1), were synthesized by PCR from the corresponding V region-encoding M13 phage vector (see §§ 5.4.1.1, 5.4.1.2, 5.4.1.3) using the 12C8for/12C8back and 8G7for/8G7back oligonucleotide combinations, respectively (see below).

12C8for 5'-GGTCGTTCCATTTTACTCCCCTCCGCCATCCAGTTGACTCAGTCTCC-3'(biotinylated) (SEQ ID NO. 1736)

12C8back 5'-

25 GATGAAGACAGATGGTGCAGCCACAGTACGTTTGATCTCCAGCTTGGTCCCTCC-3'
(SEQ ID NO. 1737)

8G7for 5'-GGTCGTTCCATTTTACTCCCCTCCGAAATTGTGTTGACACAGTCTCCAG-3' (biotinylated) (SEQ ID NO. 1738)

8G7back 5'-

30 GATGAAGACAGATGGTGCAGCCACAGTACGTTTGATATCCACTTTGGTCCCTC-3' (SEQ ID NO. 1739).

Oligonucleotides 12C8for and 8G7for contain a M13 gene 3 leader overlapping sequence (bold).
Oligonucleotides 8G7back and 12C8back contain a Ck overlapping sequence (underlined).

5.3.4- Synthesis of the V_H-233 and V_L-233 genes

V_H-233 and V_L-233 heavy and light chain genes, used in the context of a chimaeric Fab
5 positive control (V_H-233+V_L-233) or of library A (V_L sub1+V_H-233), were synthesized by PCR
from the corresponding pSTBlue-1 (see § 5.1)vector using the 233Hfor/233Hback and
233Lfor/233Lback oligonucleotide combinations, respectively (see below).

233Hfor 5'-

GCTGGTGGTGCCGTTCTATAGCCATAGCGAGGTGAAGCTGGTGGAGTCTGGAGGAG-
10 3' (biotinylated) (SEQ ID NO. 1740)

233Hback 5'-

GGAAGACCGATGGGCCCTTGGTGGAGGCTGAGGAGACGGTGACTGAGGTTTCCTTG-3'
(SEQ ID NO. 1741)

233Lfor 5'-

GGTCGTTCCATTTTACTCCCACTCCGATATTGTGCTAACTCAGTCTCCAGCCACCCTG
15 -3' (biotinylated) (SEQ ID NO. 1742)

233Lback 5'-

GATGAAGACAGATGGTGCAGCCACAGTACGTTTCAGCTCCAGCTTGGTCCCAGCACCG
AACG-3' (SEQ ID NO. 1743)

20 Oligonucleotides 233Hfor and 233Lfor contain a M13 gene 3 leader overlapping sequence (bold).
Oligonucleotide 233Hback contains a Cκ1 overlapping sequence (underlined). Oligonucleotide
233Lback contains a Cκ overlapping sequence (underlined).

5.3.5- Cloning of the various V regions into a phage expression vector

Libraries A, B and C as well as the chimaeric Fab version of mAb B233 were cloned
25 into a M13-based phage expression vector. This vector allows the expression of Fab
fragments that contain the first constant domain of a human γ1 heavy chain and the constant
domain of a human kappa (κ) light chain under the control of the *lacZ* promoter (Figure 2).
The cloning was carried out by hybridization mutagenesis, Kunkel *et al.*, Methods Enzymol.
154:367-382 (1987), as described Wu *et al.*, Methods Mol. Biol. 207: 213-233 (2003).
30 Briefly, minus single-stranded DNA corresponding to the various V regions of interest (see

§5.3.2, §5.3.3 and §5.3.4) was purified from the final PCR products by ethanol precipitation after dissociation of the double-stranded PCR product using sodium hydroxide and elimination of the biotinylated strand by streptavidin-coated magnetic beads as described (H. Wu, *et al.*, Methods Mol. Biol. 207: 213-233(2003); H. Wu, Methods Mol. Biol. 207: 197-212 (2003)). Equimolar amounts of different minus strands were mixed as follows: V_H-233/V_L sub1, V_H sub1/V_L-8G7/V_L-12C8, V_H sub2/V_L sub2 and V_H-233 /V_L-233 to construct library A, library B, library C and chimaeric Fab 233, respectively. These different mixes were then individually annealed to two regions of the vector containing each one palindromic loop. Those loops contained a unique XbaI site which allows for the selection of the vectors that contain both V_L and V_H chains fused in frame with the human kappa (κ) constant and first human γ constant regions, respectively. Synthesized DNA was then electroporated into XL1-Blue for plaque formation on XL1-Blue bacterial lawn or production of Fab fragments as described Wu *et al.*, Methods Mol. Biol. 207: 213-233 (2003).

5.4- Screening of the libraries

5.4.1- Primary screen

5.4.1.1- Description

The primary screen consisted of a single point ELISA (SPE) which was carried out using periplasmic extracts prepared from 1 ml-bacterial culture grown in 96 deep-well plates and infected with individual recombinant M13 clones (see §5.3.5) essentially as described in Wu *et al.*, Methods Mol. Biol. 207: 213-233 (2003). Briefly, individual wells of a 96-well Maxisorp Immunoplate were coated with 20-500 ng of a goat anti-human Fab antibody, blocked with 3% BSA/PBS for 2h at 37°C and incubated with samples (periplasm-expressed Fabs) for 1h at room temperature. 300 ng/well of biotinylated human EphA2-Fc was then added for 1h at room temperature. This was followed by incubation with neutravidin-horseradish peroxidase (HRP) conjugate for 40 min at room temperature. HRP activity was detected with tetra methyl benzidine (TMB) substrate and the reaction quenched with 0.2 M H₂SO₄. Plates were read at 450 nm.

