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(54) Titre : ANTICORPS HUMAINS NEUTRALISANT LE VIRUS ZIKA ET LEURS PROCEDES D'UTILISATION
(54) Title: HUMAN ANTIBODIES THAT NEUTRALIZE ZIKA VIRUS AND METHODS OF USE THEREFOR

(57) Abrégé/Abstract:

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Abstract:

The present disclosure is directed to antibodies binding to and neutralizing Zika virus and methods for use thereof.

DESCRIPTION

HUMAN ANTIBODIES THAT NEUTRALIZE ZIKA VIRUS AND METHODS OF USE THEREFOR

PRIORITY CLAIM

This application claims benefit of priority to U.S. Provisional Application Serial No. 62/937,603, filed November 19, 2019, the entire contents of which are hereby incorporated by reference.

FEDERAL FUNDING STATEMENT

This invention was made with government support under grant number HR0011-18-2-0001 awarded by the Department of Defense. The government has certain rights in the invention.

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BACKGROUND

1. Field of the Disclosure

The present disclosure relates generally to the fields of medicine, infectious disease, and immunology. More particular, the disclosure relates to human antibodies binding to Zika virus and uses thereof.

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2. Background

ZIKV is an emerging mosquito-transmitted flavivirus that has become a global public health threat. Recent ZIKV epidemics in Micronesia, Brazil, other parts of South and Central America, and Mexico (Duffy *et al.*, 2009) are linked to Guillain-Barre syndrome in adults and microcephaly in newborn infants (Oehler *et al.*, 2014; Musso *et al.*, 2014) in the setting of infection during pregnancy (Araugo *et al.*, 2016; Gatherer & Kohl, 2016). As ZIKV is transmitted by *Aedes* species mosquitoes, which are global in distribution, countries in which these vectors are present could be sites for future epidemics. Despite the potential for causing disease in millions, specific treatments or vaccines for ZIKV are not available, leaving a considerable unmet need in the field.

SUMMARY

Thus, in accordance with the present disclosure, there is provided method of detecting a Zika virus infection in a subject comprising (a) contacting a sample from said subject with an antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively; and (b) detecting Zika virus in said sample by binding of said antibody or antibody fragment to a Zika] virus antigen in said sample. The sample may be a body fluid, such as blood, sputum, tears, saliva, mucous or serum, semen, cervical or vaginal secretions, amniotic fluid, placental tissues, urine, exudate, transudate, tissue scrapings or feces. Detection may comprise ELISA, RIA, lateral flow assay or Western blot. The method may further comprise performing steps (a) and (b) a second time and determining a change in Zika virus antigen levels as compared to the first assay. The antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The antibody or antibody fragment may comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The antibody fragment may be a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.

In another embodiment, there is provided a method of treating a subject infected with Zika virus or reducing the likelihood of infection of a subject at risk of contracting Zika virus, comprising delivering to said subject an antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively. The antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The antibody or antibody fragment may comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The

antibody fragment may be a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment. The antibody may be an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The antibody may be a chimeric antibody or a bispecific antibody.

The antibody or antibody fragment may be administered prior to infection or after infection. The subject may be a pregnant female, a sexually active female, or a female undergoing fertility treatments. Delivering may comprise antibody or antibody fragment administration, or genetic delivery with an RNA or DNA sequence or vector encoding the antibody or antibody fragment.

In yet another embodiment, there is provided a monoclonal antibody, wherein the antibody or antibody fragment is characterized by clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively. The antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The antibody or antibody fragment may comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The antibody fragment may be a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment. The antibody may be an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The antibody may be a chimeric antibody or a bispecific antibody. The antibody or antibody fragment may further comprise a cell penetrating peptide and/or is an intrabody.

In still yet another embodiment, there is provided a hybridoma or engineered cell encoding an antibody or antibody fragment wherein the antibody or antibody fragment is characterized by clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively. The hybridoma or engineered cell may encode an antibody or antibody fragment
5 may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The hybridoma or engineered cell may encode an antibody or antibody fragment comprising light and heavy chain variable sequences
10 according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The hybridoma or engineered cell may encode an antibody fragment may be a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂
15 fragment, or Fv fragment. The hybridoma or engineered cell may encode an antibody that is an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or
20 removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The hybridoma or engineered cell may encode a chimeric antibody or a bispecific antibody. The hybridoma or engineered cell may encode an antibody or antibody fragment that further comprises a cell penetrating peptide and/or is an intrabody.

In a further embodiment, there is provided a vaccine formulation comprising one or
25 more antibodies or antibody fragments characterized by clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively. The antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The antibody or antibody fragment may
30 comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable

sequences having 95% identity to clone-paired sequences from Table 2. The antibody fragment may be a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment. The antibody may be an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The antibody may be a chimeric antibody or a bispecific antibody. The antibody or antibody fragment may further comprise a cell penetrating peptide and/or is an intrabody.

Also provided is a vaccine formulation comprising one or more expression vectors encoding a first antibody or antibody fragment as described herein. The expression vector(s) may be Sindbis virus or VEE vector(s). The vaccine formulation may be formulated for delivery by needle injection, jet injection, or electroporation. The vaccine formulation may further comprise one or more expression vectors encoding for a second antibody or antibody fragment, such as a distinct antibody or antibody fragment as described herein.

In an additional embodiment, there is provided a method of protecting the health of a placenta and/or fetus of a pregnant a subject infected with or at risk of infection with Zika virus comprising delivering to said subject an antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively. The antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The antibody or antibody fragment may comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The antibody fragment may be a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment. The antibody may be an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or

enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The antibody may be a chimeric antibody or a bispecific antibody. The antibody or antibody fragment may further comprise a cell penetrating peptide and/or is an intrabody.

5 The antibody or antibody fragment may be administered prior to infection or after infection. The subject may be a pregnant female, a sexually active female, or a female undergoing fertility treatments. Delivering may comprise antibody or antibody fragment administration, or genetic delivery with an RNA or DNA sequence or vector encoding the antibody or antibody fragment. The antibody or antibody fragment may increase the size of the
10 placenta as compared to an untreated control. The antibody or antibody fragment may reduce viral load and/or pathology of the fetus as compared to an untreated control.

 In an additional embodiment, there is provided a method of determining the antigenic integrity, correct conformation and/or correct sequence of a Zika virus antigen comprising (a) contacting a sample comprising said antigen with a first antibody or antibody fragment having
15 clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively; and (b) determining antigenic integrity, correct conformation and/or correct sequence of said antigen by detectable binding of said first antibody or antibody fragment to said antigen. The sample may comprise recombinantly produced antigen or a vaccine formulation or vaccine production batch. Detection may comprise ELISA, RIA, western blot, a biosensor using surface plasmon
20 resonance or biolayer interferometry, or flow cytometric staining.

 The first antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in
25 Table 1. The first antibody or antibody fragment may comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The first antibody fragment may be a recombinant scFv
30 (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment. The first antibody may be an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS

mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The first antibody may be a chimeric antibody or a bispecific antibody. The first antibody or antibody fragment may further comprise a cell penetrating peptide and/or
5 is an intrabody. The method may further comprise performing steps (a) and (b) a second time to determine the antigenic stability of the antigen over time.

The method may further comprise (c) contacting a sample comprising said antigen with a second antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively; and (d) determining antigenic integrity of said
10 antigen by detectable binding of said second antibody or antibody fragment to said antigen. The second antibody or antibody fragment may be encoded by clone-paired variable sequences as set forth in Table 1, by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1, or by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1. The
15 second antibody or antibody fragment may comprise light and heavy chain variable sequences according to clone-paired sequences from Table 2, may comprise light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2 or may comprise light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2. The second antibody fragment may be a recombinant scFv (single
20 chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment. The second antibody may be an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical
25 addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern. The second antibody may be a chimeric antibody or a bispecific antibody. The second antibody or antibody fragment may further comprise a cell penetrating peptide and/or is an intrabody. The method may further comprise performing steps (c) and (d) a second time to determine the antigenic stability of the antigen over time.

30 In yet a further embodiment, there is provided a human monoclonal antibody or antibody fragment, or hybridoma or engineered cell producing the same, wherein said antibody binds to a Zika virus E2 antigen, recognizes a highly quaternary epitope and recognizes one or more residues selected from D83, P222, F218 and K123. The epitope may be a domain II

epitope. The antibody or antibody fragment may recognize each of residues D83, P222, F218 and K123. The antibody or antibody fragment may neutralize at least one Zika virus of African lineage and at least one Zika virus of Asian lineage.

5 The use of the word “a” or “an” when used in conjunction with the term “comprising” in the claims and/or the specification may mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.” The word “about” means plus or minus 5% of the stated number.

10 It is contemplated that any method or composition described herein can be implemented with respect to any other method or composition described herein. Other objects, features and advantages of the present disclosure will become apparent from the following detailed description. It should be understood, however, that the detailed description and the specific examples, while indicating specific embodiments of the disclosure, are given by way of illustration only, since various changes and modifications within the spirit and scope of the disclosure will become apparent to those skilled in the art from this detailed description.

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BRIEF DESCRIPTION OF THE DRAWINGS

The following drawings form part of the present specification and are included to further demonstrate certain aspects of the present disclosure. The disclosure may be better understood by reference to one or more of these drawings in combination with the detailed description of specific embodiments presented herein.

FIGS. 1A-D. Rescue and sequence analysis of antibody genes from ZIKV E2 antigen-specific human B cells. (FIG. 1A) Assessing the frequency of ZIKV E2 antigen-specific B cells from PBMCs of available subjects. Plots are gated on viable B cells. (FIG. 1B) Two approaches for labeling and sorting of ZIKV E2 antigen-specific B cells. Red arrows indicate sorted cells. (FIG. 1C) *In vitro* expansion of sorted B cells using an irradiated 3T3 cell line that was engineered to express human CD40L, IL-21 and BAFF. (FIG. 1D) Bioinformatics filtering steps to select mAb sequences for synthesis.

FIGS. 2A-E. High-throughput mAb production and screening to identify lead candidates for *in vivo* protection study. (FIG. 2A) Quantification of micro-scale purified mAbs. Example plates showing a capacity to purify simultaneously <1,000 mAbs (left, unpublished data) and estimated mAb concentration for ZIKV mAb discovery study (right) are shown. Each dot on the left panel indicates the concentration of an individual mAb. LOD – limit of the detection (5 µg/mL). Values for mAbs whose concentrations were below the LOD (123 mAbs) were set up to 5 µg/mL (LOD). Median mAb concentration (286 µg/mL) is shown with the violet line. (FIG. 2B) High-throughput screening for neutralizing activity of mAbs using real-time cell analysis (RTCA) cellular impedance assay on xCelligence (Acea Biosciences) analyzer. Enlarged brightfield image of shadowed electrodes and adherent Vero cells (with and without virus to visualize cytopathic effect [CPE]) from single wells of 96-well E-plates are shown in the top panel. Middle panel shows representative real-time impedance measurement curves for Vero cells that were inoculated with ZIKV in the presence or absence of neutralizing mAbs. Mean +/- SEM of assay duplicates are shown. Example RTCA kinetics curves from a 96-well E-plate measurement showing rapid identification of mAbs with the highest neutralizing activity are shown in the bottom panel. (FIG. 2C) Recombinant E2 antigen binding of 598 micro-scale purified mAbs of ZIKV panel shown as a heatmap of OD_{450 nm} ELISA values (6 columns of 98 to 100 mAbs per column). OD_{450 nm} of 0.4 (five-fold over the negative control) was set as a threshold for mAb reactivity. Each purified mAb was tested at a single dilution (40- or 100-fold) from a micro-scale purified sample (with fixed 100 µl volume), and concentrations of the mAbs were not normalized. (FIG. 2D) Heatmap showing

relationships between binding and neutralizing activities of individual mAbs of the panel (6 columns of 98 to 100 mAbs per column). Binding was determined as in FIG. 2C. Neutralizing activity was measured at a single 25-fold dilution from micro-scale purified mAbs or directly from CHO cell culture supernatant. A mAb was considered as neutralizing if it partially or fully inhibited CPE in Vero cell cultures against either Brazil (or in some experiments Dakar) virus strain. The estimated range of tested mAb concentrations was from <50 ng/ml to >50 microgram/ml. (FIG. 2E) Ranking for neutralizing potency by assessing the IC₅₀ values of the purified mAbs. The top twenty neutralizing mAbs are shown, and their IC₅₀ values for Brazil and Dakar strain viruses are indicated with numbers and as a heatmap.

FIGS. 3Aa-Cc. Epitopes recognized by lead therapeutic candidates of rapidly discovered human mAbs against ZIKV. (FIGS. 3Aa-c) Recombinant E2 antigen ELISA binding dose-response curves for each most-potent class representative of the neutralizing mAbs. MAb rRSV-90, which is specific to the unrelated respiratory syncytial virus (RSV) fusion protein (F) antigen served as a negative control. (FIGS. 3Ba-c) Virus neutralization. Dose-response neutralization curves against Brazil and Dakar strain viruses as determined by RTCA cellular impedance assay. Data shown are the mean $\pm$ 1 SD of assay triplicates. IC₅₀ values were estimated as cellular index change over time for eight 3-fold mAb dilutions using non-linear fit with variable slope analysis. (FIGS. 3Ca-c) Key epitope contact residues were determined using alanine scanning mutagenesis in a library for cell surface-displayed prM/E protein.

FIGS. 4A-D. Protection against lethal challenge with ZIKV that is mediated by RNA delivery or antibody protein treatments in mice. Groups of four-week-old C57Bl6/J (B6) mice (n=5 to 14 per group) were treated i.p. with anti-IFN-alpha receptor antibody at day -1. For prophylaxis, mice were treated with the indicated amount of mAb by i.p. route the same day (day -1). For the therapeutic protection study, mice were treated with mAb 1 day after viral challenge (1 dpi). On day 0, mice were challenged s.q. with 1,000 FFU of mouse-adapted ZIKV Dakar strain virus (ZIKV-MA) and monitored for 21 days for survival. Viral load in plasma was assessed by RT-PCR on 2 dpi. The previously reported ZIKV-117 mAb served as a positive control. The negative control included treatment with the IgG1 mAb 5J8, which is specific to influenza A H1N1 hemagglutinin protein. (FIG. 4A) Kaplan-Meier survival curves estimated for prophylaxis (d-1 treatment) with 70 micrograms/mouse mAb dose. ZIKV plasma titers (2 dpi) determined by RT-qPCR (FIG. 4B), and Kaplan-Meier survival curves estimated for prophylaxis (d-1 treatment) with 9 g/mouse mAb dose (FIG. 4C). (FIG. 4D) Kaplan-Meier survival curves estimated for therapeutic (1 dpi) treatment with 9 micrograms/mouse mAb dose.

Dots indicate measurements from individual mice, and values below the detection limit of the assay ($2.9 \log_{10}$ (GEQ/mL)) were set up to the LOD in FIG. 4B. Virus titers from each treated group were compared to the control group using one-way ANOVA with Dunnett's multiple comparisons test, and median about 95% CI are shown in FIG. 4B. Survival curves in FIGS. 4A, 4C, and 4D were compared using the two-sided log-rank test (Mantel-Cox) with subjects right censored if they survived until the end of the study. Each group was compared to the control group. $p < 0.05$ was considered significant and was not adjusted for multiple testing correction. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns – non-significant.

FIG. 5. Workflow for rapid discovery of potent human antibodies against ZIKV.

FIG. 6. *In vivo* protection with RNA delivery. Prophylactic treatment, 40 μ g RNA dose.

FIG. 7. *In vivo* protection with RNA delivery. Prophylactic treatment, 40 μ g RNA dose.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

As discussed above, Zika virus (ZIKV) infection causes systemic and central nervous system pathology or disease, with congenital birth defects linked to infection during pregnancy (Coyne *et al.*, 2016). To develop candidate therapeutic agents against ZIKV, the inventors
5 isolated a panel of human monoclonal antibodies (mAbs) from healthy subjects with prior ZIKV infection. The inventors then evaluated the therapeutic efficacy in various models. These and other aspects of the disclosure are described in detail below.

I. Zika Virus

10 Zika virus (ZIKV) is a member of the virus family *Flaviviridae*. It is spread by daytime-active *Aedes* mosquitoes, such as *A. aegypti* and *A. albopictus*. Its name comes from the Zika Forest of Uganda, where the virus was first isolated in 1947. Zika virus is related to the dengue, yellow fever, Japanese encephalitis, and West Nile viruses. Since the 1950s, it has been known to occur within a narrow equatorial belt from Africa to Asia. From 2007 to 2016, the virus
15 spread eastward, across the Pacific Ocean to the Americas, leading to the 2015–16 Zika virus epidemic.

The infection, known as Zika fever or Zika virus disease, often causes no or only mild symptoms, similar to a very mild form of dengue fever. While there is no specific treatment, paracetamol (acetaminophen) and rest may help with the symptoms. As of 2016, the illness
20 cannot be prevented by medications or vaccines. Zika can also spread from a pregnant woman to her fetus. This can result in microcephaly, severe brain malformations, and other birth defects. Zika infections in adults may result rarely in Guillain–Barré syndrome.

In January 2016, the United States Centers for Disease Control and Prevention (CDC) issued travel guidance on affected countries, including the use of enhanced precautions, and
25 guidelines for pregnant women including considering postponing travel. Other governments or health agencies also issued similar travel warnings, while Colombia, the Dominican Republic, Puerto Rico, Ecuador, El Salvador, and Jamaica advised women to postpone getting pregnant until more is known about the risks.

The Zika virus belongs to the *Flaviviridae* family and the *Flavivirus* genus, and is thus
30 related to the dengue, yellow fever, Japanese encephalitis, and West Nile viruses. Like other flaviviruses, Zika virus is enveloped and icosahedral and has a non-segmented, single-stranded, 10 kb positive-sense RNA genome. It is most closely related to the Spondweni virus and is one of the two known viruses in the Spondweni virus clade.