5.4.1.2- Results of the primary screen

Out of ~ 500 clones from library A that were screened using 100 ng of the goat anti-human Fab capture reagent, 14 exhibited a significant signal (OD₄₅₀ ranging from 0.2-0.6). This typically corresponded to a signal at least 1.3-fold above the corresponding background signal (OD₄₅₀ ranged

from 0.1-0.4) of an irrelevant antibody (MEDI-493; S. Johnson *et al.*, J. Infect. Dis. 176: 1215-1224 (1997)). Under these conditions, Fab 233 exhibited an OD₄₅₀ ranging from 0.4-0.6.

Out of ~ 200 clones from library A that were screened using 20 ng of the goat anti-human Fab capture reagent, 4 exhibited a significant signal (OD₄₅₀ ranging from 0.2-0.4). This typically corresponded to a signal at least 2-fold above the corresponding background signal of an irrelevant antibody (OD₄₅₀ of 0.1). Under these conditions, Fab 233 exhibited an OD₄₅₀ ranging from 0.2-0.3.

Out of ~ 750 clones from library A that were screened using 500 ng of the goat anti-human Fab capture reagent, 16 exhibited a significant signal (OD₄₅₀ ranging from 0.1-0.7). This typically corresponded to a signal at least 1.3-fold above the corresponding background signal of an irrelevant antibody (OD₄₅₀ ranged from 0.06-0.2). Under these conditions, Fab 233 exhibited an OD₄₅₀ ranging from 0.1-0.6. Clones V_H-233/V_L-12C8 and V_H-233/V_L-8G7 were isolated from this round of screening and both exhibited an OD₄₅₀ of 0.4 (same plate background OD₄₅₀ values were 0.1 and 0.2, respectively; same plate Fab 233 OD₄₅₀ values were 0.2 and 0.5, respectively).

Out of ~ 750 clones from library B that were screened using 500 ng of the goat anti-human Fab capture reagent, 27 exhibited a significant signal (OD₄₅₀ ranging from 0.3-2.8). This typically corresponded to a signal at least 1.3-fold above the corresponding background signal of an irrelevant antibody (OD₄₅₀ ranged from 0.2-0.3). Under these conditions, both V_H-233/V_L-12C8 and V_H-233/V_L-8G7 exhibited OD₄₅₀ values ranging from 0.2-0.4. Clones V_H-2G6/V_L-12C8, V_H-6H11/V_L-8G7 and V_H-7E8/V_L-8G7 were isolated from this round of screening and exhibited an OD₄₅₀ of 2.8, 2.5 and 1.6, respectively (same plate background OD₄₅₀ values were 0.3, 0.2 and 0.2, respectively; same plate V_H-233/V_L-12C8 OD₄₅₀ values were 0.4, 0.3 and 0.3, respectively; same plate V_H-233/V_L-8G7 OD₄₅₀ values were 0.4, 0.3 and 0.3, respectively).

Out of ~ 1150 clones from library C that were screened using 500 ng of the goat anti-human Fab capture reagent, 36 exhibited a significant signal (OD₄₅₀ ranging from 0.1-0.3). This typically corresponded to a signal at least 1.3-fold above the corresponding background signal of an irrelevant antibody (OD₄₅₀ ranged from 0.07-0.1). Under these conditions, Fab 233 exhibited an OD₄₅₀ ranging from 0.1-0.2.

5.4.1.3- Validation of the positive clones

Altogether, 9 clones from library A, 7 clones from library B and 0 clone from library C were re-confirmed in a second, independent, single point ELISA using periplasmic extracts prepared from 15 ml-bacterial culture and 500 ng of the goat anti-human Fab capture reagent. Specifically,

two clones from library A (V_H-233/V_L-12C8 and V_H-233/V_L-8G7) that exhibited amongst the highest [specific OD₄₅₀/background OD₄₅₀] ratio (ranging from approximately 15-50) were further characterized by dideoxynucleotide sequencing using a ABI3000 genomic analyzer. DNA sequence analysis of clone V_H-233/V_L-12C8 revealed that its heavy chain contained a single base substitution at base 104 resulting in a substitution (N to S) at position H35 (Kabat numbering). This mutation was corrected using the QuickChange XL site-directed mutagenesis Kit (Stratagene, La Jolla, CA) according to the manufacturer's instructions. Corrected clone V_H-233/V_L-12C8 exhibited a [specific OD₄₅₀/background OD₄₅₀] ratio up to approximately 50 (similar to mutated V_H-233/V_L-12C8) which indicated retention of binding to EphA2-Fc. Partially humanized clones V_H-233/V_L-12C8 and V_H-233/V_L-8G7 were then selected for further characterization by a secondary screen (see §5.4.2). The sequences of V_L-12C8 and V_L-8G7 are indicated in Figure 3. As mentioned above, these two humanized light chains were then included in the design of Library B. Three clones from this library that exhibited amongst the highest [specific OD₄₅₀/background OD₄₅₀] ratio (approximately 40) were further characterized by dideoxynucleotide sequencing. This lead to the identification of three different humanized heavy chains (V_H-2G6, V_H-6H11 and V_H-7E8; see Figure 3). V_H-2G6, V_H-6H11 and V_H-7E8 were found to be paired with V_L-12C8, V_L-8G7 and V_L-8G7, respectively. These three fully humanized clones were then selected for further characterization by a secondary screen (see §5.4.2).

5.4.2- Secondary screen

5.4.2.1- Description

In order to further characterize the previously identified humanized clones (see §5.4.1.3), a secondary screen using Fab fragments expressed in periplasmic extracts prepared from 15 ml-bacterial culture was carried out. More precisely, two ELISAs were used: (i) a functional ELISA in which individual wells of a 96-well Maxisorp Immunoplate were coated with 500 ng of human EphA2-Fc and blocked with 3%BSA/PBS for 2h at 37°C. 2-fold serially diluted samples were then added and incubated for 1h at room temperature. Incubation with a goat anti-human kappa horseradish peroxidase (HRP) conjugate then followed. HRP activity was detected with TMB substrate and the reaction quenched with 0.2 M H₂SO₄. Plates were read at 450 nm; (ii) an anti-human Fab quantification ELISA which was carried out essentially as described. Wu *et al.*, Methods Mol. Biol. 207: 213-233 (2003). Briefly, individual wells of a 96-well Immulon Immunoplate were coated with 100 ng of a goat anti-human Fab antibody and then incubated with 2-fold serially diluted samples (starting at a 1/25 dilution) or standard (human IgG Fab, 500-3.91 ng/ml). Incubation with a goat anti-human kappa horseradish peroxidase (HRP) conjugate then

followed. HRP activity was detected with TMB substrate and the reaction quenched with 0.2 M H₂SO₄. Plates were read at 450 nm.

5.4.2.2- Results of the secondary screen

The two-part secondary ELISA screen allowed us to compare Fab clones V_H-233/V_L-12C8, V_H-233/V_L-8G7, V_H-2G6/V_L-12C8, V_H-6H11/V_L-8G7 and V_H-7E8/V_L-8G7 to each other and to the chimaeric Fab of mAb B233 (V_H-233/V_L-233) in terms of binding to human EphA2. As shown in Figure 4, all framework shuffled Fabs retain binding to human EphA2 as compared with the chimaeric Fab of mAb B233. Interestingly, some clones whose heavy and light chains are both humanized (V_H-2G6/V_L-12C8 and V_H-7E8/V_L-8G7) exhibit better apparent binding to human EphA2-Fc than clones in which only the same light chains are humanized (V_H-233/V_L-12C8 and V_H-233/V_L-8G7). This indicates the existence of a process whereby humanized heavy chains are specifically selected for optimal binding to the antigen in the context of a given humanized light chain. In order to further characterize the different fully humanized molecules, clones V_H-2G6/V_L-12C8, V_H-6H11/V_L-8G7 and V_H-7E8/V_L-8G7 as well as the chimaeric form of mAb B233 (V_H-233/V_L-233) were then cloned and expressed as a full length human IgG1 (see § 5.5).

5.5 Cloning, expression and purification of the various humanized versions of mAb B233 in a human IgG1 format

The variable regions of framework shuffled clones V_H-2G6, V_H-6H11, V_H-7E8, V_L-12C8 and V_L-8G7 and of V_H-233 and V_L-233 were PCR-amplified from the corresponding V region-encoding M13 phage vectors using *pfu* DNA polymerase. They were then individually cloned into mammalian expression vectors encoding a human cytomegalovirus major immediate early (hCMVie) enhancer, promoter and 5'-untranslated region. M. Boshart, *et al.*, Cell 41:521-530 (1985). In this system, a human γ chain is secreted along with a human κ chain. S. Johnson, *et al.*, Infect. Dis. 176:1215-1224 (1997). The different constructs were expressed transiently in human embryonic kidney (HEK) 293 cells and harvested 72 hours post-transfection. The secreted, soluble human IgG1s were purified from the conditioned media directly on 1 ml HiTrap protein A or protein G columns according to the manufacturer's instructions (APBiotec, Inc., Piscataway, NJ). Purified human IgG1s (typically >95% homogeneity, as judged by SDS-PAGE) were recovered in yields varying from 2-13 μ g/ml conditioned media, dialyzed against phosphate buffered saline (PBS), flash frozen and stored at -70°C.

5.6 BIAcore analysis of the binding of framework-shuffled, chimaeric and mAb B233 IgGs to EphA2-Fc

The interaction of soluble V_H-2G6/V_L-12C8, V_H-6H11/V_L-8G7, V_H-7E8/V_L-8G7 and V_H-233/V_L-233 IgGs as well as of mAb B233 with immobilized EphA2-Fc was monitored by surface plasmon resonance detection using a BIAcore 3000 instrument (Pharmacia Biosensor, Uppsala, Sweden). EphA2-Fc was coupled to the dextran matrix of a CM5 sensor chip (Pharmacia Biosensor) using an Amine Coupling Kit as described (B. Johnsson *et al.*, Anal. Biochem. 198: 268-277 (1991)) at a surface density of between 105 and 160 RU. IgGs were diluted in 0.01 M HEPES pH 7.4 containing 0.15 M NaCl, 3 mM EDTA and 0.005% P20. All subsequent dilutions were made in the same buffer. All binding experiments were performed at 25°C with IgG concentrations typically ranging from 100 nM to 0.2 nM at a flow rate of 75 µL/min; data were collected for approximately 25 min and one 1-min pulse of 1M NaCl, 50 mM NaOH was used to regenerate the surfaces. IgGs were also flowed over an uncoated cell and the sensorgrams from these blank runs subtracted from those obtained with EphA2-Fc-coupled chips. Data were fitted to a 1:1 Langmuir binding model. This algorithm calculates both the k_{on} and the k_{off} , from which the apparent equilibrium dissociation constant, K_D , is deduced as the ratio of the two rate constants (k_{off}/k_{on}). The values obtained are indicated in Table 66.