A positive-sense RNA genome can be directly translated into viral proteins. As in other flaviviruses, such as the similarly sized West Nile virus, the RNA genome encodes seven nonstructural proteins and three structural proteins. One of the structural proteins encapsulates the virus. The RNA genome forms a nucleocapsid along with copies of the 12-kDa capsid protein. The nucleocapsid, in turn, is enveloped within a host-derived membrane modified with two viral glycoproteins. Viral genome replication depends on the synthesis of double sided RNA from the single stranded positive sense RNA (ssRNA(+)) genome followed by transcription and replication to provide viral mRNAs and new ssRNA(+) genomes.

There are two Zika lineages: the African lineage and the Asian lineage. Phylogenetic studies indicate that the virus spreading in the Americas is 89% identical to African genotypes but is most closely related to the Asian strain that circulated in French Polynesia during the 2013–2014 outbreak.

The vertebrate hosts of the virus were primarily monkeys in a so-called enzootic mosquito-monkey-mosquito cycle, with only occasional transmission to humans. Before the current pandemic began in 2007, Zika “rarely caused recognized ‘spillover’ infections in humans, even in highly enzootic areas.” Infrequently, however, other arboviruses have become established as a human disease and spread in a mosquito–human–mosquito cycle, like the yellow fever virus and the dengue fever virus (both flaviviruses), and the chikungunya virus (a togavirus). Though the reason for the pandemic is unknown, dengue, a related arbovirus that infects the same species of mosquito vectors, is known in particular to be intensified by urbanization and globalization. Zika is primarily spread by *Aedes aegypti* mosquitoes and can also be transmitted through sexual contact or blood transfusions. The basic reproduction number (R_0 , a measure of transmissibility) of Zika virus has been estimated to be between 1.4 and 6.6.

In 2015, news reports drew attention to the rapid spread of Zika in Latin America and the Caribbean. At that time, the Pan American Health Organization published a list of countries and territories that experienced “local Zika virus transmission” comprising Barbados, Bolivia, Brazil, Colombia, the Dominican Republic, Ecuador, El Salvador, French Guiana, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Martinique, Mexico, Panama, Paraguay, Puerto Rico, Saint Martin, Suriname, and Venezuela. By August 2016, more than 50 countries had experienced active (local) transmission of Zika virus.

Zika is primarily spread by the female *Aedes aegypti* mosquito, which is active mostly in the daytime, although researchers have found the virus in common *Culex* house mosquitoes as well. The mosquitos must feed on blood in order to lay eggs. The virus has also been isolated

from a number of arboreal mosquito species in the *Aedes* genus, such as *A. africanus*, *A. apicoargenteus*, *A. furcifer*, *A. hensilli*, *A. luteocephalus* and *A. vittatus*, with an extrinsic incubation period in mosquitoes of about 10 days.

5 The true extent of the vectors is still unknown. Zika has been detected in many more species of *Aedes*, along with *Anopheles coustani*, *Mansonia uniformis*, and *Culex perfuscus*, although this alone does not incriminate them as a vector.

Transmission by *A. albopictus*, the tiger mosquito, was reported from a 2007 urban outbreak in Gabon where it had newly invaded the country and become the primary vector for the concomitant chikungunya and dengue virus outbreaks. There is concern for autochthonous
10 infections in urban areas of European countries infested by *A. albopictus* because the first two cases of laboratory-confirmed Zika infections imported into Italy were reported from viremic travelers returning from French Polynesia.

The potential societal risk of Zika can be delimited by the distribution of the mosquito species that transmit it. The global distribution of the most cited carrier of Zika, *A. aegypti*, is
15 expanding due to global trade and travel. *A. aegypti* distribution is now the most extensive ever recorded – across all continents including North America and even the European periphery (Madeira, the Netherlands, and the northeastern Black Sea coast). A mosquito population capable of carrying Zika has been found in a Capitol Hill neighborhood of Washington, D.C., and genetic evidence suggests they survived at least four consecutive winters in the region. The
20 study authors conclude that mosquitos are adapting for persistence in a northern climate. The Zika virus appears to be contagious via mosquitoes for around a week after infection. The virus is thought to be infectious for a longer period of time after infection (at least 2 weeks) when transmitted via semen.

Research into its ecological niche suggests that Zika may be influenced to a greater
25 degree by changes in precipitation and temperature than Dengue, making it more likely to be confined to tropical areas. However, rising global temperatures would allow for the disease vector to expand their range further north, allowing Zika to follow.

Zika can be transmitted from men and women to their sexual partners. As of April 2016 sexual transmission of Zika has been documented in six countries – Argentina, Chile, France,
30 Italy, New Zealand and the United States – during the 2015 outbreak.

In 2014, Zika capable of growth in lab culture was found in the semen of a man at least two weeks (and possibly up to 10 weeks) after he fell ill with Zika fever. In 2011 a study found that a U.S. biologist who had been bitten many times while studying mosquitoes in Senegal developed symptoms six days after returning home in August 2008, but not before having

unprotected intercourse with his wife, who had not been outside the U.S. since 2008. Both husband and wife were confirmed to have Zika antibodies, raising awareness of the possibility of sexual transmission. In early February 2016, the Dallas County Health and Human Services department reported that a man from Texas who had not travelled abroad had been infected after his male monogamous sexual partner had anal penetrative sex with him one day before and one day after onset of symptoms. As of February 2016, fourteen additional cases of possible sexual transmission have been under investigation, but it remained unknown whether women can transmit Zika to their sexual partners. At that time, the understanding of the "incidence and duration of shedding in the male genitourinary tract [was] limited to one case report." Therefore, the CDC interim guideline recommended against testing men for purposes of assessing the risk of sexual transmission.

In March 2016, the CDC updated its recommendations about length of precautions for couples, and advised that heterosexual couples with men who have confirmed Zika fever or symptoms of Zika should consider using condoms or not having penetrative sex (*i.e.*, vaginal intercourse, anal intercourse, or fellatio) for at least 6 months after symptoms begin. This includes men who live in—and men who traveled to—areas with Zika. Couples with men who traveled to an area with Zika, but did not develop symptoms of Zika, should consider using condoms or not having sex for at least 8 weeks after their return in order to minimize risk. Couples with men who live in an area with Zika, but have not developed symptoms, might consider using condoms or not having sex while there is active Zika transmission in the area. The Zika virus can spread from an infected mother to her fetus during pregnancy or at delivery.

As of April 2016, two cases of Zika transmission through blood transfusions have been reported globally, both from Brazil, after which the US Food and Drug Administration (FDA) recommended screening blood donors and deferring high-risk donors for 4 weeks. A potential risk had been suspected based on a blood-donor screening study during the French Polynesian Zika outbreak, in which 2.8% (42) of donors from November 2013 and February 2014 tested positive for Zika RNA and were all asymptomatic at the time of blood donation. Eleven of the positive donors reported symptoms of Zika fever after their donation, but only three of 34 samples grew in culture.

Zika virus replicates in the mosquito's midgut epithelial cells and then its salivary gland cells. After 5–10 days, the virus can be found in the mosquito's saliva. If the mosquito's saliva is inoculated into human skin, the virus can infect epidermal keratinocytes, skin fibroblasts in the skin and the Langerhans cells. The pathogenesis of the virus is hypothesized to continue

with a spread to lymph nodes and the bloodstream. Flaviviruses generally replicate in the cytoplasm, but Zika antigens have been found in infected cell nuclei.

Zika fever (also known as Zika virus disease) is an illness caused by the Zika virus. Most cases have no symptoms, but when present they are usually mild and can resemble dengue fever. Symptoms may include fever, red eyes, joint pain, headache, and a maculopapular rash. Symptoms generally last less than seven days. It has not caused any reported deaths during the initial infection. Infection during pregnancy causes microcephaly and other brain malformations in some babies. Infection in adults has been linked to Guillain–Barré syndrome (GBS). Diagnosis is by testing the blood, urine, or saliva for the presence of Zika virus RNA when the person is sick.

Prevention involves decreasing mosquito bites in areas where the disease occurs, and proper use of condoms. Efforts to prevent bites include the use of insect repellent, covering much of the body with clothing, mosquito nets, and getting rid of standing water where mosquitoes reproduce. There is no effective vaccine. Health officials recommended that women in areas affected by the 2015–16 Zika outbreak consider putting off pregnancy and that pregnant women not travel to these areas. While there is no specific treatment, paracetamol (acetaminophen) and rest may help with the symptoms. Admission to hospital is rarely necessary.

Effective vaccines have existed for several viruses of the flaviviridae family, namely yellow fever vaccine, Japanese encephalitis vaccine, and tick-borne encephalitis vaccine, since the 1930s, and dengue fever vaccine since the mid-2010s. World Health Organization (WHO) experts have suggested that the priority should be to develop inactivated vaccines and other non-live vaccines, which are safe to use in pregnant women and those of childbearing age.

As of March 2016, eighteen companies and institutions internationally were developing vaccines against Zika but a vaccine was unlikely to be widely available for about ten years. In June 2016 the FDA granted the first approval for a human clinical trial for a Zika vaccine.

The virus was first isolated in April 1947 from a rhesus macaque monkey that had been placed in a cage in the Zika Forest of Uganda, near Lake Victoria, by the scientists of the Yellow Fever Research Institute. A second isolation from the mosquito *A. africanus* followed at the same site in January 1948. When the monkey developed a fever, researchers isolated from its serum a "filterable transmissible agent" that was named Zika in 1948.

Zika had been known to infect humans from the results of serological surveys in Uganda and Nigeria, published in 1952: Among 84 people of all ages, 50 individuals had antibodies to Zika, and all above 40 years of age were immune. A 1952 research study

conducted in India had shown a "significant number" of Indians tested for Zika had exhibited an immune response to the virus, suggesting it had long been widespread within human populations.

5 It was not until 1954 that the isolation of Zika from a human was published. This came as part of a 1952 outbreak investigation of jaundice suspected to be yellow fever. It was found in the blood of a 10-year-old Nigerian female with low-grade fever, headache, and evidence of malaria, but no jaundice, who recovered within three days. Blood was injected into the brain of laboratory mice, followed by up to 15 mice passages. The virus from mouse brains was then tested in neutralization tests using rhesus monkey sera specifically immune to Zika. In contrast,
10 no virus was isolated from the blood of two infected adults with fever, jaundice, cough, diffuse joint pains in one and fever, headache, pain behind the eyes and in the joints. Infection was proven by a rise in Zika-specific serum antibodies.

From 1951 through 1983, evidence of human infection with Zika was reported from other African countries, such as the Central African Republic, Egypt, Gabon, Sierra Leone,
15 Tanzania, and Uganda, as well as in parts of Asia including India, Indonesia, Malaysia, the Philippines, Thailand, Vietnam and Pakistan. From its discovery until 2007, there were only 14 confirmed human cases of Zika infection from Africa and Southeast Asia.

In April 2007, the first outbreak outside of Africa and Asia occurred on the island of Yap in the Federated States of Micronesia, characterized by rash, conjunctivitis, and arthralgia,
20 which was initially thought to be dengue, chikungunya, or Ross River disease. Serum samples from patients in the acute phase of illness contained RNA of Zika. There were 49 confirmed cases, 59 unconfirmed cases, no hospitalizations, and no deaths. Between 2013 and 2014, further epidemics occurred in French Polynesia, Easter Island, the Cook Islands, and New Caledonia. On 22 March 2016 Reuters reported that Zika was isolated from a 2014 blood
25 sample of an elderly man in Chittagong in Bangladesh as part of a retrospective study.

As of early 2016, a widespread outbreak of Zika was ongoing, primarily in the Americas. The outbreak began in April 2015 in Brazil, and has spread to other countries in South America, Central America, North America, and the Caribbean. The Zika virus reached Singapore and Malaysia in Aug 2016. In January 2016, the WHO said the virus was likely to
30 spread throughout most of the Americas by the end of the year; and in February 2016, the WHO declared the cluster of microcephaly and Guillain–Barré syndrome cases reported in Brazil – strongly suspected to be associated with the Zika outbreak – a Public Health Emergency of International Concern. It is estimated that 1.5 million people have been infected by Zika in

Brazil, with over 3,500 cases of microcephaly reported between October 2015 and January 2016.

5 A number of countries have issued travel warnings, and the outbreak is expected to significantly impact the tourism industry. Several countries have taken the unusual step of advising their citizens to delay pregnancy until more is known about the virus and its impact on fetal development. With the 2016 Summer Olympic Games hosted in Rio de Janeiro, health officials worldwide have voiced concerns over a potential crisis, both in Brazil and when international athletes and tourists, who may be unknowingly infected, return home and possibly spread the virus. Some researchers speculate that only one or two tourists may be infected during the three-week period, or approximately 3.2 infections per 100,000 tourists.

II. Monoclonal Antibodies and Production Thereof

15 An "isolated antibody" is one that has been separated and/or recovered from a component of its natural environment. Contaminant components of its natural environment are materials that would interfere with diagnostic or therapeutic uses for the antibody, and may include enzymes, hormones, and other proteinaceous or non-proteinaceous solutes. In particular embodiments, the antibody is purified: (1) to greater than 95% by weight of antibody as determined by the Lowry method, and most particularly more than 99% by weight; (2) to a degree sufficient to obtain at least 15 residues of N-terminal or internal amino acid sequence by use of a spinning cup sequenator; or (3) to homogeneity by SDS-PAGE under reducing or non-reducing conditions using Coomassie blue or silver stain. Isolated antibody includes the antibody *in situ* within recombinant cells since at least one component of the antibody's natural environment will not be present. Ordinarily, however, isolated antibody will be prepared by at least one purification step.

25 The basic four-chain antibody unit is a heterotetrameric glycoprotein composed of two identical light (L) chains and two identical heavy (H) chains. An IgM antibody consists of 5 basic heterotetramer units along with an additional polypeptide called J chain, and therefore contain 10 antigen binding sites, while secreted IgA antibodies can polymerize to form polyvalent assemblages comprising 2-5 of the basic 4-chain units along with J chain. In the case of IgGs, the 4-chain unit is generally about 150,000 daltons. Each L chain is linked to an H chain by one covalent disulfide bond, while the two H chains are linked to each other by one or more disulfide bonds depending on the H chain isotype. Each H and L chain also has regularly spaced intrachain disulfide bridges. Each H chain has at the N-terminus, a variable region (V_H) followed by three constant domains (C_H) for each of the alpha and gamma chains

and four C_H domains for mu and isotopes. Each L chain has at the N-terminus, a variable region (V_L) followed by a constant domain (C_L) at its other end. The V_L is aligned with the V_H and the C_L is aligned with the first constant domain of the heavy chain (C_{H1}). Particular amino acid residues are believed to form an interface between the light chain and heavy chain variable regions. The pairing of a V_H and V_L together forms a single antigen-binding site. For the structure and properties of the different classes of antibodies, see, *e.g.*, Basic and Clinical Immunology, 8th edition, Daniel P. Stites, Abba I. Terr and Tristram G. Parslow (eds.), Appleton & Lange, Norwalk, Conn., 1994, page 71, and Chapter 6.

The L chain from any vertebrate species can be assigned to one of two clearly distinct types, called kappa and lambda based on the amino acid sequences of their constant domains (C_L). Depending on the amino acid sequence of the constant domain of their heavy chains (C_H), immunoglobulins can be assigned to different classes or isotopes. There are five classes of immunoglobulins: IgA, IgD, IgE, IgG, and IgM, having heavy chains designated alpha, delta, epsilon, gamma and mu, respectively. They gamma and alpha classes are further divided into subclasses on the basis of relatively minor differences in C_H sequence and function, humans express the following subclasses: IgG1, IgG2, IgG3, IgG4, IgA1, and IgA2.

The term "variable" refers to the fact that certain segments of the V domains differ extensively in sequence among antibodies. The V domain mediates antigen binding and defines specificity of a particular antibody for its particular antigen. However, the variability is not evenly distributed across the 110-amino acid span of the variable regions. Instead, the V regions consist of relatively invariant stretches called framework regions (FRs) of 15-30 amino acids separated by shorter regions of extreme variability called "hypervariable regions" that are each 9-12 amino acids long. The variable regions of native heavy and light chains each comprise four FRs, largely adopting a beta-sheet configuration, connected by three hypervariable regions, which form loops connecting, and in some cases forming part of, the beta-sheet structure. The hypervariable regions in each chain are held together in close proximity by the FRs and, with the hypervariable regions from the other chain, contribute to the formation of the antigen-binding site of antibodies (see Kabat *et al.*, Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, Md. (1991)). The constant domains are not involved directly in binding an antibody to an antigen, but exhibit various effector functions, such as participation of the antibody in antibody dependent cellular cytotoxicity (ADCC), antibody-dependent cellular phagocytosis (ADCP), antibody-dependent neutrophil phagocytosis (ADNP), and antibody-dependent complement deposition (ADCD).

The term "hypervariable region" when used herein refers to the amino acid residues of an antibody that are responsible for antigen binding. The hypervariable region generally comprises amino acid residues from a "complementarity determining region" or "CDR" (*e.g.*, around about residues 24-34 (L1), 50-56 (L2) and 89-97 (L3) in the V_L, and around about 31-35 (H1), 50-65 (H2) and 95-102 (H3) in the V_H when numbered in accordance with the Kabat numbering system; Kabat *et al.*, Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, Md. (1991)); and/or those residues from a "hypervariable loop" (*e.g.*, residues 24-34 (L1), 50-56 (L2) and 89-97 (L3) in the V_L, and 26-32 (H1), 52-56 (H2) and 95-101 (H3) in the V_H when numbered in accordance with the Chothia numbering system; Chothia and Lesk, J. Mol. Biol. 196:901-917 (1987)); and/or those residues from a "hypervariable loop"/CDR (*e.g.*, residues 27-38 (L1), 56-65 (L2) and 105-120 (L3) in the V_L, and 27-38 (H1), 56-65 (H2) and 105-120 (H3) in the V_H when numbered in accordance with the IMGT numbering system; Lefranc, M. P. *et al.* Nucl. Acids Res. 27:209-212 (1999), Ruiz, M. *et al.* Nucl. Acids Res. 28:219-221 (2000)). Optionally the antibody has symmetrical insertions at one or more of the following points 28, 36 (L1), 63, 74-75 (L2) and 123 (L3) in the V_L, and 28, 36 (H1), 63, 74-75 (H2) and 123 (H3) in the V_{subH} when numbered in accordance with AHO; Honneger, A. and Plunkthun, A. J. Mol. Biol. 309:657-670 (2001)).