Table 66. Affinity measurements for the binding of different IgGs to human EphA2-Fc^a

Antibody Constant (K_D) ^c	Association rate (k_{on}) ^b (M ⁻¹ .s ⁻¹)	Dissociation rate (k_{off}) ^b (s ⁻¹)	Dissociation (nM)
B233 (murine)	2.8 x 10 ⁵	1.1 x 10 ⁻⁴	0.4V _H -
B233/V _L -B233 (chimaeric)	2.4 x 10 ⁵	8.0 x 10 ⁻⁵	0.3
V _H -2G6/V _L -12C8 (humanized)	6.4 x 10 ⁴	1.9 x 10 ⁻⁴	3.0
V _H -6H11/V _L -8G7 (humanized)	9.6 x 10 ⁴	1.8 x 10 ⁻⁴	1.9
V _H -7E8/V _L -8G7 (humanized)	9.3 x 10 ³	4.5 x 10 ⁻⁴	48

^aAffinity measurements were carried out by BIAcore as reported in Description of Method. ^bKinetic parameters represent the average of 5-18 individual measurements. ^c K_D was calculated as a ration of the rate constants (k_{off}/k_{on}).

5.7- Analysis of the framework-shuffled variants

5.7.1- Sequence analysis

Overall, two unique humanized light chains (V_L-12C8 and V_L-8G7) and three unique humanized heavy chains (V_H-2G6, V_H-6H11 and V_H-7E8) were found that supported efficient binding to human EphA2-Fc. The promiscuous nature of humanized light chain V_L-8G7 is highlighted by its ability to mediate productive binding in the context of two different heavy chains (V_H-7E8 and V_H-6H11). All of these humanized variants exhibited a high level of global amino acid identity to mAb B233 in the corresponding framework regions, ranging from 76-83% for the

heavy chains and from 64-69% for the light chains (Figure 5). This can be explained by the fact that high-homology human frameworks are more likely to retain parental key residues. Analysis of individual frameworks revealed a wider range of differences, ranging from 48% for the first framework of V_L-12C8 to 91% for the fourth framework of V_H-2G6, V_H-6H11 and V_H-7E8.

5 Interestingly, humanized heavy chain V_H-7E8 consisted exclusively of human frameworks that were a perfect match with human framework germline sequences (Figure 5). Humanized heavy chains V_H-6H11 and V_H-2G6 contained one and two human frameworks, respectively, that exhibited a near-perfect match with the most related human framework germline sequences (Figure 5). The differences amounted to a maximum of
10 three residues per chain (V_H-2G6) and two residues per framework (first framework of V_H-2G6). In no cases did these differences encode amino acids not found in other most distant human framework germline sequences. Thus, arguably, these clones may also be referred to as “fully humanized”. Humanized light chains V_L-12C8 and V_L-8G7 contained one and three human frameworks, respectively, that exhibited a near-perfect match with the most
15 related human framework germline sequences (Figure 5). The number of differences amounted to a maximum of three residues per chain (V_L-8G7) and one residue per framework (first, second and fourth framework of V_L-8G7; fourth framework of V_L-12C8). However, here again, the residues at these positions were also found in other, less homologous human framework sequences; therefore these variants may also be referred to
20 as fully humanized. Since these differences were not built-in within our libraries, we attribute their origin to a combination of factors such as PCR fidelity and/or oligonucleotides quality.

5.7.2- Binding analysis

25 It is worth noting that only a two-step humanization process in which the light and heavy chains of mAb B233 were successively humanized (Library A and B) allowed us to isolate humanized clones retaining binding to human EphA2-Fc. Indeed, screening of a library in which both the light and heavy chains were simultaneously humanized (Library C) did not allow us to recover molecules exhibiting detectable binding to this antigen. This probably reflects factors such
30 as sub-optimal library quality, incomplete library sampling and/or inefficient prokaryotic expression of a portion of the library. We anticipate that screening a larger number of clones would have resulted in the identification of humanized antibody fragments retaining binding to human EphA2.

As expected in light of their identical heavy and light chains variable regions, parental mAb B233 and its chimaeric IgG version exhibited virtually identical dissociation constant ($K_D = 0.4$ and 0.3 nM, respectively; Table 66). Humanized clones V_H -6H11/ V_L -8G7 and V_H -2G6/ V_L -12C8, when formatted as a human IgG1, exhibited avidities towards human EphA2 which were similar to the parental and chimaeric version of mAb B233 ($K_D = 1.9$ and 3.0 nM, respectively; Table 66). This corresponded to a small avidity decrease of 6 and 10-fold, respectively, when compared with parental mAb B233. Humanized clone V_H -7E8/ V_L -8G7 exhibited the lowest avidity ($K_D = 48$ nM), which corresponded to a larger decrease of 160-fold when compared with parental mAb B233. It is worth noting that in terms of strength of binding to EphA2-Fc, the BIAcore-based ranking of humanized IgG clones V_H -6H11/ V_L -8G7, V_H -2G6/ V_L -12C8 and V_H -7E8/ V_L -8G7 (Table 66) was different from the ELISA-based ranking that utilized their Fab counterparts (Figure 4). This is particularly striking in the case of clone V_H -7E8/ V_L -8G7 which showed the lowest avidity (Table 66), yet consistently exhibited the highest signal by ELISA titration (Figure 4). We do not know what accounts for this difference but think that it is likely attributable to the format of the assays and/or imprecision in the quantification ELISA. Alternatively, it is possible that this discrepancy reflects unique, clone-specific correlations between affinity (as measured in Figure 4) and avidity (as measured in Table 66). Indeed, individual bivalent binding measurements depend on various factors such as the particular spatial arrangements of the corresponding antigen binding sites or the local antigen surface distribution (D.M. Crothers, et al. *Immunochemistry* 9: 341-357(1972); K.M. Müller, et al., *Anal. Biochem.* 261: 49-158(1998)).