By "germline nucleic acid residue" is meant the nucleic acid residue that naturally occurs in a germline gene encoding a constant or variable region. "Germline gene" is the DNA found in a germ cell (*i.e.*, a cell destined to become an egg or in the sperm). A "germline mutation" refers to a heritable change in a particular DNA that has occurred in a germ cell or the zygote at the single-cell stage, and when transmitted to offspring, such a mutation is incorporated in every cell of the body. A germline mutation is in contrast to a somatic mutation which is acquired in a single body cell. In some cases, nucleotides in a germline DNA sequence encoding for a variable region are mutated (*i.e.*, a somatic mutation) and replaced with a different nucleotide.

The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, *i.e.*, the individual antibodies comprising the population are identical except for possible naturally occurring mutations that may be present in minor amounts. Monoclonal antibodies are highly specific, being directed against a single antigenic site. Furthermore, in contrast to polyclonal antibody preparations that include different antibodies directed against different determinants (epitopes), each monoclonal antibody is directed against a single determinant on the antigen. In addition to their specificity,

the monoclonal antibodies are advantageous in that they may be synthesized uncontaminated by other antibodies. The modifier "monoclonal" is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies useful in the present disclosure may be prepared by the hybridoma methodology first described by Kohler *et al.*, Nature, 256:495 (1975), or may be made using recombinant DNA methods in bacterial, eukaryotic animal or plant cells (see, *e.g.*, U.S. Patent 4,816,567) after single cell sorting of an antigen specific B cell, an antigen specific plasmablast responding to an infection or immunization, or capture of linked heavy and light chains from single cells in a bulk sorted antigen specific collection. The "monoclonal antibodies" may also be isolated from phage antibody libraries using the techniques described in Clackson *et al.*, Nature, 352:624-628 (1991) and Marks *et al.*, J. Mol. Biol., 222:581-597 (1991), for example.

A. General Methods

It will be understood that monoclonal antibodies binding to Zika virus will have several applications. These include the production of diagnostic kits for use in detecting and diagnosing Zika virus infection, as well as for treating the same. In these contexts, one may link such antibodies to diagnostic or therapeutic agents, use them as capture agents or competitors in competitive assays, or use them individually without additional agents being attached thereto. The antibodies may be mutated or modified, as discussed further below. Methods for preparing and characterizing antibodies are well known in the art (see, *e.g.*, Antibodies: A Laboratory Manual, Cold Spring Harbor Laboratory, 1988; U.S. Patent 4,196,265).

The methods for generating monoclonal antibodies (MAbs) generally begin along the same lines as those for preparing polyclonal antibodies. The first step for both these methods is immunization of an appropriate host or identification of subjects who are immune due to prior natural infection or vaccination with a licensed or experimental vaccine. As is well known in the art, a given composition for immunization may vary in its immunogenicity. It is often necessary therefore to boost the host immune system, as may be achieved by coupling a peptide or polypeptide immunogen to a carrier. Exemplary and preferred carriers are keyhole limpet hemocyanin (KLH) and bovine serum albumin (BSA). Other albumins such as ovalbumin, mouse serum albumin or rabbit serum albumin can also be used as carriers. Means for conjugating a polypeptide to a carrier protein are well known in the art and include glutaraldehyde, m-maleimidobencoyl-N-hydroxysuccinimide ester, carbodiimide and bis-biazotized benzidine. As also is well known in the art, the immunogenicity of a particular immunogen composition can be enhanced by the use of non-specific stimulators of the immune

response, known as adjuvants. Exemplary and preferred adjuvants in animals include complete Freund's adjuvant (a non-specific stimulator of the immune response containing killed *Mycobacterium tuberculosis*), incomplete Freund's adjuvants and aluminum hydroxide adjuvant and in humans include alum, CpG, MFP59 and combinations of immunostimulatory molecules ("Adjuvant Systems", such as AS01 or AS03). Additional experimental forms of inoculation to induce Zika-specific B cells is possible, including nanoparticle vaccines, or gene-encoded antigens delivered as DNA or RNA genes in a physical delivery system (such as lipid nanoparticle or on a gold biolistic bead), and delivered with needle, gene gun, transcutaneous electroporation device. The antigen gene also can be carried as encoded by a replication competent or defective viral vector such as adenovirus, adeno-associated virus, poxvirus, herpesvirus, or alphavirus replicon, or alternatively a virus like particle.

In the case of human antibodies against natural pathogens, a suitable approach is to identify subjects that have been exposed to the pathogens, such as those who have been diagnosed as having contracted the disease, or those who have been vaccinated to generate protective immunity against the pathogen or to test the safety or efficacy of an experimental vaccine. Circulating anti-pathogen antibodies can be detected, and antibody encoding or producing B cells from the antibody-positive subject may then be obtained.

The amount of immunogen composition used in the production of polyclonal antibodies varies upon the nature of the immunogen as well as the animal used for immunization. A variety of routes can be used to administer the immunogen (subcutaneous, intramuscular, intradermal, intravenous and intraperitoneal). The production of polyclonal antibodies may be monitored by sampling blood of the immunized animal at various points following immunization. A second, booster injection, also may be given. The process of boosting and titering is repeated until a suitable titer is achieved. When a desired level of immunogenicity is obtained, the immunized animal can be bled and the serum isolated and stored, and/or the animal can be used to generate MAbs.

Following immunization, somatic cells with the potential for producing antibodies, specifically B lymphocytes (B cells), are selected for use in the MAb generating protocol. These cells may be obtained from biopsied spleens, lymph nodes, tonsils or adenoids, bone marrow aspirates or biopsies, tissue biopsies from mucosal organs like lung or GI tract, or from circulating blood. The antibody-producing B lymphocytes from the immunized animal or immune human are then fused with cells of an immortal myeloma cell, generally one of the same species as the animal that was immunized or human or human/mouse chimeric cells. Myeloma cell lines suited for use in hybridoma-producing fusion procedures preferably are

non-antibody-producing, have high fusion efficiency, and enzyme deficiencies that render them incapable of growing in certain selective media which support the growth of only the desired fused cells (hybridomas). Any one of a number of myeloma cells may be used, as are known to those of skill in the art (Goding, pp. 65-66, 1986; Campbell, pp. 75-83, 1984). HMMMA2.5
5 cells or MFP-2 cells are particularly useful examples of such cells.

Methods for generating hybrids of antibody-producing spleen or lymph node cells and myeloma cells usually comprise mixing somatic cells with myeloma cells in a 2:1 proportion, though the proportion may vary from about 20:1 to about 1:1, respectively, in the presence of an agent or agents (chemical or electrical) that promote the fusion of cell membranes. In some
10 cases, transformation of human B cells with Epstein Barr virus (EBV) as an initial step increases the size of the B cells, enhancing fusion with the relatively large-sized myeloma cells. Transformation efficiency by EBV is enhanced by using CpG and a Chk2 inhibitor drug in the transforming medium. Alternatively, human B cells can be activated by co-culture with transfected cell lines expressing CD40 Ligand (CD154) in medium containing additional
15 soluble factors, such as IL-21 and human B cell Activating Factor (BAFF), a Type II member of the TNF superfamily. Fusion methods using Sendai virus have been described by Kohler and Milstein (1975; 1976), and those using polyethylene glycol (PEG), such as 37% (v/v) PEG, by Gefter *et al.* (1977). The use of electrically induced fusion methods also is appropriate (Goding, pp. 71-74, 1986) and there are processes for better efficiency (Yu *et al.*, 2008). Fusion
20 procedures usually produce viable hybrids at low frequencies, about 1×10^{-6} to 1×10^{-8} , but with optimized procedures one can achieve fusion efficiencies close to 1 in 200 (Yu *et al.*, 2008). However, relatively low efficiency of fusion does not pose a problem, as the viable, fused hybrids are differentiated from the parental, infused cells (particularly the infused myeloma cells that would normally continue to divide indefinitely) by culturing in a selective
25 medium. The selective medium is generally one that contains an agent that blocks the *de novo* synthesis of nucleotides in the tissue culture medium. Exemplary and preferred agents are aminopterin, methotrexate, and azaserine. Aminopterin and methotrexate block *de novo* synthesis of both purines and pyrimidines, whereas azaserine blocks only purine synthesis. Where aminopterin or methotrexate is used, the medium is supplemented with hypoxanthine
30 and thymidine as a source of nucleotides (HAT medium). Where azaserine is used, the medium is supplemented with hypoxanthine. Ouabain is added if the B cell source is an EBV-transformed human B cell line, in order to eliminate EBV-transformed lines that have not fused to the myeloma.

The preferred selection medium is HAT or HAT with ouabain. Only cells capable of operating nucleotide salvage pathways are able to survive in HAT medium. The myeloma cells are defective in key enzymes of the salvage pathway, *e.g.*, hypoxanthine phosphoribosyl transferase (HPRT), and they cannot survive. The B cells can operate this pathway, but they have a limited life span in culture and generally die within about two weeks. Therefore, the only cells that can survive in the selective media are those hybrids formed from myeloma and B cells. When the source of B cells used for fusion is a line of EBV-transformed B cells, as here, ouabain may also be used for drug selection of hybrids as EBV-transformed B cells are susceptible to drug killing, whereas the myeloma partner used is chosen to be ouabain resistant.

Culturing provides a population of hybridomas from which specific hybridomas are selected. Typically, selection of hybridomas is performed by culturing the cells by single-clone dilution in microtiter plates, followed by testing the individual clonal supernatants (after about two to three weeks) for the desired reactivity. The assay should be sensitive, simple and rapid, such as radioimmunoassays, enzyme immunoassays, cytotoxicity assays, plaque assays dot immunobinding assays, and the like. The selected hybridomas are then serially diluted or single-cell sorted by flow cytometric sorting and cloned into individual antibody-producing cell lines, which clones can then be propagated indefinitely to provide mAbs. The cell lines may be exploited for MAb production in two basic ways. A sample of the hybridoma can be injected (often into the peritoneal cavity) into an animal (*e.g.*, a mouse). Optionally, the animals are primed with a hydrocarbon, especially oils such as pristane (tetramethylpentadecane) prior to injection. When human hybridomas are used in this way, it is optimal to inject immunocompromised mice, such as SCID mice, to prevent tumor rejection. The injected animal develops tumors secreting the specific monoclonal antibody produced by the fused cell hybrid. The body fluids of the animal, such as serum or ascites fluid, can then be tapped to provide MAbs in high concentration. The individual cell lines could also be cultured *in vitro*, where the MAbs are naturally secreted into the culture medium from which they can be readily obtained in high concentrations. Alternatively, human hybridoma cells lines can be used *in vitro* to produce immunoglobulins in cell supernatant. The cell lines can be adapted for growth in serum-free medium to optimize the ability to recover human monoclonal immunoglobulins of high purity.

MAbs produced by either means may be further purified, if desired, using filtration, centrifugation and various chromatographic methods such as FPLC or affinity chromatography. Fragments of the monoclonal antibodies of the disclosure can be obtained from the purified monoclonal antibodies by methods which include digestion with enzymes,

such as pepsin or papain, and/or by cleavage of disulfide bonds by chemical reduction. Alternatively, monoclonal antibody fragments encompassed by the present disclosure can be synthesized using an automated peptide synthesizer.

It also is contemplated that a molecular cloning approach may be used to generate
5 monoclonal antibodies. Single B cells labelled with the antigen of interest can be sorted physically using paramagnetic bead selection or flow cytometric sorting, then RNA can be isolated from the single cells and antibody genes amplified by RT-PCR. Alternatively, antigen-specific bulk sorted populations of cells can be segregated into microvesicles and the matched heavy and light chain variable genes recovered from single cells using physical linkage of
10 heavy and light chain amplicons, or common barcoding of heavy and light chain genes from a vesicle. Matched heavy and light chain genes from single cells also can be obtained from populations of antigen specific B cells by treating cells with cell-penetrating nanoparticles bearing RT-PCR primers and barcodes for marking transcripts with one barcode per cell. The antibody variable genes also can be isolated by RNA extraction of a hybridoma line and the
15 antibody genes obtained by RT-PCR and cloned into an immunoglobulin expression vector. Alternatively, combinatorial immunoglobulin phagemid libraries are prepared from RNA isolated from the cell lines and phagemids expressing appropriate antibodies are selected by panning using viral antigens. The advantages of this approach over conventional hybridoma techniques are that approximately 10^4 times as many antibodies can be produced and screened
20 in a single round, and that new specificities are generated by H and L chain combination which further increases the chance of finding appropriate antibodies.

Other U.S. patents, each incorporated herein by reference, that teach the production of antibodies useful in the present disclosure include U.S. Patent 5,565,332, which describes the production of chimeric antibodies using a combinatorial approach; U.S. Patent 4,816,567
25 which describes recombinant immunoglobulin preparations; and U.S. Patent 4,867,973 which describes antibody-therapeutic agent conjugates.

B. Antibodies of the Present Disclosure

Antibodies according to the present disclosure may be defined, in the first instance, by
30 their binding specificity. Those of skill in the art, by assessing the binding specificity/affinity of a given antibody using techniques well known to those of skill in the art, can determine whether such antibodies fall within the scope of the instant claims. For example, the epitope to which a given antibody bind may consist of a single contiguous sequence of 3 or more (*e.g.*, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20) amino acids located within the antigen

molecule (*e.g.*, a linear epitope in a domain). Alternatively, the epitope may consist of a plurality of non-contiguous amino acids (or amino acid sequences) located within the antigen molecule (*e.g.*, a conformational epitope).

Various techniques known to persons of ordinary skill in the art can be used to determine whether an antibody “interacts with one or more amino acids” within a polypeptide or protein. Exemplary techniques include, for example, routine cross-blocking assays, such as that described in Antibodies, Harlow and Lane (Cold Spring Harbor Press, Cold Spring Harbor, N.Y.). Cross-blocking can be measured in various binding assays such as ELISA, biolayer interferometry, or surface plasmon resonance. Other methods include alanine scanning mutational analysis, peptide blot analysis (Reineke (2004) *Methods Mol. Biol.* 248: 443-63), peptide cleavage analysis, high-resolution electron microscopy techniques using single particle reconstruction, cryoEM, or tomography, crystallographic studies and NMR analysis. In addition, methods such as epitope excision, epitope extraction and chemical modification of antigens can be employed (Tomer (2000) *Prot. Sci.* 9: 487-496). Another method that can be used to identify the amino acids within a polypeptide with which an antibody interacts is hydrogen/deuterium exchange detected by mass spectrometry. In general terms, the hydrogen/deuterium exchange method involves deuterium-labeling the protein of interest, followed by binding the antibody to the deuterium-labeled protein. Next, the protein/antibody complex is transferred to water and exchangeable protons within amino acids that are protected by the antibody complex undergo deuterium-to-hydrogen back-exchange at a slower rate than exchangeable protons within amino acids that are not part of the interface. As a result, amino acids that form part of the protein/antibody interface may retain deuterium and therefore exhibit relatively higher mass compared to amino acids not included in the interface. After dissociation of the antibody, the target protein is subjected to protease cleavage and mass spectrometry analysis, thereby revealing the deuterium-labeled residues which correspond to the specific amino acids with which the antibody interacts. See, *e.g.*, Ehring (1999) *Analytical Biochemistry* 267: 252-259; Engen and Smith (2001) *Anal. Chem.* 73: 256A-265A. When the antibody neutralizes Zika, antibody escape mutant variant organisms can be isolated by propagating Zika *in vitro* or in animal models in the presence of high concentrations of the antibody. Sequence analysis of the Zika gene encoding the antigen targeted by the antibody reveals the mutation(s) conferring antibody escape, indicating residues in the epitope or that affect the structure of the epitope allosterically.

The term “epitope” refers to a site on an antigen to which B and/or T cells respond. B-cell epitopes can be formed both from contiguous amino acids or noncontiguous amino acids

juxtaposed by tertiary folding of a protein. Epitopes formed from contiguous amino acids are typically retained on exposure to denaturing solvents, whereas epitopes formed by tertiary folding are typically lost on treatment with denaturing solvents. An epitope typically includes at least 3, and more usually, at least 5 or 8-10 amino acids in a unique spatial conformation.

5 Modification-Assisted Profiling (MAP), also known as Antigen Structure-based Antibody Profiling (ASAP) is a method that categorizes large numbers of monoclonal antibodies (mAbs) directed against the same antigen according to the similarities of the binding profile of each antibody to chemically or enzymatically modified antigen surfaces (see US 2004/0101920, herein specifically incorporated by reference in its entirety). Each category may
10 reflect a unique epitope either distinctly different from or partially overlapping with epitope represented by another category. This technology allows rapid filtering of genetically identical antibodies, such that characterization can be focused on genetically distinct antibodies. When applied to hybridoma screening, MAP may facilitate identification of rare hybridoma clones that produce mAbs having the desired characteristics. MAP may be used to sort the antibodies
15 of the disclosure into groups of antibodies binding different epitopes.

 The present disclosure includes antibodies that may bind to the same epitope, or a portion of the epitope. Likewise, the present disclosure also includes antibodies that compete for binding to a target or a fragment thereof with any of the specific exemplary antibodies described herein. One can easily determine whether an antibody binds to the same epitope as,
20 or competes for binding with, a reference antibody by using routine methods known in the art. For example, to determine if a test antibody binds to the same epitope as a reference, the reference antibody is allowed to bind to target under saturating conditions. Next, the ability of a test antibody to bind to the target molecule is assessed. If the test antibody is able to bind to the target molecule following saturation binding with the reference antibody, it can be
25 concluded that the test antibody binds to a different epitope than the reference antibody. On the other hand, if the test antibody is not able to bind to the target molecule following saturation binding with the reference antibody, then the test antibody may bind to the same epitope as the epitope bound by the reference antibody.

 To determine if an antibody competes for binding with a reference anti-Zika virus
30 antibody, the above-described binding methodology is performed in two orientations: In a first orientation, the reference antibody is allowed to bind to the Zika virus antigen under saturating conditions followed by assessment of binding of the test antibody to the Zika virus molecule. In a second orientation, the test antibody is allowed to bind to the Zika virus antigen molecule under saturating conditions followed by assessment of binding of the reference antibody to the

Zika virus molecule. If, in both orientations, only the first (saturating) antibody is capable of binding to the Zika virus, then it is concluded that the test antibody and the reference antibody compete for binding to the Zika virus. As will be appreciated by a person of ordinary skill in the art, an antibody that competes for binding with a reference antibody may not necessarily
5 bind to the identical epitope as the reference antibody but may sterically block binding of the reference antibody by binding an overlapping or adjacent epitope.

Two antibodies bind to the same or overlapping epitope if each competitively inhibits (blocks) binding of the other to the antigen. That is, a 1-, 5-, 10-, 20- or 100-fold excess of one antibody inhibits binding of the other by at least 50% but preferably 75%, 90% or even 99%
10 as measured in a competitive binding assay (see, *e.g.*, Junghans *et al.*, Cancer Res. 1990 50:1495-1502). Alternatively, two antibodies have the same epitope if essentially all amino acid mutations in the antigen that reduce or eliminate binding of one antibody reduce or eliminate binding of the other. Two antibodies have overlapping epitopes if some amino acid mutations that reduce or eliminate binding of one antibody reduce or eliminate binding of the
15 other.

Additional routine experimentation (*e.g.*, peptide mutation and binding analyses) can then be carried out to confirm whether the observed lack of binding of the test antibody is in fact due to binding to the same epitope as the reference antibody or if steric blocking (or another phenomenon) is responsible for the lack of observed binding. Experiments of this sort can be
20 performed using ELISA, RIA, surface plasmon resonance, flow cytometry or any other quantitative or qualitative antibody-binding assay available in the art. Structural studies with EM or crystallography also can demonstrate whether or not two antibodies that compete for binding recognize the same epitope.

In another aspect, there are provided monoclonal antibodies having clone-paired CDRs
25 from the heavy and light chains as illustrated in Tables 3 and 4, respectively. Such antibodies may be produced by the clones discussed below in the Examples section using methods described herein.

In another aspect, the antibodies may be defined by their variable sequence, which include additional "framework" regions. These are provided in Tables 1 and 2 that encode or
30 represent full variable regions. Furthermore, the antibodies sequences may vary from these sequences, optionally using methods discussed in greater detail below. For example, nucleic acid sequences may vary from those set out above in that (a) the variable regions may be segregated away from the constant domains of the light and heavy chains, (b) the nucleic acids may vary from those set out above while not affecting the residues encoded thereby, (c) the

nucleic acids may vary from those set out above by a given percentage, *e.g.*, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% homology, (d) the nucleic acids may vary from those set out above by virtue of the ability to hybridize under high stringency conditions, as exemplified by low salt and/or high temperature conditions, such as provided by about 0.02 M to about 0.15 M NaCl at temperatures of about 50°C to about 70°C, (e) the amino acids may vary from those set out above by a given percentage, *e.g.*, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% homology, or (f) the amino acids may vary from those set out above by permitting conservative substitutions (discussed below). Each of the foregoing applies to the nucleic acid sequences set forth as Table 1 and the amino acid sequences of Table 2.

When comparing polynucleotide and polypeptide sequences, two sequences are said to be "identical" if the sequence of nucleotides or amino acids in the two sequences is the same when aligned for maximum correspondence, as described below. Comparisons between two sequences are typically performed by comparing the sequences over a comparison window to identify and compare local regions of sequence similarity. A "comparison window" as used herein, refers to a segment of at least about 20 contiguous positions, usually 30 to about 75, 40 to about 50, in which a sequence may be compared to a reference sequence of the same number of contiguous positions after the two sequences are optimally aligned.

Optimal alignment of sequences for comparison may be conducted using the Megalign program in the Lasergene suite of bioinformatics software (DNASTAR, Inc., Madison, Wis.), using default parameters. This program embodies several alignment schemes described in the following references: Dayhoff, M. O. (1978) A model of evolutionary change in proteins--Matrices for detecting distant relationships. In Dayhoff, M. O. (ed.) Atlas of Protein Sequence and Structure, National Biomedical Research Foundation, Washington D.C. Vol. 5, Suppl. 3, pp. 345-358; Hein J. (1990) Unified Approach to Alignment and Phylogeny pp. 626-645 Methods in Enzymology vol. 183, Academic Press, Inc., San Diego, Calif.; Higgins, D. G. and Sharp, P. M. (1989) CABIOS 5:151-153; Myers, E. W. and Muller W. (1988) CABIOS 4:11-17; Robinson, E. D. (1971) Comb. Theor 11:105; Santou, N. Nes, M. (1987) Mol. Biol. Evol. 4:406-425; Sneath, P. H. A. and Sokal, R. R. (1973) Numerical Taxonomy--the Principles and Practice of Numerical Taxonomy, Freeman Press, San Francisco, Calif.; Wilbur, W. J. and Lipman, D. J. (1983) Proc. Natl. Acad., Sci. USA 80:726-730.

Alternatively, optimal alignment of sequences for comparison may be conducted by the local identity algorithm of Smith and Waterman (1981) Add. APL. Math 2:482, by the identity alignment algorithm of Needleman and Wunsch (1970) J. Mol. Biol. 48:443, by the search for

similarity methods of Pearson and Lipman (1988) Proc. Natl. Acad. Sci. USA 85: 2444, by computerized implementations of these algorithms (GAP, BESTFIT, BLAST, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group (GCG), 575 Science Dr., Madison, Wis.), or by inspection.

5 One particular example of algorithms that are suitable for determining percent sequence identity and sequence similarity are the BLAST and BLAST 2.0 algorithms, which are described in Altschul *et al.* (1977) Nucl. Acids Res. 25:3389-3402 and Altschul *et al.* (1990) J. Mol. Biol. 215:403-410, respectively. BLAST and BLAST 2.0 can be used, for example, with the parameters described herein, to determine percent sequence identity for the polynucleotides and polypeptides of the disclosure. Software for performing BLAST analyses is publicly available through the National Center for Biotechnology Information. The rearranged nature of an antibody sequence and the variable length of each gene requires multiple rounds of BLAST searches for a single antibody sequence. Also, manual assembly of different genes is difficult and error-prone. The sequence analysis tool IgBLAST (world-wide-web at
10 ncbi.nlm.nih.gov/igblast/) identifies matches to the germline V, D and J genes, details at rearrangement junctions, the delineation of Ig V domain framework regions and complementarity determining regions. IgBLAST can analyze nucleotide or protein sequences and can process sequences in batches and allows searches against the germline gene databases and other sequence databases simultaneously to minimize the chance of missing possibly the
15 best matching germline V gene.
20 In one illustrative example, cumulative scores can be calculated using, for nucleotide sequences, the parameters M (reward score for a pair of matching residues; always >0) and N (penalty score for mismatching residues; always <0). Extension of the word hits in each direction are halted when: the cumulative alignment score falls off by the quantity X from its
25 maximum achieved value; the cumulative score goes to zero or below, due to the accumulation of one or more negative-scoring residue alignments; or the end of either sequence is reached. The BLAST algorithm parameters W, T and X determine the sensitivity and speed of the alignment. The BLASTN program (for nucleotide sequences) uses as defaults a wordlength (W) of 11, and expectation (E) of 10, and the BLOSUM62 scoring matrix (see Henikoff and
30 Henikoff (1989) Proc. Natl. Acad. Sci. USA 89:10915) alignments, (B) of 50, expectation (E) of 10, M=5, N=-4 and a comparison of both strands.

For amino acid sequences, a scoring matrix can be used to calculate the cumulative score. Extension of the word hits in each direction are halted when: the cumulative alignment score falls off by the quantity X from its maximum achieved value; the cumulative score goes

to zero or below, due to the accumulation of one or more negative-scoring residue alignments; or the end of either sequence is reached. The BLAST algorithm parameters W, T and X determine the sensitivity and speed of the alignment.

In one approach, the "percentage of sequence identity" is determined by comparing two
5 optimally aligned sequences over a window of comparison of at least 20 positions, wherein the portion of the polynucleotide or polypeptide sequence in the comparison window may comprise additions or deletions (*i.e.*, gaps) of 20 percent or less, usually 5 to 15 percent, or 10 to 12 percent, as compared to the reference sequences (which does not comprise additions or deletions) for optimal alignment of the two sequences. The percentage is calculated by
10 determining the number of positions at which the identical nucleic acid bases or amino acid residues occur in both sequences to yield the number of matched positions, dividing the number of matched positions by the total number of positions in the reference sequence (*i.e.*, the window size) and multiplying the results by 100 to yield the percentage of sequence identity.

Yet another way of defining an antibody is as a "derivative" of any of the below-
15 described antibodies and their antigen-binding fragments. The term "derivative" refers to an antibody or antigen-binding fragment thereof that immunospecifically binds to an antigen but which comprises, one, two, three, four, five or more amino acid substitutions, additions, deletions or modifications relative to a "parental" (or wild-type) molecule. Such amino acid substitutions or additions may introduce naturally occurring (*i.e.*, DNA-encoded) or non-
20 naturally occurring amino acid residues. The term "derivative" encompasses, for example, as variants having altered CH1, hinge, CH2, CH3 or CH4 regions, so as to form, for example, antibodies, *etc.*, having variant Fc regions that exhibit enhanced or impaired effector or binding characteristics. The term "derivative" additionally encompasses non-amino acid modifications, for example, amino acids that may be glycosylated (*e.g.*, have altered mannose, 2-N-acetylglucosamine, galactose, fucose, glucose, sialic acid, 5-N-acetylneuraminic acid, 5-
25 glycolneuraminic acid, *etc.* content), acetylated, pegylated, phosphorylated, amidated, derivatized by known protecting/blocking groups, proteolytic cleavage, linked to a cellular ligand or other protein, *etc.* In some embodiments, the altered carbohydrate modifications modulate one or more of the following: solubilization of the antibody, facilitation of subcellular
30 transport and secretion of the antibody, promotion of antibody assembly, conformational integrity, and antibody-mediated effector function. In a specific embodiment, the altered carbohydrate modifications enhance antibody mediated effector function relative to the antibody lacking the carbohydrate modification. Carbohydrate modifications that lead to altered antibody mediated effector function are well known in the art (for example, see Shields,

R. L. *et al.* (2002), *J. Biol. Chem.* 277(30): 26733-26740; Davies J. *et al.* (2001), *Biotechnology & Bioengineering* 74(4): 288-294). Methods of altering carbohydrate contents are known to those skilled in the art, see, *e.g.*, Wallick, S. C. *et al.* (1988), *J. Exp. Med.* 168(3): 1099-1109; Tao, M. H. *et al.* (1989), *J. Immunol.* 143(8): 2595-2601; Routledge, E. G. *et al.* (1995),
5 Transplantation 60(8):847-53; Elliott, S. *et al.* (2003), *Nature Biotechnol.* 21:414-21; Shields, R. L. *et al.* (2002), *J. Biol. Chem.* 277(30): 26733-26740).

A derivative antibody or antibody fragment can be generated with an engineered sequence or glycosylation state to confer preferred levels of activity in antibody dependent cellular cytotoxicity (ADCC), antibody-dependent cellular phagocytosis (ADCP), antibody-
10 dependent neutrophil phagocytosis (ADNP), or antibody-dependent complement deposition (ADCD) functions as measured by bead-based or cell-based assays or *in vivo* studies in animal models.

A derivative antibody or antibody fragment may be modified by chemical modifications using techniques known to those of skill in the art, including, but not limited to, specific
15 chemical cleavage, acetylation, formulation, metabolic synthesis of tunicamycin, *etc.* In one embodiment, an antibody derivative will possess a similar or identical function as the parental antibody. In another embodiment, an antibody derivative will exhibit an altered activity relative to the parental antibody. For example, a derivative antibody (or fragment thereof) can bind to its epitope more tightly or be more resistant to proteolysis than the parental antibody.

20

C. Engineering of Antibody Sequences

In various embodiments, one may choose to engineer sequences of the identified antibodies for a variety of reasons, such as improved expression, improved cross-reactivity or diminished off-target binding. Modified antibodies may be made by any technique known to
25 those of skill in the art, including expression through standard molecular biological techniques, or the chemical synthesis of polypeptides. Methods for recombinant expression are addressed elsewhere in this document. The following is a general discussion of relevant goals techniques for antibody engineering.

Hybridomas may be cultured, then cells lysed, and total RNA extracted. Random
30 hexamers may be used with RT to generate cDNA copies of RNA, and then PCR performed using a multiplex mixture of PCR primers expected to amplify all human variable gene sequences. PCR product can be cloned into pGEM-T Easy vector, then sequenced by automated DNA sequencing using standard vector primers. Assay of binding and neutralization

may be performed using antibodies collected from hybridoma supernatants and purified by FPLC, using Protein G columns.

Recombinant full-length IgG antibodies can be generated by subcloning heavy and light chain Fv DNAs from the cloning vector into an IgG plasmid vector, transfected into 293 (*e.g.*, Freestyle) cells or CHO cells, and antibodies can be collected and purified from the 293 or CHO cell supernatant. Other appropriate host cells systems include bacteria, such as *E. coli*, insect cells (S2, Sf9, Sf29, High Five), plant cells (*e.g.*, tobacco, with or without engineering for human-like glycans), algae, or in a variety of non-human transgenic contexts, such as mice, rats, goats or cows.

Expression of nucleic acids encoding antibodies, both for the purpose of subsequent antibody purification, and for immunization of a host, is also contemplated. Antibody coding sequences can be RNA, such as native RNA or modified RNA. Modified RNA contemplates certain chemical modifications that confer increased stability and low immunogenicity to mRNAs, thereby facilitating expression of therapeutically important proteins. For instance, N1-methyl-pseudouridine (N1m Ψ) outperforms several other nucleoside modifications and their combinations in terms of translation capacity. In addition to turning off the immune/eIF2 α phosphorylation-dependent inhibition of translation, incorporated N1m Ψ nucleotides dramatically alter the dynamics of the translation process by increasing ribosome pausing and density on the mRNA. Increased ribosome loading of modified mRNAs renders them more permissive for initiation by favoring either ribosome recycling on the same mRNA or de novo ribosome recruitment. Such modifications could be used to enhance antibody expression *in vivo* following inoculation with RNA. The RNA, whether native or modified, may be delivered as naked RNA or in a delivery vehicle, such as a lipid nanoparticle.

Alternatively, DNA encoding the antibody may be employed for the same purposes. The DNA is included in an expression cassette comprising a promoter active in the host cell for which it is designed. The expression cassette is advantageously included in a replicable vector, such as a conventional plasmid or minivector. Vectors include viral vectors, such as poxviruses, adenoviruses, herpesviruses, adeno-associated viruses, and lentiviruses are contemplated. Replicons encoding antibody genes such as alphavirus replicons based on VEE virus or Sindbis virus are also contemplated. Delivery of such vectors can be performed by needle through intramuscular, subcutaneous, or intradermal routes, or by transcutaneous electroporation when *in vivo* expression is desired.

The rapid availability of antibody produced in the same host cell and cell culture process as the final cGMP manufacturing process has the potential to reduce the duration of

process development programs. Lonza has developed a generic method using pooled transfectants grown in CDACF medium, for the rapid production of small quantities (up to 50 g) of antibodies in CHO cells. Although slightly slower than a true transient system, the advantages include a higher product concentration and use of the same host and process as the production cell line. Example of growth and productivity of GS-CHO pools, expressing a model antibody, in a disposable bioreactor: in a disposable bag bioreactor culture (5 L working volume) operated in fed-batch mode, a harvest antibody concentration of 2 g/L was achieved within 9 weeks of transfection.

Antibody molecules will comprise fragments (such as $F(ab')$, $F(ab')_2$) that are produced, for example, by the proteolytic cleavage of the mAbs, or single-chain immunoglobulins producible, for example, via recombinant means. $F(ab')$ antibody derivatives are monovalent, while $F(ab')_2$ antibody derivatives are bivalent. In one embodiment, such fragments can be combined with one another, or with other antibody fragments or receptor ligands to form “chimeric” binding molecules. Significantly, such chimeric molecules may contain substituents capable of binding to different epitopes of the same molecule.

In related embodiments, the antibody is a derivative of the disclosed antibodies, *e.g.*, an antibody comprising the CDR sequences identical to those in the disclosed antibodies (*e.g.*, a chimeric, or CDR-grafted antibody). Alternatively, one may wish to make modifications, such as introducing conservative changes into an antibody molecule. In making such changes, the hydropathic index of amino acids may be considered. The importance of the hydropathic amino acid index in conferring interactive biologic function on a protein is generally understood in the art (Kyte and Doolittle, 1982). It is accepted that the relative hydropathic character of the amino acid contributes to the secondary structure of the resultant protein, which in turn defines the interaction of the protein with other molecules, for example, enzymes, substrates, receptors, DNA, antibodies, antigens, and the like.

It also is understood in the art that the substitution of like amino acids can be made effectively on the basis of hydrophilicity. U.S. Patent 4,554,101, incorporated herein by reference, states that the greatest local average hydrophilicity of a protein, as governed by the hydrophilicity of its adjacent amino acids, correlates with a biological property of the protein. As detailed in U.S. Patent 4,554,101, the following hydrophilicity values have been assigned to amino acid residues: basic amino acids: arginine (+3.0), lysine (+3.0), and histidine (-0.5); acidic amino acids: aspartate (+3.0 $\pm$ 1), glutamate (+3.0 $\pm$ 1), asparagine (+0.2), and glutamine (+0.2); hydrophilic, nonionic amino acids: serine (+0.3), asparagine (+0.2), glutamine (+0.2),

and threonine (-0.4), sulfur containing amino acids: cysteine (-1.0) and methionine (-1.3); hydrophobic, nonaromatic amino acids: valine (-1.5), leucine (-1.8), isoleucine (-1.8), proline (-0.5 $\pm$ 1), alanine (-0.5), and glycine (0); hydrophobic, aromatic amino acids: tryptophan (-3.4), phenylalanine (-2.5), and tyrosine (-2.3).

5 It is understood that an amino acid can be substituted for another having a similar hydrophilicity and produce a biologically or immunologically modified protein. In such changes, the substitution of amino acids whose hydrophilicity values are within ± 2 is preferred, those that are within ± 1 are particularly preferred, and those within ± 0.5 are even more particularly preferred.