This application claims the benefit of United States provisional application serial number 60/496,367, filed on August 18, 2003, which is incorporated by reference in its entirety.

References Cited and Equivalents:

All references cited herein are incorporated herein by reference in their entireties and for all purposes to the same extent as if each individual publication or patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety for all purposes. Many modifications and variations of this invention can be made without departing from its spirit and scope, as will be apparent to those skilled in the art.

WHAT IS CLAIMED IS:

1. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide sequence encoding the humanized heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and each heavy chain framework region is from a sub-bank of human heavy chain framework regions.
2. The nucleic acid sequence of claim 1 further comprising a second nucleotide sequence encoding a donor light chain variable region.
3. The nucleic acid sequence of claim 1 further comprising a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and each light chain framework region is from a sub-bank of human light chain framework regions.
4. The nucleic acid sequence of claim 1, wherein one or more of the CDRs derived from the donor antibody heavy chain variable region contains one or more mutations relative to the nucleic acid sequence encoding the corresponding CDR in the donor antibody.

5. The nucleic acid sequence of claim 3, wherein one or more of the CDRs derived from the donor antibody light chain variable region contains one or more mutations relative to the nucleic acid sequence encoding the corresponding CDR in the donor antibody.

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6. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized light chain variable region, said first nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and each light chain framework region is from a sub-bank of human light chain framework regions.

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7. The nucleic acid sequence of claim 6 further comprising a second nucleotide sequence encoding a donor heavy chain variable region.

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8. The nucleic acid sequence of claim 6, wherein one or more of the CDRs derived from the donor antibody light chain variable region contains one or more mutations relative to the nucleic acid sequence encoding the corresponding CDR in the donor antibody.

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9. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized heavy chain variable region, said first nucleotide acid sequence encoding the humanized heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein at least one CDR is from a sub-bank of heavy chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

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10. The nucleic acid of claim 9 further comprising a second nucleotide sequence encoding a donor light chain variable region.

5 11. The nucleic acid sequence of claim 9 further comprising a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions.

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12. The nucleic acid sequence of claim 9 further comprising a second nucleotide sequence encoding a humanized light chain variable region, said second nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.

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13. A nucleic acid sequence comprising a first nucleotide sequence encoding a humanized light chain variable region, said first nucleotide sequence encoding the humanized light chain variable region produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein at least one CDR is from

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a sub-bank of light chain CDRs derived from donor antibodies that immunospecifically bind to an antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions.

5 14. The nucleic acid sequence of claim 13 further comprising a second nucleotide sequence encoding a donor heavy chain variable region.

10 15. The nucleic acid sequence of claim 13 further comprising a second nucleotide sequence encoding a humanized heavy chain variable region, said second nucleotide sequence encoding the humanized heavy chain variable region produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain complementarity determining region (CDR) 1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

20 16. A cell engineered to contain the nucleic acid sequence of any one of claims 1- 15.

25 17. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- 30 (a) generating sub-banks of heavy chain framework regions;
- (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy
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chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region that immunospecifically binds said antigen and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions;

- 5 (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized variable light chain variable region; and
- (d) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

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18. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- 15 (b) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor
- 20 antibody light chain variable region that immunospecifically binds said antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- (c) introducing the nucleic acid sequence into a cell containing a nucleic acid sequence comprising a nucleotide sequence encoding a
- 30 humanized variable heavy chain variable region; and
- (d) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.

19. The method of claim 17 or 18 further comprising (e) screening for a

35 humanized antibody that immunospecifically binds to the antigen.

20. A method of producing a humanized antibody that immunospecifically binds to an antigen, said method comprising:

- (a) generating sub-banks of light chain framework regions;
- 5 (b) generating sub-banks of heavy chain framework regions;
- (c) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized heavy chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region that immunospecifically binds said antigen is from a sub-bank of human heavy chain framework regions;
- 10 (d) synthesizing a nucleic acid sequence comprising a nucleotide sequence encoding a humanized light chain variable region, said nucleotide sequence produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region that immunospecifically binds said antigen and at least one light chain framework region is from a sub-bank of human light chain framework regions;
- 15 (e) introducing the nucleic acid sequences into a cell; and
- 20 (f) expressing the nucleotide sequences encoding the humanized heavy chain variable region and the humanized light chain variable region.
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21. A humanized antibody produced by the method of any one of claims 17-20.

22. A composition comprising the humanized antibody of claim 21, and a carrier, diluent or excipient.

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23. A plurality of nucleic acid sequences comprising nucleotide sequences encoding humanized heavy chain variable regions, said nucleotide sequences encoding the humanized heavy chain variable regions each produced by fusing together a nucleic acid sequence encoding a heavy chain framework region 1, a nucleic acid sequence encoding a heavy chain CDR1, a nucleic acid sequence encoding a heavy chain framework region 2, a nucleic acid sequence encoding a heavy chain CDR2, a nucleic acid sequence encoding a heavy chain framework region 3, a nucleic acid sequence encoding a heavy chain CDR3, and a nucleic acid sequence encoding a heavy chain framework region 4, wherein the CDRs are derived from a donor antibody heavy chain variable region and at least one heavy chain framework region is from a sub-bank of human heavy chain framework regions.

24. A plurality of nucleic acid sequences comprising nucleotide sequences encoding humanized light chain variable regions, said nucleotide sequences encoding the humanized light chain variable regions each produced by fusing together a nucleic acid sequence encoding a light chain framework region 1, a nucleic acid sequence encoding a light chain CDR1, a nucleic acid sequence encoding a light chain framework region 2, a nucleic acid sequence encoding a light chain CDR2, a nucleic acid sequence encoding a light chain framework region 3, a nucleic acid sequence encoding a light chain CDR3, and a nucleic acid sequence encoding a light chain framework region 4, wherein the CDRs are derived from a donor antibody light chain variable region and at least one light chain framework region is from a sub-bank of human light chain framework regions.

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V_H-233

5' GAGGTGAAGCTGGTGGAGTCTGGAGGAGGCTTGGTACAGCCTGGGGGTTCTCTGAGTCTCTCCTGTGCAGCTTCTGGATTCACT
TTCAC[TGATTACTCCATGAAC]TGGGTCCGCCAGCCTCCAGGGAAGGCACTTGAGTGGTTGGGT[TTTATTAGAAACAAAGCTAATGA]
[TTACACAACAGAGTACAGTGCATCTGTGAAGGGT]CGGTTCACCATCTCCAGAGATAATTCCCAAAGCATCCTCTATCTTCAAATGA
ATGCCCTGAGAGCTGAGGACAGTGCCACTTATTACTGTGTAAGA[TACCCTAGGTATCATGCTATGGACTCC]TGGGGTCAAGGAACC
TCAGTCACCGTCTCCTCA3' (SEQ ID NO. 1773)

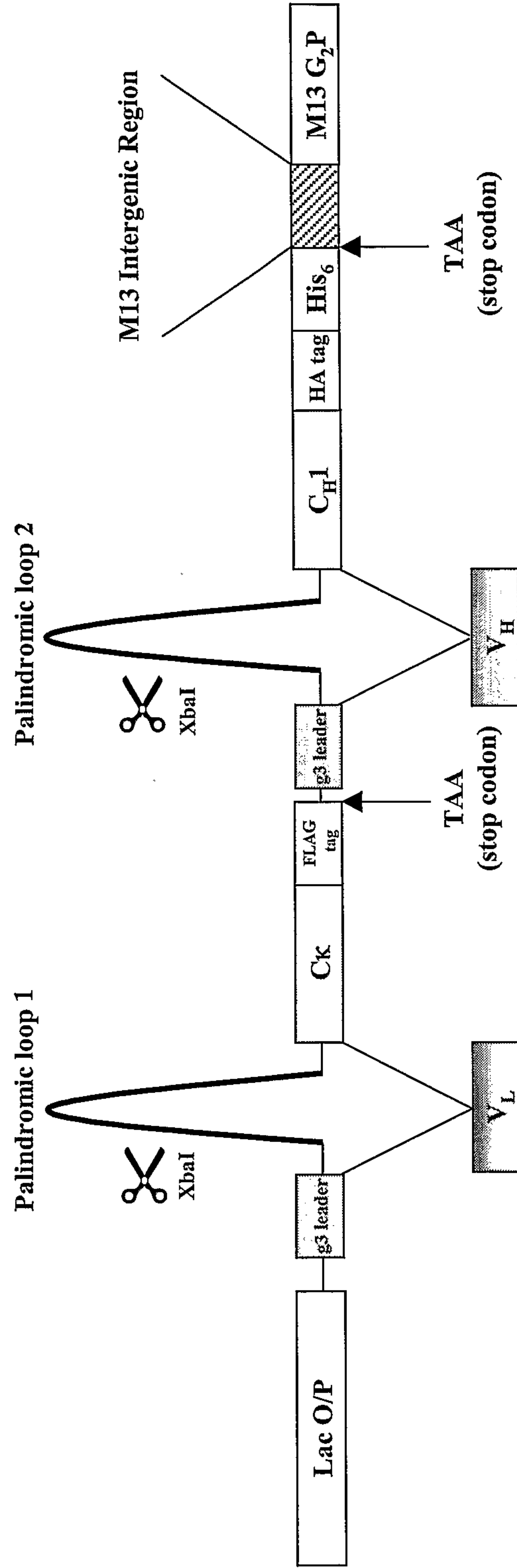
EVKLVESGGGLVQPGGSLSLSCAASGFTFT[DYSMN]WVRQPPGKALEWLG[FIRNKANDYTTEYSASVKGRFTISRDNQSILYLQMN
ALRAEDSATYYCVR[YPRYHAMDS]WGQGTSTVTVSS (SEQ ID NO. 1775)

V_L-233

5' GATATTGTGCTAACTCAGTCTCCAGCCACCCTGTCTGTGACTCCAGGAGATAGCGTCAATCTTTCCTGC[AGGGCCAGCCAAAGT]
[ATTAGCAACAACCTACAC]TGGTATCAACAAAAATCACATGAGTCTCCAAGGCTTCTCATCAAG[TATGTTTCCAGTCCATCTCT]GG
GATCCCCTCCAGGTTCAAGTGGCAGTGGATCAGGGACAGATTTCACTCTCAGTATCAACAGTGTGGAGACTGAAGATTTTGGAATGT
ATTTCTGT[CAACAGAGTAACAGCTGGCCGCTCACG]TTCGGTGCTGGGACCAAGCTGGAGCTGAAA3' (SEQ ID NO. 1774)

DIVLTQSPATLSVTPGDVNLSC[RASQISNNLH]WYQQKSHESPRLLIK[YVFQSI]GIPSRFSGSGSGTDFTLINSVETEDFGMY
FC[QQSNSWPLT]FGAGTKLELK (SEQ ID NO. 1776)