10 As outlined above, amino acid substitutions generally are based on the relative similarity of the amino acid side-chain substituents, for example, their hydrophobicity, hydrophilicity, charge, size, and the like. Exemplary substitutions that take into consideration the various foregoing characteristics are well known to those of skill in the art and include: arginine and lysine; glutamate and aspartate; serine and threonine; glutamine and asparagine;
15 and valine, leucine and isoleucine.

 The present disclosure also contemplates isotype modification. By modifying the Fc region to have a different isotype, different functionalities can be achieved. For example, changing to IgG₁ can increase antibody dependent cell cytotoxicity, switching to class A can improve tissue distribution, and switching to class M can improve valency.

20 Alternatively or additionally, it may be useful to combine amino acid modifications with one or more further amino acid modifications that alter C1q binding and/or the complement dependent cytotoxicity (CDC) function of the Fc region of an IL-23p19 binding molecule. The binding polypeptide of particular interest may be one that binds to C1q and displays complement dependent cytotoxicity. Polypeptides with pre-existing C1q binding
25 activity, optionally further having the ability to mediate CDC may be modified such that one or both of these activities are enhanced. Amino acid modifications that alter C1q and/or modify its complement dependent cytotoxicity function are described, for example, in WO/0042072, which is hereby incorporated by reference.

 One can design an Fc region of an antibody with altered effector function, *e.g.*, by
30 modifying C1q binding and/or Fc γ R binding and thereby changing CDC activity and/or ADCC activity. "Effector functions" are responsible for activating or diminishing a biological activity (*e.g.*, in a subject). Examples of effector functions include, but are not limited to: C1q binding; complement dependent cytotoxicity (CDC); Fc receptor binding; antibody-dependent cell-mediated cytotoxicity (ADCC); phagocytosis; down regulation of cell surface receptors (*e.g.*,

B cell receptor; BCR), *etc.* Such effector functions may require the Fc region to be combined with a binding domain (*e.g.*, an antibody variable domain) and can be assessed using various assays (*e.g.*, Fc binding assays, ADCC assays, CDC assays, *etc.*).

For example, one can generate a variant Fc region of an antibody with improved C1q
5 binding and improved FcγRIII binding (*e.g.*, having both improved ADCC activity and improved CDC activity). Alternatively, if it is desired that effector function be reduced or ablated, a variant Fc region can be engineered with reduced CDC activity and/or reduced ADCC activity. In other embodiments, only one of these activities may be increased, and, optionally, also the other activity reduced (*e.g.*, to generate an Fc region variant with improved
10 ADCC activity, but reduced CDC activity and *vice versa*).

FcRn binding. Fc mutations can also be introduced and engineered to alter their interaction with the neonatal Fc receptor (FcRn) and improve their pharmacokinetic properties. A collection of human Fc variants with improved binding to the FcRn have been described (Shields *et al.*, (2001). High resolution mapping of the binding site on human IgG1 for FcγRI,
15 FcγRII, FcγRIII, and FcRn and design of IgG1 variants with improved binding to the FcγR, (J. Biol. Chem. 276:6591-6604). A number of methods are known that can result in increased half-life (Kuo and Aveson, (2011)), including amino acid modifications may be generated through techniques including alanine scanning mutagenesis, random mutagenesis and screening to assess the binding to the neonatal Fc receptor (FcRn) and/or the *in vivo* behavior.
20 Computational strategies followed by mutagenesis may also be used to select one of amino acid mutations to mutate.

The present disclosure therefore provides a variant of an antigen binding protein with optimized binding to FcRn. In a particular embodiment, the said variant of an antigen binding protein comprises at least one amino acid modification in the Fc region of said antigen binding
25 protein, wherein said modification is selected from the group consisting of 226, 227, 228, 230, 231, 233, 234, 239, 241, 243, 246, 250, 252, 256, 259, 264, 265, 267, 269, 270, 276, 284, 285, 288, 289, 290, 291, 292, 294, 297, 298, 299, 301, 302, 303, 305, 307, 308, 309, 311, 315, 317, 320, 322, 325, 327, 330, 332, 334, 335, 338, 340, 342, 343, 345, 347, 350, 352, 354, 355, 356, 359, 360, 361, 362, 369, 370, 371, 375, 378, 380, 382, 384, 385, 386, 387, 389, 390, 392, 393,
30 394, 395, 396, 397, 398, 399, 400, 401 403, 404, 408, 411, 412, 414, 415, 416, 418, 419, 420, 421, 422, 424, 426, 428, 433, 434, 438, 439, 440, 443, 444, 445, 446 and 447 of the Fc region as compared to said parent polypeptide, wherein the numbering of the amino acids in the Fc region is that of the EU index in Kabat. In a further aspect of the disclosure the modifications are M252Y/S254T/T256E.

Additionally, various publications describe methods for obtaining physiologically active molecules whose half-lives are modified, see for example Kontermann (2009) either by introducing an FcRn-binding polypeptide into the molecules or by fusing the molecules with antibodies whose FcRn-binding affinities are preserved but affinities for other Fc receptors have been greatly reduced or fusing with FcRn binding domains of antibodies.

Derivatized antibodies may be used to alter the half-lives (*e.g.*, serum half-lives) of parental antibodies in a mammal, particularly a human. Such alterations may result in a half-life of greater than 15 days, preferably greater than 20 days, greater than 25 days, greater than 30 days, greater than 35 days, greater than 40 days, greater than 45 days, greater than 2 months, greater than 3 months, greater than 4 months, or greater than 5 months. The increased half-lives of the antibodies of the present disclosure or fragments thereof in a mammal, preferably a human, results in a higher serum titer of said antibodies or antibody fragments in the mammal, and thus reduces the frequency of the administration of said antibodies or antibody fragments and/or reduces the concentration of said antibodies or antibody fragments to be administered. Antibodies or fragments thereof having increased *in vivo* half-lives can be generated by techniques known to those of skill in the art. For example, antibodies or fragments thereof with increased *in vivo* half-lives can be generated by modifying (*e.g.*, substituting, deleting or adding) amino acid residues identified as involved in the interaction between the Fc domain and the FcRn receptor.

Beltramello *et al.* (2010) previously reported the modification of neutralizing mAbs, due to their tendency to enhance dengue virus infection, by generating in which leucine residues at positions 1.3 and 1.2 of CH2 domain (according to the IMGT unique numbering for C-domain) were substituted with alanine residues. This modification, also known as "LALA" mutation, abolishes antibody binding to FcγRI, FcγRII and FcγRIIIa, as described by Hessel *et al.* (2007). The variant and unmodified recombinant mAbs were compared for their capacity to neutralize and enhance infection by the four dengue virus serotypes. LALA variants retained the same neutralizing activity as unmodified mAb but were completely devoid of enhancing activity. LALA mutations of this nature are therefore contemplated in the context of the presently disclosed antibodies.

Altered Glycosylation. A particular embodiment of the present disclosure is an isolated monoclonal antibody, or antigen binding fragment thereof, containing a substantially homogeneous glycan without sialic acid, galactose, or fucose. The monoclonal antibody comprises a heavy chain variable region and a light chain variable region, both of which may be attached to heavy chain or light chain constant regions respectively. The aforementioned

substantially homogeneous glycan may be covalently attached to the heavy chain constant region.

Another embodiment of the present disclosure comprises a mAb with a novel Fc glycosylation pattern. The isolated monoclonal antibody, or antigen binding fragment thereof, is present in a substantially homogenous composition represented by the GNGN or G1/G2 glycoform. Fc glycosylation plays a significant role in anti-viral and anti-cancer properties of therapeutic mAbs. The disclosure is in line with a recent study that shows increased anti-lentivirus cell-mediated viral inhibition of a fucose free anti-HIV mAb *in vitro*. This embodiment of the present disclosure with homogenous glycans lacking a core fucose, showed increased protection against specific viruses by a factor greater than two-fold. Elimination of core fucose dramatically improves the ADCC activity of mAbs mediated by natural killer (NK) cells but appears to have the opposite effect on the ADCC activity of polymorphonuclear cells (PMNs).

The isolated monoclonal antibody, or antigen binding fragment thereof, comprising a substantially homogenous composition represented by the GNGN or G1/G2 glycoform exhibits increased binding affinity for Fc gamma RI and Fc gamma RIII compared to the same antibody without the substantially homogeneous GNGN glycoform and with G0, G1F, G2F, GNF, GNGNF or GNGNFX containing glycoforms. In one embodiment of the present disclosure, the antibody dissociates from Fc gamma RI with a K_d of 1×10^{-8} M or less and from Fc gamma RIII with a K_d of 1×10^{-7} M or less.

Glycosylation of an Fc region is typically either N-linked or O-linked. N-linked refers to the attachment of the carbohydrate moiety to the side chain of an asparagine residue. O-linked glycosylation refers to the attachment of one of the sugars N-acetylgalactosamine, galactose, or xylose to a hydroxyamino acid, most commonly serine or threonine, although 5-hydroxyproline or 5-hydroxylysine may also be used. The recognition sequences for enzymatic attachment of the carbohydrate moiety to the asparagine side chain peptide sequences are asparagine-X-serine and asparagine-X-threonine, where X is any amino acid except proline. Thus, the presence of either of these peptide sequences in a polypeptide creates a potential glycosylation site.

The glycosylation pattern may be altered, for example, by deleting one or more glycosylation site(s) found in the polypeptide, and/or adding one or more glycosylation site(s) that are not present in the polypeptide. Addition of glycosylation sites to the Fc region of an antibody is conveniently accomplished by altering the amino acid sequence such that it contains one or more of the above-described tripeptide sequences (for N-linked glycosylation sites). An

exemplary glycosylation variant has an amino acid substitution of residue Asn 297 of the heavy chain. The alteration may also be made by the addition of, or substitution by, one or more serine or threonine residues to the sequence of the original polypeptide (for O-linked glycosylation sites). Additionally, a change of Asn 297 to Ala can remove one of the glycosylation sites.

5 In certain embodiments, the antibody is expressed in cells that express beta (1,4)-N-acetylglucosaminyltransferase III (GnT III), such that GnT III adds GlcNAc to the IL-23p19 antibody. Methods for producing antibodies in such a fashion are provided in WO/9954342, WO/03011878, patent publication 20030003097A1, and Umana *et al.*, Nature Biotechnology, 17:176-180, February 1999. Cell lines can be altered to enhance or reduce or eliminate certain
10 post-translational modifications, such as glycosylation, using genome editing technology such as Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR). For example, CRISPR technology can be used to eliminate genes encoding glycosylating enzymes in 293 or CHO cells used to express recombinant monoclonal antibodies.

Elimination of monoclonal antibody protein sequence liabilities. It is possible to
15 engineer the antibody variable gene sequences obtained from human B cells to enhance their manufacturability and safety. Potential protein sequence liabilities can be identified by searching for sequence motifs associated with sites containing:

- 1) Unpaired Cys residues,
- 2) N-linked glycosylation,
- 20 3) Asn deamidation,
- 4) Asp isomerization,
- 5) SYE truncation,
- 6) Met oxidation,
- 7) Trp oxidation,
- 25 8) N-terminal glutamate,
- 9) Integrin binding,
- 10) CD11c/CD18 binding, or
- 11) Fragmentation

Such motifs can be eliminated by altering the synthetic gene for the cDNA encoding
30 recombinant antibodies.

Protein engineering efforts in the field of development of therapeutic antibodies clearly reveal that certain sequences or residues are associated with solubility differences (Fernandez-Escamilla *et al.*, *Nature Biotech.*, 22 (10), 1302-1306, 2004; Chennamsetty *et al.*, *PNAS*, 106 (29), 11937-11942, 2009; Voynov *et al.*, *Biocon. Chem.*, 21 (2), 385-392, 2010) Evidence from

solubility-altering mutations in the literature indicate that some hydrophilic residues such as aspartic acid, glutamic acid, and serine contribute significantly more favorably to protein solubility than other hydrophilic residues, such as asparagine, glutamine, threonine, lysine, and arginine.

5 **Stability.** Antibodies can be engineered for enhanced biophysical properties. One can use elevated temperature to unfold antibodies to determine relative stability, using average apparent melting temperatures. Differential Scanning Calorimetry (DSC) measures the heat capacity, C_p , of a molecule (the heat required to warm it, per degree) as a function of temperature. One can use DSC to study the thermal stability of antibodies. DSC data for mAbs
10 is particularly interesting because it sometimes resolves the unfolding of individual domains within the mAb structure, producing up to three peaks in the thermogram (from unfolding of the Fab, C_H2 , and C_H3 domains). Typically unfolding of the Fab domain produces the strongest peak. The DSC profiles and relative stability of the Fc portion show characteristic differences for the human IgG₁, IgG₂, IgG₃, and IgG₄ subclasses (Garber and Demarest, *Biochem. Biophys.*
15 *Res. Commun.* 355, 751-757, 2007). One also can determine average apparent melting temperature using circular dichroism (CD), performed with a CD spectrometer. Far-UV CD spectra will be measured for antibodies in the range of 200 to 260 nm at increments of 0.5 nm. The final spectra can be determined as averages of 20 accumulations. Residue ellipticity values can be calculated after background subtraction. Thermal unfolding of antibodies (0.1 mg/mL)
20 can be monitored at 235 nm from 25-95 °C and a heating rate of 1 °C/min. One can use dynamic light scattering (DLS) to assess for propensity for aggregation. DLS is used to characterize size of various particles including proteins. If the system is not disperse in size, the mean effective diameter of the particles can be determined. This measurement depends on the size of the particle core, the size of surface structures, and particle concentration. Since DLS essentially
25 measures fluctuations in scattered light intensity due to particles, the diffusion coefficient of the particles can be determined. DLS software in commercial DLA instruments displays the particle population at different diameters. Stability studies can be done conveniently using DLS. DLS measurements of a sample can show whether the particles aggregate over time or with temperature variation by determining whether the hydrodynamic radius of the particle
30 increases. If particles aggregate, one can see a larger population of particles with a larger radius. Stability depending on temperature can be analyzed by controlling the temperature *in situ*. Capillary electrophoresis (CE) techniques include proven methodologies for determining features of antibody stability. One can use an iCE approach to resolve antibody protein charge variants due to deamidation, C-terminal lysines, sialylation, oxidation, glycosylation, and any

other change to the protein that can result in a change in pI of the protein. Each of the expressed antibody proteins can be evaluated by high throughput, free solution isoelectric focusing (IEF) in a capillary column (cIEF), using a Protein Simple Maurice instrument. Whole-column UV absorption detection can be performed every 30 seconds for real time monitoring of molecules focusing at the isoelectric points (pIs). This approach combines the high resolution of traditional gel IEF with the advantages of quantitation and automation found in column-based separations while eliminating the need for a mobilization step. The technique yields reproducible, quantitative analysis of identity, purity, and heterogeneity profiles for the expressed antibodies. The results identify charge heterogeneity and molecular sizing on the antibodies, with both absorbance and native fluorescence detection modes and with sensitivity of detection down to 0.7 µg/mL.

Solubility. One can determine the intrinsic solubility score of antibody sequences. The intrinsic solubility scores can be calculated using CamSol Intrinsic (Sormanni *et al.*, *J Mol Biol* 427, 478-490, 2015). The amino acid sequences for residues 95-102 (Kabat numbering) in HCDR3 of each antibody fragment such as a scFv can be evaluated via the online program to calculate the solubility scores. One also can determine solubility using laboratory techniques. Various techniques exist, including addition of lyophilized protein to a solution until the solution becomes saturated and the solubility limit is reached, or concentration by ultrafiltration in a microconcentrator with a suitable molecular weight cut-off. The most straightforward method is induction of amorphous precipitation, which measures protein solubility using a method involving protein precipitation using ammonium sulfate (Trevino *et al.*, *J Mol Biol*, 366: 449-460, 2007). Ammonium sulfate precipitation gives quick and accurate information on relative solubility values. Ammonium sulfate precipitation produces precipitated solutions with well-defined aqueous and solid phases and requires relatively small amounts of protein. Solubility measurements performed using induction of amorphous precipitation by ammonium sulfate also can be done easily at different pH values. Protein solubility is highly pH dependent, and pH is considered the most important extrinsic factor that affects solubility.

Autoreactivity. Generally, it is thought that autoreactive clones should be eliminated during ontogeny by negative selection, however it has become clear that many human naturally occurring antibodies with autoreactive properties persist in adult mature repertoires, and the autoreactivity may enhance the antiviral function of many antibodies to pathogens. It has been noted that HCDR3 loops in antibodies during early B cell development are often rich in positive charge and exhibit autoreactive patterns (Wardemann *et al.*, *Science* 301, 1374-1377, 2003).

One can test a given antibody for autoreactivity by assessing the level of binding to human origin cells in microscopy (using adherent HeLa or HEp-2 epithelial cells) and flow cytometric cell surface staining (using suspension Jurkat T cells and 293S human embryonic kidney cells). Autoreactivity also can be surveyed using assessment of binding to tissues in tissue arrays.

5 **Preferred residues (“Human Likeness”).** B cell repertoire deep sequencing of human B cells from blood donors is being performed on a wide scale in many recent studies. Sequence information about a significant portion of the human antibody repertoire facilitates statistical assessment of antibody sequence features common in healthy humans. With knowledge about the antibody sequence features in a human recombined antibody variable gene reference
10 database, the position specific degree of “Human Likeness” (HL) of an antibody sequence can be estimated. HL has been shown to be useful for the development of antibodies in clinical use, like therapeutic antibodies or antibodies as vaccines. The goal is to increase the human likeness of antibodies to reduce potential adverse effects and anti-antibody immune responses that will lead to significantly decreased efficacy of the antibody drug or can induce serious health
15 implications. One can assess antibody characteristics of the combined antibody repertoire of three healthy human blood donors of about 400 million sequences in total and created a novel “relative Human Likeness” (rHL) score that focuses on the hypervariable region of the antibody. The rHL score allows one to easily distinguish between human (positive score) and non-human sequences (negative score). Antibodies can be engineered to eliminate residues that are not
20 common in human repertoires.