Figure 1



Palindromic loop 1 sequence: AGGGGGTCTAGAGGGGGTCAAAAGACCCCTCTAGACCCCTTTA
Xba I

Palindromic loop 2 sequence: GATTGCTCTAGAGTGCGGACAAAGTCGCACCTCTAGAGCAATCATTA
Xba I

HA tag sequence: CACTACCCGTACGACGTTCCGGACTACGCTTCT
(HYPYDVPDYAS)

Figure 2

Heavy chains

EVKLVESGGGLVQPGGSLRLSCAASGFTFTDYSMNWVRQPPGKALEWLG FIRNKANDYTTEYSASVKG RFTISRDNQSILY 233
EVQLVESGGGVVRPGLRLSCAASGFTVS DYSMNWVRQAPGKLEWIG FIRNKANDYTTEYSASVKG RFTISRDDSKNTLY 2G6
EVQLVESGGGLVQPGGSLRLSCAASGFTFS DYSMNWVRQAPGKLEWVA FIRNKANDYTTEYSASVKG RFTISRDNKNTLY 6H11
EVQLVESGGGLVKPGGSLRLSCAASGFTFS DYSMNWVRQASGKLEWVG FIRNKANDYTTEYSASVKG RFTISRDDSKNTLY 7E8

LQMNALRAEDSATYYCVR YPRYHAMDS WGQGTSTVTVSS 233
LQMNSLKTEDTAVYYCTT YPRYHAMDS WGQGTMTVTVSS 2G6 (SEQ ID NO. 1777)
LQMNSLRAEDTAMYYCAR YPRYHAMDS WGQGTSLTVTVSS 6H11 (SEQ ID NO. 1778)
LQMNSLKTEDTAVYYCTT YPRYHAMDS WGQGTSLTVTVSS 7E8 (SEQ ID NO. 1779)

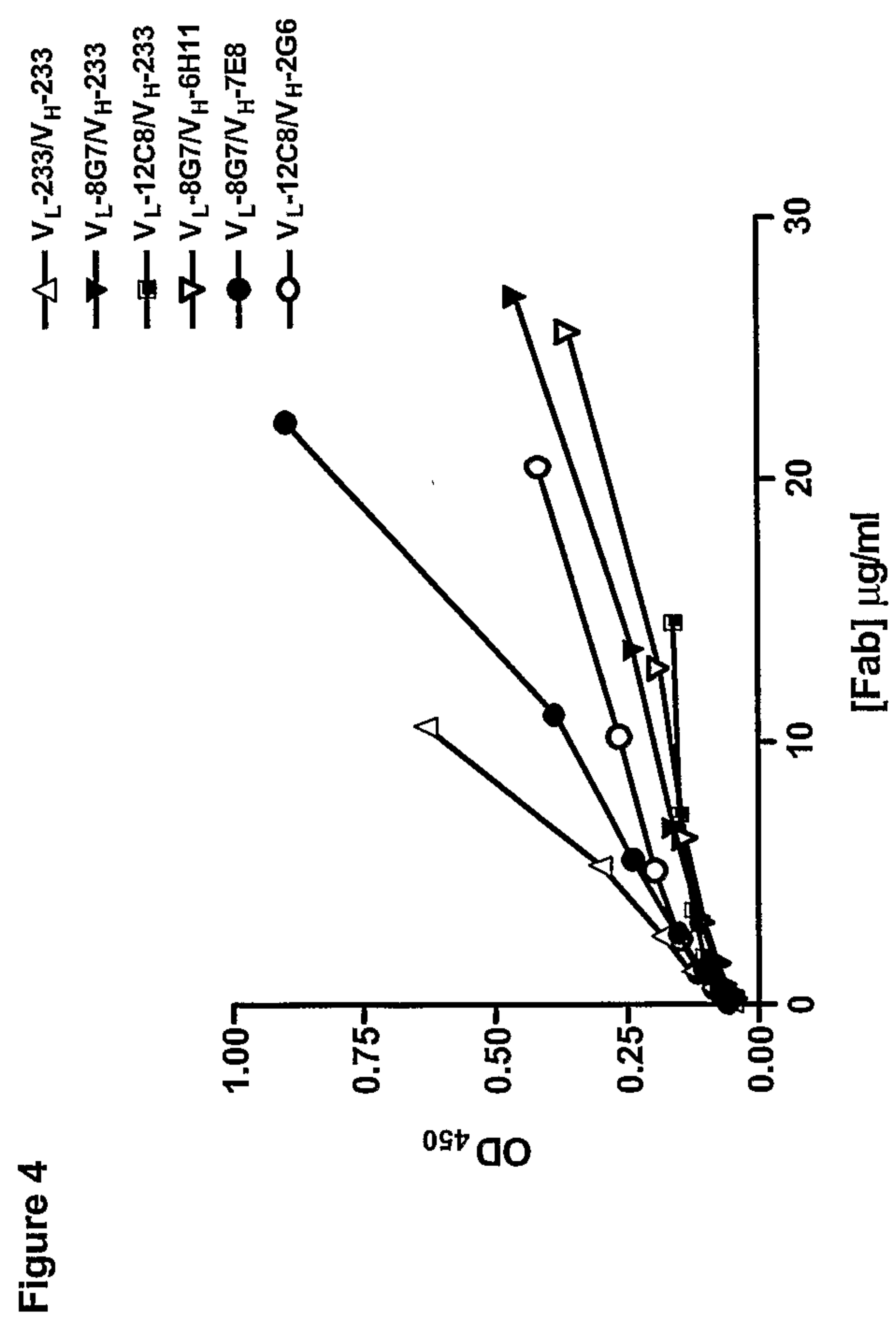
Light chains

DIVLTQSPATLSVTPGDSVNLSC RASQSSNNLHWYQQKSHESPRLLIK YVFQSIGIPSRFSGSGSGTDFTLSINSVE 233
AIQLTQSPSSLSASVGDRVTITC RASQSSNNLHWYLQKPGQSPQLLIY YVFQSIGVPSRFSGSGSGTDFTLTISLQ 12C8
EIVLTQSPATLSVSPGERATLSC RASQSSNNLHWYQQKPGKAPKSLIY YVFQSIGVPSRFSGSGSGTDFTLTINSLE 8G7