D. Single Chain Antibodies

A single chain variable fragment (scFv) is a fusion of the variable regions of the heavy and light chains of immunoglobulins, linked together with a short (usually serine, glycine)
25 linker. This chimeric molecule retains the specificity of the original immunoglobulin, despite removal of the constant regions and the introduction of a linker peptide. This modification usually leaves the specificity unaltered. These molecules were created historically to facilitate phage display where it is highly convenient to express the antigen binding domain as a single peptide. Alternatively, scFv can be created directly from subcloned heavy and light chains
30 derived from a hybridoma or B cell. Single chain variable fragments lack the constant Fc region found in complete antibody molecules, and thus, the common binding sites (*e.g.*, protein A/G) used to purify antibodies. These fragments can often be purified/immobilized using Protein L since Protein L interacts with the variable region of kappa light chains.

Flexible linkers generally are comprised of helix- and turn-promoting amino acid residues such as alanine, serine and glycine. However, other residues can function as well. Tang *et al.* (1996) used phage display as a means of rapidly selecting tailored linkers for single-chain antibodies (scFvs) from protein linker libraries. A random linker library was constructed in which the genes for the heavy and light chain variable domains were linked by a segment encoding an 18-amino acid polypeptide of variable composition. The scFv repertoire (approx. 5×10^6 different members) was displayed on filamentous phage and subjected to affinity selection with hapten. The population of selected variants exhibited significant increases in binding activity but retained considerable sequence diversity. Screening 1054 individual variants subsequently yielded a catalytically active scFv that was produced efficiently in soluble form. Sequence analysis revealed a conserved proline in the linker two residues after the V_H C terminus and an abundance of arginines and prolines at other positions as the only common features of the selected tethers.

The recombinant antibodies of the present disclosure may also involve sequences or moieties that permit dimerization or multimerization of the receptors. Such sequences include those derived from IgA, which permit formation of multimers in conjunction with the J-chain. Another multimerization domain is the Gal4 dimerization domain. In other embodiments, the chains may be modified with agents such as biotin/avidin, which permit the combination of two antibodies.

In a separate embodiment, a single-chain antibody can be created by joining receptor light and heavy chains using a non-peptide linker or chemical unit. Generally, the light and heavy chains will be produced in distinct cells, purified, and subsequently linked together in an appropriate fashion (*i.e.*, the N-terminus of the heavy chain being attached to the C-terminus of the light chain via an appropriate chemical bridge).

Cross-linking reagents are used to form molecular bridges that tie functional groups of two different molecules, *e.g.*, a stabilizing and coagulating agent. However, it is contemplated that dimers or multimers of the same analog or heteromeric complexes comprised of different analogs can be created. To link two different compounds in a step-wise manner, hetero-bifunctional cross-linkers can be used that eliminate unwanted homopolymer formation.

An exemplary hetero-bifunctional cross-linker contains two reactive groups: one reacting with primary amine group (*e.g.*, N-hydroxy succinimide) and the other reacting with a thiol group (*e.g.*, pyridyl disulfide, maleimides, halogens, *etc.*). Through the primary amine reactive group, the cross-linker may react with the lysine residue(s) of one protein (*e.g.*, the selected antibody or fragment) and through the thiol reactive group, the cross-linker, already

5 tied up to the first protein, reacts with the cysteine residue (free sulfhydryl group) of the other protein (*e.g.*, the selective agent).

It is preferred that a cross-linker having reasonable stability in blood will be employed. Numerous types of disulfide-bond containing linkers are known that can be successfully
5 employed to conjugate targeting and therapeutic/preventative agents. Linkers that contain a disulfide bond that is sterically hindered may prove to give greater stability *in vivo*, preventing release of the targeting peptide prior to reaching the site of action. These linkers are thus one group of linking agents.

Another cross-linking reagent is SMPT, which is a bifunctional cross-linker containing
10 a disulfide bond that is “sterically hindered” by an adjacent benzene ring and methyl groups. It is believed that steric hindrance of the disulfide bond serves a function of protecting the bond from attack by thiolate anions such as glutathione which can be present in tissues and blood, and thereby help in preventing decoupling of the conjugate prior to the delivery of the attached agent to the target site.

15 The SMPT cross-linking reagent, as with many other known cross-linking reagents, lends the ability to cross-link functional groups such as the SH of cysteine or primary amines (*e.g.*, the epsilon amino group of lysine). Another possible type of cross-linker includes the hetero-bifunctional photoreactive phenylazides containing a cleavable disulfide bond such as sulfosuccinimidyl-2-(p-azido salicylamido) ethyl-1,3'-dithiopropionate. The N-hydroxy-
20 succinimidyl group reacts with primary amino groups and the phenylazide (upon photolysis) reacts non-selectively with any amino acid residue.

In addition to hindered cross-linkers, non-hindered linkers also can be employed in accordance herewith. Other useful cross-linkers, not considered to contain or generate a
25 protected disulfide, include SATA, SPDP and 2-iminothiolane (Wawrzynczak & Thorpe, 1987). The use of such cross-linkers is well understood in the art. Another embodiment involves the use of flexible linkers.

U.S. Patent 4,680,338, describes bifunctional linkers useful for producing conjugates of ligands with amine-containing polymers and/or proteins, especially for forming antibody
30 conjugates with chelators, drugs, enzymes, detectable labels and the like. U.S. Patents 5,141,648 and 5,563,250 disclose cleavable conjugates containing a labile bond that is cleavable under a variety of mild conditions. This linker is particularly useful in that the agent of interest may be bonded directly to the linker, with cleavage resulting in release of the active

agent. Particular uses include adding a free amino or free sulfhydryl group to a protein, such as an antibody, or a drug.

U.S. Patent 5,856,456 provides peptide linkers for use in connecting polypeptide constituents to make fusion proteins, *e.g.*, single chain antibodies. The linker is up to about 50 amino acids in length, contains at least one occurrence of a charged amino acid (preferably arginine or lysine) followed by a proline, and is characterized by greater stability and reduced aggregation. U.S. Patent 5,880,270 discloses aminooxy-containing linkers useful in a variety of immunodiagnostic and separative techniques.

E. Multispecific Antibodies

In certain embodiments, antibodies of the present disclosure are bispecific or multispecific. Bispecific antibodies are antibodies that have binding specificities for at least two different epitopes. Exemplary bispecific antibodies may bind to two different epitopes of a single antigen. Other such antibodies may combine a first antigen binding site with a binding site for a second antigen. Alternatively, an anti-pathogen arm may be combined with an arm that binds to a triggering molecule on a leukocyte, such as a T-cell receptor molecule (*e.g.*, CD3), or Fc receptors for IgG (FcγR), such as FcγRI (CD64), FcγRII (CD32) and Fc gamma RIII (CD16), so as to focus and localize cellular defense mechanisms to the infected cell. Bispecific antibodies may also be used to localize cytotoxic agents to infected cells. These antibodies possess a pathogen-binding arm and an arm that binds the cytotoxic agent (*e.g.*, saporin, anti-interferon-α, vinca alkaloid, ricin A chain, methotrexate or radioactive isotope hapten). Bispecific antibodies can be prepared as full-length antibodies or antibody fragments (*e.g.*, F(ab')₂ bispecific antibodies). WO 96/16673 describes a bispecific anti-ErbB2/anti-Fc gamma RIII antibody and U.S. Patent 5,837,234 discloses a bispecific anti-ErbB2/anti-Fc gamma RI antibody. A bispecific anti-ErbB2/Fc alpha antibody is shown in WO98/02463. U.S. Patent 5,821,337 teaches a bispecific anti-ErbB2/anti-CD3 antibody.

Methods for making bispecific antibodies are known in the art. Traditional production of full-length bispecific antibodies is based on the co-expression of two immunoglobulin heavy chain-light chain pairs, where the two chains have different specificities (Millstein *et al.*, Nature, 305:537-539 (1983)). Because of the random assortment of immunoglobulin heavy and light chains, these hybridomas (quadromas) produce a potential mixture of ten different antibody molecules, of which only one has the correct bispecific structure. Purification of the correct molecule, which is usually done by affinity chromatography steps, is rather

cumbersome, and the product yields are low. Similar procedures are disclosed in WO 93/08829, and in Traunecker *et al.*, EMBO J., 10:3655-3659 (1991).

According to a different approach, antibody variable regions with the desired binding specificities (antibody-antigen combining sites) are fused to immunoglobulin constant domain sequences. Preferably, the fusion is with an Ig heavy chain constant domain, comprising at least part of the hinge, C_{H2}, and C_{H3} regions. It is preferred to have the first heavy-chain constant region (C_{H1}) containing the site necessary for light chain bonding, present in at least one of the fusions. DNAs encoding the immunoglobulin heavy chain fusions and, if desired, the immunoglobulin light chain, are inserted into separate expression vectors, and are co-transfected into a suitable host cell. This provides for greater flexibility in adjusting the mutual proportions of the three polypeptide fragments in embodiments when unequal ratios of the three polypeptide chains used in the construction provide the optimum yield of the desired bispecific antibody. It is, however, possible to insert the coding sequences for two or all three polypeptide chains into a single expression vector when the expression of at least two polypeptide chains in equal ratios results in high yields or when the ratios have no significant effect on the yield of the desired chain combination.

In a particular embodiment of this approach, the bispecific antibodies are composed of a hybrid immunoglobulin heavy chain with a first binding specificity in one arm, and a hybrid immunoglobulin heavy chain-light chain pair (providing a second binding specificity) in the other arm. It was found that this asymmetric structure facilitates the separation of the desired bispecific compound from unwanted immunoglobulin chain combinations, as the presence of an immunoglobulin light chain in only one half of the bispecific molecule provides for a facile way of separation. This approach is disclosed in WO 94/04690. For further details of generating bispecific antibodies see, for example, Suresh *et al.*, Methods in Enzymology, 121:210 (1986).

According to another approach described in U.S. Patent 5,731,168, the interface between a pair of antibody molecules can be engineered to maximize the percentage of heterodimers that are recovered from recombinant cell culture. The preferred interface comprises at least a part of the C_{H3} domain. In this method, one or more small amino acid side chains from the interface of the first antibody molecule are replaced with larger side chains (*e.g.*, tyrosine or tryptophan). Compensatory "cavities" of identical or similar size to the large side chain(s) are created on the interface of the second antibody molecule by replacing large amino acid side chains with smaller ones (*e.g.*, alanine or threonine). This provides a

mechanism for increasing the yield of the heterodimer over other unwanted end-products such as homodimers.

Bispecific antibodies include cross-linked or "heteroconjugate" antibodies. For example, one of the antibodies in the heteroconjugate can be coupled to avidin, the other to
5 biotin. Such antibodies have, for example, been proposed to target immune system cells to unwanted cells (U.S. Patent 4,676,980), and for treatment of HIV infection (WO 91/00360, WO 92/200373, and EP 03089). Heteroconjugate antibodies may be made using any convenient cross-linking methods. Suitable cross-linking agents are well known in the art, and are disclosed in U.S. Patent 4,676,980, along with a number of cross-linking techniques.

10 Techniques for generating bispecific antibodies from antibody fragments have also been described in the literature. For example, bispecific antibodies can be prepared using chemical linkage. Brennan *et al.*, Science, 229: 81 (1985) describe a procedure wherein intact antibodies are proteolytically cleaved to generate F(ab')₂ fragments. These fragments are reduced in the presence of the dithiol complexing agent, sodium arsenite, to stabilize vicinal
15 dithiols and prevent intermolecular disulfide formation. The Fab' fragments generated are then converted to thionitrobenzoate (TNB) derivatives. One of the Fab'-TNB derivatives is then reconverted to the Fab'-thiol by reduction with mercaptoethylamine and is mixed with an equimolar amount of the other Fab'-TNB derivative to form the bispecific antibody. The bispecific antibodies produced can be used as agents for the selective immobilization of
20 enzymes.

Techniques exist that facilitate the direct recovery of Fab'-SH fragments from *E. coli*, which can be chemically coupled to form bispecific antibodies. Shalaby *et al.*, J. Exp. Med., 175: 217-225 (1992) describe the production of a humanized bispecific antibody F(ab')₂ molecule. Each Fab' fragment was separately secreted from *E. coli* and subjected to directed
25 chemical coupling *in vitro* to form the bispecific antibody. The bispecific antibody thus formed was able to bind to cells overexpressing the ErbB2 receptor and normal human T cells, as well as trigger the lytic activity of human cytotoxic lymphocytes against human breast tumor targets.

Various techniques for making and isolating bispecific antibody fragments directly from recombinant cell culture have also been described (Merchant *et al.*, *Nat. Biotechnol.* **16**, 677-681, 1998). For example, bispecific antibodies have been produced using
30 leucine zippers (Kostelny *et al.*, J. Immunol., 148(5):1547-1553, 1992). The leucine zipper peptides from the Fos and Jun proteins were linked to the Fab' portions of two different antibodies by gene fusion. The antibody homodimers were reduced at the hinge region to form monomers and then re-oxidized to form the antibody heterodimers. This method can also be

utilized for the production of antibody homodimers. The "diabody" technology described by Hollinger *et al.*, Proc. Natl. Acad. Sci. USA, 90:6444-6448 (1993) has provided an alternative mechanism for making bispecific antibody fragments. The fragments comprise a V_H connected to a V_L by a linker that is too short to allow pairing between the two domains on the same chain.

- 5 Accordingly, the V_H and V_L domains of one fragment are forced to pair with the complementary V_L and V_H domains of another fragment, thereby forming two antigen-binding sites. Another strategy for making bispecific antibody fragments by the use of single-chain Fv (sFv) dimers has also been reported. See Gruber *et al.*, J. Immunol., 152:5368 (1994).

- 10 In a particular embodiment, a bispecific or multispecific antibody may be formed as a DOCK-AND-LOCK™ (DNL™) complex (see, *e.g.*, U.S. Patents 7,521,056; 7,527,787; 7,534,866; 7,550,143 and 7,666,400, the Examples section of each of which is incorporated herein by reference.) Generally, the technique takes advantage of the specific and high-affinity binding interactions that occur between a dimerization and docking domain (DDD) sequence of the regulatory (R) subunits of cAMP-dependent protein kinase (PKA) and an anchor domain
15 (AD) sequence derived from any of a variety of AKAP proteins (Baillie *et al.*, *FEBS Letters*. 2005; 579: 3264; Wong and Scott, *Nat. Rev. Mol. Cell Biol.* 2004; 5: 959). The DDD and AD peptides may be attached to any protein, peptide or other molecule. Because the DDD sequences spontaneously dimerize and bind to the AD sequence, the technique allows the formation of complexes between any selected molecules that may be attached to DDD or AD
20 sequences.

- Antibodies with more than two valencies are contemplated. For example, trispecific antibodies can be prepared (Tutt *et al.*, J. Immunol. 147: 60, 1991; Xu *et al.*, *Science*, 358(6359):85-90, 2017). A multivalent antibody may be internalized (and/or catabolized) faster than a bivalent antibody by a cell expressing an antigen to which the antibodies bind.
25 The antibodies of the present disclosure can be multivalent antibodies with three or more antigen binding sites (*e.g.*, tetravalent antibodies), which can be readily produced by recombinant expression of nucleic acid encoding the polypeptide chains of the antibody. The multivalent antibody can comprise a dimerization domain and three or more antigen binding sites. The preferred dimerization domain comprises (or consists of) an Fc region or a hinge region. In this scenario, the antibody will comprise an Fc region and three or more antigen
30 binding sites amino-terminal to the Fc region. The preferred multivalent antibody herein comprises (or consists of) three to about eight, but preferably four, antigen binding sites. The multivalent antibody comprises at least one polypeptide chain (and preferably two polypeptide chains), wherein the polypeptide chain(s) comprise two or more variable regions. For instance,

the polypeptide chain(s) may comprise $VD1-(X1)_n-VD2-(X2)_n-Fc$, wherein $VD1$ is a first variable region, $VD2$ is a second variable region, Fc is one polypeptide chain of an Fc region, $X1$ and $X2$ represent an amino acid or polypeptide, and n is 0 or 1. For instance, the polypeptide chain(s) may comprise: $VH-CH1$ -flexible linker- $VH-CH1-Fc$ region chain; or $VH-CH1-VH-CH1-Fc$ region chain. The multivalent antibody herein preferably further comprises at least two (and preferably four) light chain variable region polypeptides. The multivalent antibody herein may, for instance, comprise from about two to about eight light chain variable region polypeptides. The light chain variable region polypeptides contemplated here comprise a light chain variable region and, optionally, further comprise a C_L domain.

Charge modifications are particularly useful in the context of a multispecific antibody, where amino acid substitutions in Fab molecules result in reducing the mispairing of light chains with non-matching heavy chains (Bence-Jones-type side products), which can occur in the production of Fab-based bi-/multispecific antigen binding molecules with a VH/VL exchange in one (or more, in case of molecules comprising more than two antigen-binding Fab molecules) of their binding arms (see also PCT publication no. WO 2015/150447, particularly the examples therein, incorporated herein by reference in its entirety).

Accordingly, in particular embodiments, an antibody comprised in the therapeutic agent comprises

- (a) a first Fab molecule which specifically binds to a first antigen
 - (b) a second Fab molecule which specifically binds to a second antigen, and wherein the variable domains VL and VH of the Fab light chain and the Fab heavy chain are replaced by each other,
- wherein the first antigen is an activating T cell antigen and the second antigen is a target cell antigen, or the first antigen is a target cell antigen and the second antigen is an activating T cell antigen; and
- wherein
- i) in the constant domain CL of the first Fab molecule under a) the amino acid at position 124 is substituted by a positively charged amino acid (numbering according to Kabat), and wherein in the constant domain $CH1$ of the first Fab molecule under a) the amino acid at position 147 or the amino acid at position 213 is substituted by a negatively charged amino acid (numbering according to Kabat EU index); or
 - ii) in the constant domain CL of the second Fab molecule under b) the amino acid at position 124 is substituted by a positively charged amino acid (numbering according to Kabat), and wherein in the constant domain $CH1$ of the second Fab molecule under b)

the amino acid at position 147 or the amino acid at position 213 is substituted by a negatively charged amino acid (numbering according to Kabat EU index).

The antibody may not comprise both modifications mentioned under i) and ii). The constant domains CL and CH1 of the second Fab molecule are not replaced by each other (*i.e.*, remain unexchanged).