TEDFGMYFC QQSNSWPLT FGAGTKLELK 233
PEDFATYYC QQSNSWPLT FGGGTKLEIK 12C8 (SEQ ID NO. 1780)
AEDAATYYC QQSNSWPLT FGGGTKVDIK 8G7 (SEQ ID NO. 1781)

Figure 3

Figure 4.pzm:Graph-1 - Mon Mar 29 17:27:21 2004



Sequence analysis of framework shuffled antibodies													
Antibody	Identity to mAb B233 (%)				Global ^b	Closest human V _H germline ^c				Closest human V _L germline ^c			
	FR1 ^a	FR2 ^a	FR3 ^a	FR4 ^a		FR1	FR2	FR3	FR4	FR1	FR2	FR3	FR4
V _H -B233	100	100	100	100	100	VH3-48 [3] ^{d,e}	VH3-72 [3] ^{e,f}	VH3-33 [7] ^e	JH3 [1]				N.A.
V _H -2G6	80	79	66	91	76	VH3-20 [2]	VH3-72 [1] ^{e,f}	VH3-15 [0]	JH3 [0]				N.A.
V _H -6H11	90	71	78	91	83	VH3-48 [0] ^e	VH3-30 [0] ^e	VH3-33 [1] ^e	JH4 [0]	-			N.A.
V _H -7E8	87	71	66	91	77	VH3-21 [0] ^e	VH3-73 [0]	VH3-15 [0]	JH4 [0]				N.A.
V _L -B233	100	100	100	100	100		N.A.			L2 [7] ^{d,e,f}	A26 [4] ^e	A26 [8] ^{e,f}	Jκ2 [2]
V _L -12C8	48	60	72	80	64		N.A.			L18 [0] ^e	A18 [0] ^{e,f}	L19 [0] ^{e,f}	Jκ4 [1]
V _L -8G7	74	53	75	60	69		N.A.			L2 [1] ^{e,f}	O2 [1] ^{e,f}	A26 [0] ^e	Jκ4 [1]

^a Identity at the amino acid level was calculated for each individual framework using mAb B233 for reference. ^b Identity at the amino acid level was calculated for all four frameworks together using mAb B233 for reference. ^c Human germline frameworks with the highest homology to the corresponding antibody frameworks. ^d For each individual framework, the number of amino acid differences as compared with the most homologous human germline framework is indicated in brackets. ^e At least one other same-family human germline framework exists that exhibits the same homology characteristics. ^f At least one other different-family human germline framework exists that exhibits the same homology characteristics. FR: Framework. N.A.: Not Applicable.

Figure 5

V_H-233

5' GAGGTGAAGCTGGTGGAGTCTGGAGGAGGCTTGGTACAGCCTGGGGGTTCTCTGAGTCTCTCCTGTGCAGCTTCTGGATTCAACC
TTCACCTGATTACTCCATGAAC TGGGTCCGCCAGCCTCCAGGGAAGGCACTTGAGTGGTTGGGT TTTATTAGAAACAAAGCTAATGA
TTACACAACAGAGTACAGTGCATCTGTGAAGGGT CGGTTCACCATCTCCAGAGATAATTCCCAAAGCATCCTCTATCTTCAAATGA
ATGCCCTGAGAGCTGAGGACAGTGCCACTTATTACTGTGTAAGA TACCCTAGGTATCATGCTATGGACTCC TGGGGTCAAGGAACC
TCAGTCACCGTCTCCTCA3' (SEQ ID NO. 1773)

EVKLVESGGGLVQPGGSLSLSCAASGFTFTDYSMNWVRQPPGKALEWLGFIRNKANDYTTEYSASVKGRFTISRDNSSQSIYLQMN
ALRAEDSATYYCVRYPHYHAMDSWGQGTSVTVSS (SEQ ID NO. 1775)

V_L-233

5' GATATTGTGCTAACTCAGTCTCCAGCCACCCTGTCTGTGACTCCAGGAGATAGCGTCAATCTTTCCTGCAGGGCCAGCCAAAGT
ATTAGCAACAACCTACACTGGTATCAACAAAAATCACATGAGTCTCCAAGGCTTCTCATCAAGTATGTTTTCCAGTCCATCTCTGG
GATCCCCTCCAGGTTCAAGTGGCAGTGGATCAGGGACAGATTTCACTCTCAGTATCAACAGTGTGGAGACTGAAGATTTTGGAATGT
ATTTCTGTCAACAGAGTAACAGCTGGCCGCTCACGTTCCGGTGCTGGGACCAAGCTGGAGCTGAAA3' (SEQ ID NO. 1774)

DIVLTQSPATLSVTPGDSVNLSCRASQSISSNNLHWYQQKSHESPRLLIKYVFQSSIGIPSRFSGSGSGTDFTLSINSVETEDFGMY
FCQQSNSWPLTFGAGTKLELK (SEQ ID NO. 1776)