In another embodiment of the antibody, in the constant domain CL of the first Fab molecule under a) the amino acid at position 124 is substituted independently by lysine (K), arginine (R) or histidine (H) (numbering according to Kabat) (in one preferred embodiment independently by lysine (K) or arginine (R)), and in the constant domain CH1 of the first Fab molecule under a) the amino acid at position 147 or the amino acid at position 213 is substituted independently by glutamic acid (E), or aspartic acid (D) (numbering according to Kabat EU index).

In a further embodiment, in the constant domain CL of the first Fab molecule under a) the amino acid at position 124 is substituted independently by lysine (K), arginine (R) or histidine (H) (numbering according to Kabat), and in the constant domain CH1 of the first Fab molecule under a) the amino acid at position 147 is substituted independently by glutamic acid (E), or aspartic acid (D) (numbering according to Kabat EU index).

In a particular embodiment, in the constant domain CL of the first Fab molecule under a) the amino acid at position 124 is substituted independently by lysine (K), arginine (R) or histidine (H) (numbering according to Kabat) (in one preferred embodiment independently by lysine (K) or arginine (R)) and the amino acid at position 123 is substituted independently by lysine (K), arginine (R) or histidine (H) (numbering according to Kabat) (in one preferred embodiment independently by lysine (K) or arginine (R)), and in the constant domain CH1 of the first Fab molecule under a) the amino acid at position 147 is substituted independently by glutamic acid (E), or aspartic acid (D) (numbering according to Kabat EU index) and the amino acid at position 213 is substituted independently by glutamic acid (E), or aspartic acid (D) (numbering according to Kabat EU index).

In a more particular embodiment, in the constant domain CL of the first Fab molecule under a) the amino acid at position 124 is substituted by lysine (K) (numbering according to Kabat) and the amino acid at position 123 is substituted by lysine (K) or arginine (R) (numbering according to Kabat), and in the constant domain CH1 of the first Fab molecule under a) the amino acid at position 147 is substituted by glutamic acid (E) (numbering according to Kabat EU index) and the amino acid at position 213 is substituted by glutamic acid (E) (numbering according to Kabat EU index).

In an even more particular embodiment, in the constant domain CL of the first Fab molecule under a) the amino acid at position 124 is substituted by lysine (K) (numbering according to Kabat) and the amino acid at position 123 is substituted by arginine (R) (numbering according to Kabat), and in the constant domain CH1 of the first Fab molecule under a) the amino acid at position 147 is substituted by glutamic acid (E) (numbering according to Kabat EU index) and the amino acid at position 213 is substituted by glutamic acid (E) (numbering according to Kabat EU index).

F. Chimeric Antigen Receptors

Artificial T cell receptors (also known as chimeric T cell receptors, chimeric immunoreceptors, chimeric antigen receptors (CARs)) are engineered receptors, which graft an arbitrary specificity onto an immune effector cell. Typically, these receptors are used to graft the specificity of a monoclonal antibody onto a T cell, with transfer of their coding sequence facilitated by retroviral vectors. In this way, a large number of target-specific T cells can be generated for adoptive cell transfer. Phase I clinical studies of this approach show efficacy.

The most common form of these molecules are fusions of single-chain variable fragments (scFv) derived from monoclonal antibodies, fused to CD3-zeta transmembrane and endodomain. Such molecules result in the transmission of a zeta signal in response to recognition by the scFv of its target. An example of such a construct is 14g2a-Zeta, which is a fusion of a scFv derived from hybridoma 14g2a (which recognizes disialoganglioside GD2). When T cells express this molecule (usually achieved by oncoretroviral vector transduction), they recognize and kill target cells that express GD2 (*e.g.*, neuroblastoma cells). To target malignant B cells, investigators have redirected the specificity of T cells using a chimeric immunoreceptor specific for the B-lineage molecule, CD19.

The variable portions of an immunoglobulin heavy and light chain are fused by a flexible linker to form a scFv. This scFv is preceded by a signal peptide to direct the nascent protein to the endoplasmic reticulum and subsequent surface expression (this is cleaved). A flexible spacer allows to the scFv to orient in different directions to enable antigen binding. The transmembrane domain is a typical hydrophobic alpha helix usually derived from the original molecule of the signaling endodomain which protrudes into the cell and transmits the desired signal.

Type I proteins are in fact two protein domains linked by a transmembrane alpha helix in between. The cell membrane lipid bilayer, through which the transmembrane domain passes,

acts to isolate the inside portion (endodomain) from the external portion (ectodomain). It is not so surprising that attaching an ectodomain from one protein to an endodomain of another protein results in a molecule that combines the recognition of the former to the signal of the latter.

5 **Ectodomain.** A signal peptide directs the nascent protein into the endoplasmic reticulum. This is essential if the receptor is to be glycosylated and anchored in the cell membrane. Any eukaryotic signal peptide sequence usually works fine. Generally, the signal peptide natively attached to the amino-terminal most component is used (*e.g.*, in a scFv with orientation light chain - linker - heavy chain, the native signal of the light-chain is used

10 The antigen recognition domain is usually an scFv. There are however many alternatives. An antigen recognition domain from native T-cell receptor (TCR) alpha and beta single chains have been described, as have simple ectodomains (*e.g.*, CD4 ectodomain to recognize HIV infected cells) and more exotic recognition components such as a linked cytokine (which leads to recognition of cells bearing the cytokine receptor). In fact, almost
15 anything that binds a given target with high affinity can be used as an antigen recognition region.

A spacer region links the antigen binding domain to the transmembrane domain. It should be flexible enough to allow the antigen binding domain to orient in different directions to facilitate antigen recognition. The simplest form is the hinge region from IgG1. Alternatives
20 include the CH₂CH₃ region of immunoglobulin and portions of CD3. For most scFv based constructs, the IgG1 hinge suffices. However, the best spacer often has to be determined empirically.

Transmembrane domain. The transmembrane domain is a hydrophobic alpha helix that spans the membrane. Generally, the transmembrane domain from the most membrane
25 proximal component of the endodomain is used. Interestingly, using the CD3-zeta transmembrane domain may result in incorporation of the artificial TCR into the native TCR a factor that is dependent on the presence of the native CD3-zeta transmembrane charged aspartic acid residue. Different transmembrane domains result in different receptor stability. The CD28 transmembrane domain results in a brightly expressed, stable receptor.

30 **Endodomain.** This is the "business-end" of the receptor. After antigen recognition, receptors cluster and a signal is transmitted to the cell. The most commonly used endodomain component is CD3-zeta which contains 3 ITAMs. This transmits an activation signal to the T cell after antigen is bound. CD3-zeta may not provide a fully competent activation signal and additional co-stimulatory signaling is needed.

"First-generation" CARs typically had the intracellular domain from the CD3 ξ - chain, which is the primary transmitter of signals from endogenous TCRs. "Second-generation" CARs add intracellular signaling domains from various costimulatory protein receptors (*e.g.*, CD28, 41BB, ICOS) to the cytoplasmic tail of the CAR to provide additional signals to the T cell.

5 Preclinical studies have indicated that the second generation of CAR designs improves the antitumor activity of T cells. More recent, "third-generation" CARs combine multiple signaling domains, such as CD3z-CD28-41BB or CD3z-CD28-OX40, to further augment potency.

G. ADCs

10 Antibody Drug Conjugates or ADCs are a new class of highly potent biopharmaceutical drugs designed as a targeted therapy for the treatment of people with infectious disease. ADCs are complex molecules composed of an antibody (a whole mAb or an antibody fragment such as a single-chain variable fragment, or scFv) linked, via a stable chemical linker with labile bonds, to a biological active cytotoxic/anti-viral payload or drug. Antibody Drug Conjugates

15 are examples of bioconjugates and immunoconjugates.

By combining the unique targeting capabilities of monoclonal antibodies with the cancer-killing ability of cytotoxic drugs, antibody-drug conjugates allow sensitive discrimination between healthy and diseased tissue. This means that, in contrast to traditional systemic approaches, antibody-drug conjugates target and attack the infected cell so that

20 healthy cells are less severely affected.

In the development ADC-based anti-tumor therapies, an anticancer drug (*e.g.*, a cell toxin or cytotoxin) is coupled to an antibody that specifically targets a certain cell marker (*e.g.*, a protein that, ideally, is only to be found in or on infected cells). Antibodies track these proteins down in the body and attach themselves to the surface of cancer cells. The biochemical reaction

25 between the antibody and the target protein (antigen) triggers a signal in the tumor cell, which then absorbs or internalizes the antibody together with the cytotoxin. After the ADC is internalized, the cytotoxic drug is released and kills the cell or impairs viral replication. Due to this targeting, ideally the drug has lower side effects and gives a wider therapeutic window than other agents.

30 A stable link between the antibody and cytotoxic/anti-viral agent is a crucial aspect of an ADC. Linkers are based on chemical motifs including disulfides, hydrazones or peptides (cleavable), or thioethers (noncleavable) and control the distribution and delivery of the cytotoxic agent to the target cell. Cleavable and noncleavable types of linkers have been proven to be safe in preclinical and clinical trials. Brentuximab vedotin includes an enzyme-sensitive

cleavable linker that delivers the potent and highly toxic antimicrotubule agent Monomethyl auristatin E or MMAE, a synthetic antineoplastic agent, to human specific CD30-positive malignant cells. Because of its high toxicity MMAE, which inhibits cell division by blocking the polymerization of tubulin, cannot be used as a single-agent chemotherapeutic drug.

- 5 However, the combination of MMAE linked to an anti-CD30 monoclonal antibody (cAC10, a cell membrane protein of the tumor necrosis factor or TNF receptor) proved to be stable in extracellular fluid, cleavable by cathepsin and safe for therapy. Trastuzumab emtansine, the other approved ADC, is a combination of the microtubule-formation inhibitor mertansine (DM-1), a derivative of the Maytansine, and antibody trastuzumab (Herceptin®/Genentech/Roche)
- 10 attached by a stable, non-cleavable linker.

The availability of better and more stable linkers has changed the function of the chemical bond. The type of linker, cleavable or noncleavable, lends specific properties to the cytotoxic (anti-cancer) drug. For example, a non-cleavable linker keeps the drug within the cell. As a result, the entire antibody, linker and cytotoxic agent enter the targeted cancer cell where the antibody

15 is degraded to the level of an amino acid. The resulting complex – amino acid, linker and cytotoxic agent – now becomes the active drug. In contrast, cleavable linkers are catalyzed by enzymes in the host cell where it releases the cytotoxic agent.

Another type of cleavable linker, currently in development, adds an extra molecule between the cytotoxic/anti-viral drug and the cleavage site. This linker technology allows

20 researchers to create ADCs with more flexibility without worrying about changing cleavage kinetics. Researchers are also developing a new method of peptide cleavage based on Edman degradation, a method of sequencing amino acids in a peptide. Future direction in the development of ADCs also include the development of site-specific conjugation (TDCs) to further improve stability and therapeutic index and α emitting immunoconjugates and

25 antibody-conjugated nanoparticles.

H. BiTES

Bi-specific T-cell engagers (BiTEs) are a class of artificial bispecific monoclonal antibodies that are investigated for the use as anti-cancer drugs. They direct a host's immune

30 system, more specifically the T cells' cytotoxic activity, against infected cells. *BiTE* is a registered trademark of Micromet AG.

BiTEs are fusion proteins consisting of two single-chain variable fragments (scFvs) of different antibodies, or amino acid sequences from four different genes, on a single peptide

chain of about 55 kilodaltons. One of the scFvs binds to T cells via the CD3 receptor, and the other to an infected cell via a specific molecule.

Like other bispecific antibodies, and unlike ordinary monoclonal antibodies, BiTEs form a link between T cells and target cells. This causes T cells to exert cytotoxic/anti-viral activity on infected cells by producing proteins like perforin and granzymes, independently of the presence of MHC I or co-stimulatory molecules. These proteins enter infected cells and initiate the cell's apoptosis. This action mimics physiological processes observed during T cell attacks against infected cells.

I. Intrabodies

In a particular embodiment, the antibody is a recombinant antibody that is suitable for action inside of a cell – such antibodies are known as “intrabodies.” These antibodies may interfere with target function by a variety of mechanism, such as by altering intracellular protein trafficking, interfering with enzymatic function, and blocking protein-protein or protein-DNA interactions. In many ways, their structures mimic or parallel those of single chain and single domain antibodies, discussed above. Indeed, single-transcript/single-chain is an important feature that permits intracellular expression in a target cell, and also makes protein transit across cell membranes more feasible. However, additional features are required.

The two major issues impacting the implementation of intrabody therapeutic are delivery, including cell/tissue targeting, and stability. With respect to delivery, a variety of approaches have been employed, such as tissue-directed delivery, use of cell-type specific promoters, viral-based delivery and use of cell-permeability/membrane translocating peptides. With respect to the stability, the approach is generally to either screen by brute force, including methods that involve phage display and may include sequence maturation or development of consensus sequences, or more directed modifications such as insertion stabilizing sequences (*e.g.*, Fc regions, chaperone protein sequences, leucine zippers) and disulfide replacement/modification.

An additional feature that intrabodies may require is a signal for intracellular targeting. Vectors that can target intrabodies (or other proteins) to subcellular regions such as the cytoplasm, nucleus, mitochondria and ER have been designed and are commercially available (Invitrogen Corp.; Persic *et al.*, 1997).

By virtue of their ability to enter cells, intrabodies have additional uses that other types of antibodies may not achieve. In the case of the present antibodies, the ability to interact with the MUC1 cytoplasmic domain in a living cell may interfere with functions associated with the

MUC1 CD, such as signaling functions (binding to other molecules) or oligomer formation. In particular, it is contemplated that such antibodies can be used to inhibit MUC1 dimer formation.

J. Purification

5 In certain embodiments, the antibodies of the present disclosure may be purified. The term “purified,” as used herein, is intended to refer to a composition, isolatable from other components, wherein the protein is purified to any degree relative to its naturally-obtainable state. A purified protein therefore also refers to a protein, free from the environment in which it may naturally occur. Where the term “substantially purified” is used, this designation will
10 refer to a composition in which the protein or peptide forms the major component of the composition, such as constituting about 50%, about 60%, about 70%, about 80%, about 90%, about 95% or more of the proteins in the composition.

Protein purification techniques are well known to those of skill in the art. These techniques involve, at one level, the crude fractionation of the cellular milieu to polypeptide
15 and non-polypeptide fractions. Having separated the polypeptide from other proteins, the polypeptide of interest may be further purified using chromatographic and electrophoretic techniques to achieve partial or complete purification (or purification to homogeneity). Analytical methods particularly suited to the preparation of a pure peptide are ion-exchange chromatography, exclusion chromatography; polyacrylamide gel electrophoresis; isoelectric
20 focusing. Other methods for protein purification include, precipitation with ammonium sulfate, PEG, antibodies and the like or by heat denaturation, followed by centrifugation; gel filtration, reverse phase, hydroxylapatite and affinity chromatography; and combinations of such and other techniques.

In purifying an antibody of the present disclosure, it may be desirable to express the
25 polypeptide in a prokaryotic or eukaryotic expression system and extract the protein using denaturing conditions. The polypeptide may be purified from other cellular components using an affinity column, which binds to a tagged portion of the polypeptide. As is generally known in the art, it is believed that the order of conducting the various purification steps may be changed, or that certain steps may be omitted, and still result in a suitable method for the
30 preparation of a substantially purified protein or peptide.

Commonly, complete antibodies are fractionated utilizing agents (*i.e.*, protein A) that bind the Fc portion of the antibody. Alternatively, antigens may be used to simultaneously purify and select appropriate antibodies. Such methods often utilize the selection agent bound to a support, such as a column, filter or bead. The antibodies are bound to a support,

contaminants removed (*e.g.*, washed away), and the antibodies released by applying conditions (salt, heat, *etc.*).

Various methods for quantifying the degree of purification of the protein or peptide will be known to those of skill in the art in light of the present disclosure. These include, for example, 5 determining the specific activity of an active fraction, or assessing the amount of polypeptides within a fraction by SDS/PAGE analysis. Another method for assessing the purity of a fraction is to calculate the specific activity of the fraction, to compare it to the specific activity of the initial extract, and to thus calculate the degree of purity. The actual units used to represent the amount of activity will, of course, be dependent upon the particular assay technique chosen to 10 follow the purification and whether or not the expressed protein or peptide exhibits a detectable activity.

It is known that the migration of a polypeptide can vary, sometimes significantly, with different conditions of SDS/PAGE (Capaldi *et al.*, 1977). It will therefore be appreciated that under differing electrophoresis conditions, the apparent molecular weights of purified or 15 partially purified expression products may vary.

III. Active/Passive Immunization and Treatment/Prevention of Zika virus Infection

A. Formulation and Administration

The present disclosure provides pharmaceutical compositions comprising anti- Zika 20 virus antibodies and antigens for generating the same. Such compositions comprise a prophylactically or therapeutically effective amount of an antibody or a fragment thereof, or a peptide immunogen, and a pharmaceutically acceptable carrier. 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 25 pharmacopeia for use in animals, and more particularly in humans. The term “carrier” refers to a diluent, excipient, or vehicle with which the therapeutic is 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 particular carrier when the pharmaceutical composition is administered 30 intravenously. Saline solutions and aqueous dextrose and glycerol solutions can also be employed as liquid carriers, particularly for injectable solutions. Other 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. Oral formulations can include standard carriers such as pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, *etc.* Examples of suitable pharmaceutical agents are described in "Remington's Pharmaceutical Sciences." Such compositions will contain a prophylactically or therapeutically effective amount of the antibody or fragment thereof, preferably in purified form, together with a suitable amount of carrier so as to provide the form for proper administration to the patient. The formulation should suit the mode of administration, which can be oral, intravenous, intraarterial, intrabuccal, intranasal, nebulized, bronchial inhalation, intra-rectal, vaginal, topical or delivered by mechanical ventilation.

Active vaccines are also envisioned where antibodies like those disclosed are produced *in vivo* in a subject at risk of Zika virus infection. Such vaccines can be formulated for parenteral administration, *e.g.*, formulated for injection *via* the intradermal, intravenous, intramuscular, subcutaneous, or even intraperitoneal routes. Administration by intradermal and intramuscular routes are contemplated. The vaccine could alternatively be administered by a topical route directly to the mucosa, for example, by nasal drops, inhalation, by nebulizer, or via intrarectal or vaginal delivery. Pharmaceutically acceptable salts include the acid salts and those which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids as acetic, oxalic, tartaric, mandelic, and the like. Salts formed with the free carboxyl groups may also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, 2-ethylamino ethanol, histidine, procaine, and the like.

Passive transfer of antibodies, known as artificially acquired passive immunity, generally will involve the use of intravenous or intramuscular injections. The forms of antibody can be human or animal blood plasma or serum, as pooled human immunoglobulin for intravenous (IVIG) or intramuscular (IG) use, as high-titer human IVIG or IG from immunized or from donors recovering from disease, and as monoclonal antibodies (MAb). Such immunity generally lasts for only a short period of time, and there is also a potential risk for hypersensitivity reactions, and serum sickness, especially from gamma globulin of non-human

origin. However, passive immunity provides immediate protection. The antibodies will be formulated in a carrier suitable for injection, *i.e.*, sterile and syringeable.

Generally, the ingredients of compositions of the disclosure 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 disclosure can be formulated as neutral or salt forms. 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.*

2. ADCC

Antibody-dependent cell-mediated cytotoxicity (ADCC) is an immune mechanism leading to the lysis of antibody-coated target cells by immune effector cells. The target cells are cells to which antibodies or fragments thereof comprising an Fc region specifically bind, generally via the protein part that is N-terminal to the Fc region. By “antibody having increased/reduced antibody dependent cell-mediated cytotoxicity (ADCC)” is meant an antibody having increased/reduced ADCC as determined by any suitable method known to those of ordinary skill in the art.

As used herein, the term “increased/reduced ADCC” is defined as either an increase/reduction in the number of target cells that are lysed in a given time, at a given concentration of antibody in the medium surrounding the target cells, by the mechanism of ADCC defined above, and/or a reduction/increase in the concentration of antibody, in the medium surrounding the target cells, required to achieve the lysis of a given number of target cells in a given time, by the mechanism of ADCC. The increase/reduction in ADCC is relative to the ADCC mediated by the same antibody produced by the same type of host cells, using the same standard production, purification, formulation and storage methods (which are known to those skilled in the art), but that has not been engineered. For example, the increase in ADCC mediated by an antibody produced by host cells engineered to have an altered pattern of glycosylation (*e.g.*, to express the glycosyltransferase, GnTIII, or other glycosyltransferases)

by the methods described herein, is relative to the ADCC mediated by the same antibody produced by the same type of non-engineered host cells.

3. CDC

5 Complement-dependent cytotoxicity (CDC) is a function of the complement system. It is the processes in the immune system that kill pathogens by damaging their membranes without the involvement of antibodies or cells of the immune system. There are three main processes. All three insert one or more membrane attack complexes (MAC) into the pathogen which cause lethal colloid-osmotic swelling, *i.e.*, CDC. It is one of the mechanisms by which
10 antibodies or antibody fragments have an anti-viral effect.

IV. Antibody Conjugates

Antibodies of the present disclosure may be linked to at least one agent to form an antibody conjugate. In order to increase the efficacy of antibody molecules as diagnostic or
15 therapeutic agents, it is conventional to link or covalently bind or complex at least one desired molecule or moiety. Such a molecule or moiety may be, but is not limited to, at least one effector or reporter molecule. Effector molecules comprise molecules having a desired activity, *e.g.*, cytotoxic activity. Non-limiting examples of effector molecules which have been attached to antibodies include toxins, anti-tumor agents, therapeutic enzymes, radionuclides, antiviral
20 agents, chelating agents, cytokines, growth factors, and oligo- or polynucleotides. By contrast, a reporter molecule is defined as any moiety which may be detected using an assay. Non-limiting examples of reporter molecules which have been conjugated to antibodies include enzymes, radiolabels, haptens, fluorescent labels, phosphorescent molecules, chemiluminescent molecules, chromophores, photoaffinity molecules, colored particles or
25 ligands, such as biotin.

Antibody conjugates are generally preferred for use as diagnostic agents. Antibody diagnostics generally fall within two classes, those for use in *in vitro* diagnostics, such as in a variety of immunoassays, and those for use *in vivo* diagnostic protocols, generally known as "antibody-directed imaging." Many appropriate imaging agents are known in the art, as are
30 methods for their attachment to antibodies (see, for *e.g.*, U.S. Patents 5,021,236, 4,938,948, and 4,472,509). The imaging moieties used can be paramagnetic ions, radioactive isotopes, fluorochromes, NMR-detectable substances, and X-ray imaging agents.

In the case of paramagnetic ions, one might mention by way of example ions such as chromium (III), manganese (II), iron (III), iron (II), cobalt (II), nickel (II), copper (II),

neodymium (III), samarium (III), ytterbium (III), gadolinium (III), vanadium (II), terbium (III), dysprosium (III), holmium (III) and/or erbium (III), with gadolinium being particularly preferred. Ions useful in other contexts, such as X-ray imaging, include but are not limited to lanthanum (III), gold (III), lead (II), and especially bismuth (III).

5 In the case of radioactive isotopes for therapeutic and/or diagnostic application, one might mention astatine²¹¹, ¹⁴carbon, ⁵¹chromium, ³⁶chlorine, ⁵⁷cobalt, ⁵⁸cobalt, copper⁶⁷, ¹⁵²Eu, gallium⁶⁷, ³hydrogen, iodine¹²³, iodine¹²⁵, iodine¹³¹, indium¹¹¹, ⁵⁹iron, ³²phosphorus, rhenium¹⁸⁶, rhenium¹⁸⁸, ⁷⁵selenium, ³⁵sulphur, technetium^{99m} and/or yttrium⁹⁰. ¹²⁵I is often being preferred for use in certain embodiments, and technetium^{99m} and/or indium¹¹¹ are also often preferred
10 due to their low energy and suitability for long range detection. Radioactively labeled monoclonal antibodies of the present disclosure may be produced according to well-known methods in the art. For instance, monoclonal antibodies can be iodinated by contact with sodium and/or potassium iodide and a chemical oxidizing agent such as sodium hypochlorite, or an enzymatic oxidizing agent, such as lactoperoxidase. Monoclonal antibodies according to
15 the disclosure may be labeled with technetium^{99m} by ligand exchange process, for example, by reducing pertechnetate with stannous solution, chelating the reduced technetium onto a Sephadex column and applying the antibody to this column. Alternatively, direct labeling techniques may be used, *e.g.*, by incubating pertechnetate, a reducing agent such as SnCl_2 , a buffer solution such as sodium-potassium phthalate solution, and the antibody. Intermediary functional groups
20 which are often used to bind radioisotopes which exist as metallic ions to antibody are diethylenetriaminepentaacetic acid (DTPA) or ethylene diaminetetracetic acid (EDTA).

 Among the fluorescent labels contemplated for use as conjugates include Alexa 350, Alexa 430, AMCA, BODIPY 630/650, BODIPY 650/665, BODIPY-FL, BODIPY-R6G, BODIPY-TMR, BODIPY-TRX, Cascade Blue, Cy3, Cy5,6-FAM, Fluorescein Isothiocyanate,
25 HEX, 6-JOE, Oregon Green 488, Oregon Green 500, Oregon Green 514, Pacific Blue, REG, Rhodamine Green, Rhodamine Red, Renographin, ROX, TAMRA, TET, Tetramethylrhodamine, and/or Texas Red.

 Additional types of antibodies contemplated in the present disclosure are those intended primarily for use *in vitro*, where the antibody is linked to a secondary binding ligand and/or to
30 an enzyme (an enzyme tag) that will generate a colored product upon contact with a chromogenic substrate. Examples of suitable enzymes include urease, alkaline phosphatase, (horseradish) hydrogen peroxidase or glucose oxidase. Preferred secondary binding ligands are biotin and avidin and streptavidin compounds. The use of such labels is well known to those

of skill in the art and are described, for example, in U.S. Patents 3,817,837, 3,850,752, 3,939,350, 3,996,345, 4,277,437, 4,275,149 and 4,366,241.

Yet another known method of site-specific attachment of molecules to antibodies comprises the reaction of antibodies with hapten-based affinity labels. Essentially, hapten-based affinity labels react with amino acids in the antigen binding site, thereby destroying this site and blocking specific antigen reaction. However, this may not be advantageous since it results in loss of antigen binding by the antibody conjugate.

Molecules containing azido groups may also be used to form covalent bonds to proteins through reactive nitrene intermediates that are generated by low intensity ultraviolet light (Potter and Haley, 1983). In particular, 2- and 8-azido analogues of purine nucleotides have been used as site-directed photoprobes to identify nucleotide binding proteins in crude cell extracts (Owens & Haley, 1987; Atherton *et al.*, 1985). The 2- and 8-azido nucleotides have also been used to map nucleotide binding domains of purified proteins (Khatoun *et al.*, 1989; King *et al.*, 1989; Dholakia *et al.*, 1989) and may be used as antibody binding agents.

Several methods are known in the art for the attachment or conjugation of an antibody to its conjugate moiety. Some attachment methods involve the use of a metal chelate complex employing, for example, an organic chelating agent such a diethylenetriaminepentaacetic acid anhydride (DTPA); ethylenetriaminetetraacetic acid; N-chloro-p-toluenesulfonamide; and/or tetrachloro-3 α -6 α -diphenylglycouril-3 attached to the antibody (U.S. Patents 4,472,509 and 4,938,948). Monoclonal antibodies may also be reacted with an enzyme in the presence of a coupling agent such as glutaraldehyde or periodate. Conjugates with fluorescein markers are prepared in the presence of these coupling agents or by reaction with an isothiocyanate. In U.S. Patent 4,938,948, imaging of breast tumors is achieved using monoclonal antibodies and the detectable imaging moieties are bound to the antibody using linkers such as methyl-p-hydroxybenzimidate or N-succinimidyl-3-(4-hydroxyphenyl)propionate.

In other embodiments, derivatization of immunoglobulins by selectively introducing sulfhydryl groups in the Fc region of an immunoglobulin, using reaction conditions that do not alter the antibody combining site are contemplated. Antibody conjugates produced according to this methodology are disclosed to exhibit improved longevity, specificity and sensitivity (U.S. Patent 5,196,066, incorporated herein by reference). Site-specific attachment of effector or reporter molecules, wherein the reporter or effector molecule is conjugated to a carbohydrate residue in the Fc region have also been disclosed in the literature (O'Shannessy *et al.*, 1987).

This approach has been reported to produce diagnostically and therapeutically promising antibodies which are currently in clinical evaluation.

V. Immunodetection Methods

5 In still further embodiments, the present disclosure concerns immunodetection methods for binding, purifying, removing, quantifying and otherwise generally detecting Zika virus and its associated antigens. While such methods can be applied in a traditional sense, another use will be in quality control and monitoring of vaccine and other virus stocks, where antibodies according to the present disclosure can be used to assess the amount or integrity (*i.e.*, long term
10 stability) of antigens in viruses. Alternatively, the methods may be used to screen various antibodies for appropriate/desired reactivity profiles.

Other immunodetection methods include specific assays for determining the presence of Zika virus in a subject. A wide variety of assay formats are contemplated, but specifically those that would be used to detect Zika virus in a fluid obtained from a subject, such as saliva,
15 blood, plasma, sputum, semen or urine. In particular, semen has been demonstrated as a viable sample for detecting Zika virus (Purpura *et al.*, 2016; Mansuy *et al.*, 2016; Barzon *et al.*, 2016; Gornet *et al.*, 2016; Duffy *et al.*, 2009; CDC, 2016; Halfon *et al.*, 2010; Elder *et al.* 2005). The assays may be advantageously formatted for non-healthcare (home) use, including lateral flow assays (see below) analogous to home pregnancy tests. These assays may be packaged in the
20 form of a kit with appropriate reagents and instructions to permit use by the subject of a family member.

Some immunodetection methods include enzyme linked immunosorbent assay (ELISA), radioimmunoassay (RIA), immunoradiometric assay, fluoroimmunoassay, chemiluminescent assay, bioluminescent assay, and Western blot to mention a few. In
25 particular, a competitive assay for the detection and quantitation of Zika virus antibodies directed to specific parasite epitopes in samples also is provided. The steps of various useful immunodetection methods have been described in the scientific literature, such as, *e.g.*, Doolittle and Ben-Zeev (1999), Gulbis and Galand (1993), De Jager *et al.* (1993), and Nakamura *et al.* (1987). In general, the immunobinding methods include obtaining a sample
30 suspected of containing Zika virus and contacting the sample with a first antibody in accordance with the present disclosure, as the case may be, under conditions effective to allow the formation of immunocomplexes.

These methods include methods for purifying Zika virus or related antigens from a sample. The antibody will preferably be linked to a solid support, such as in the form of a

column matrix, and the sample suspected of containing the Zika virus or antigenic component will be applied to the immobilized antibody. The unwanted components will be washed from the column, leaving the Zika virus antigen immunocomplexed to the immobilized antibody, which is then collected by removing the organism or antigen from the column.

5 The immunobinding methods also include methods for detecting and quantifying the amount of Zika virus or related components in a sample and the detection and quantification of any immune complexes formed during the binding process. Here, one would obtain a sample suspected of containing Zika virus or its antigens and contact the sample with an antibody that binds Zika virus or components thereof, followed by detecting and quantifying the amount of
10 immune complexes formed under the specific conditions. In terms of antigen detection, the biological sample analyzed may be any sample that is suspected of containing Zika virus or Zika virus antigen, such as a tissue section or specimen, a homogenized tissue extract, a biological fluid, including blood and serum, or a secretion, such as feces or urine.

 Contacting the chosen biological sample with the antibody under effective conditions
15 and for a period of time sufficient to allow the formation of immune complexes (primary immune complexes) is generally a matter of simply adding the antibody composition to the sample and incubating the mixture for a period of time long enough for the antibodies to form immune complexes with, *i.e.*, to bind to Zika virus or antigens present. After this time, the sample-antibody composition, such as a tissue section, ELISA plate, dot blot or Western blot,
20 will generally be washed to remove any non-specifically bound antibody species, allowing only those antibodies specifically bound within the primary immune complexes to be detected.

 In general, the detection of immunocomplex formation is well known in the art and may be achieved through the application of numerous approaches. These methods are generally based upon the detection of a label or marker, such as any of those radioactive, fluorescent,
25 biological and enzymatic tags. Patents concerning the use of such labels include U.S. Patents 3,817,837, 3,850,752, 3,939,350, 3,996,345, 4,277,437, 4,275,149 and 4,366,241. Of course, one may find additional advantages through the use of a secondary binding ligand such as a second antibody and/or a biotin/avidin ligand binding arrangement, as is known in the art.

 The antibody employed in the detection may itself be linked to a detectable label,
30 wherein one would then simply detect this label, thereby allowing the amount of the primary immune complexes in the composition to be determined. Alternatively, the first antibody that becomes bound within the primary immune complexes may be detected by means of a second binding ligand that has binding affinity for the antibody. In these cases, the second binding ligand may be linked to a detectable label. The second binding ligand is itself often an antibody,

which may thus be termed a “secondary” antibody. The primary immune complexes are contacted with the labeled, secondary binding ligand, or antibody, under effective conditions and for a period of time sufficient to allow the formation of secondary immune complexes. The secondary immune complexes are then generally washed to remove any non-specifically bound
5 labeled secondary antibodies or ligands, and the remaining label in the secondary immune complexes is then detected.

Further methods include the detection of primary immune complexes by a two-step approach. A second binding ligand, such as an antibody that has binding affinity for the antibody, is used to form secondary immune complexes, as described above. After washing,
10 the secondary immune complexes are contacted with a third binding ligand or antibody that has binding affinity for the second antibody, again under effective conditions and for a period of time sufficient to allow the formation of immune complexes (tertiary immune complexes). The third ligand or antibody is linked to a detectable label, allowing detection of the tertiary immune complexes thus formed. This system may provide for signal amplification if this is
15 desired.

One method of immunodetection uses two different antibodies. A first biotinylated antibody is used to detect the target antigen, and a second antibody is then used to detect the biotin attached to the complexed biotin. In that method, the sample to be tested is first incubated in a solution containing the first step antibody. If the target antigen is present, some of the
20 antibody binds to the antigen to form a biotinylated antibody/antigen complex. The antibody/antigen complex is then amplified by incubation in successive solutions of streptavidin (or avidin), biotinylated DNA, and/or complementary biotinylated DNA, with each step adding additional biotin sites to the antibody/antigen complex. The amplification steps are repeated until a suitable level of amplification is achieved, at which point the sample
25 is incubated in a solution containing the second step antibody against biotin. This second step antibody is labeled, for example, with an enzyme that can be used to detect the presence of the antibody/antigen complex by histoenzymology using a chromogen substrate. With suitable amplification, a conjugate can be produced which is macroscopically visible.

Another known method of immunodetection takes advantage of the immuno-PCR
30 (Polymerase Chain Reaction) methodology. The PCR method is similar to the Cantor method up to the incubation with biotinylated DNA, however, instead of using multiple rounds of streptavidin and biotinylated DNA incubation, the DNA/biotin/streptavidin/antibody complex is washed out with a low pH or high salt buffer that releases the antibody. The resulting wash solution is then used to carry out a PCR reaction with suitable primers with appropriate controls.

At least in theory, the enormous amplification capability and specificity of PCR can be utilized to detect a single antigen molecule.

A. ELISAs

5 Immunoassays, in their most simple and direct sense, are binding assays. Certain preferred immunoassays are the various types of enzyme linked immunosorbent assays (ELISAs) and radioimmunoassays (RIA) known in the art. Immunohistochemical detection using tissue sections is also particularly useful. However, it will be readily appreciated that detection is not limited to such techniques, and western blotting, dot blotting, FACS analyses,
10 and the like may also be used.

 In one exemplary ELISA, the antibodies of the disclosure are immobilized onto a selected surface exhibiting protein affinity, such as a well in a polystyrene microtiter plate. Then, a test composition suspected of containing the Zika virus or Zika virus antigen is added to the wells. After binding and washing to remove non-specifically bound immune complexes,
15 the bound antigen may be detected. Detection may be achieved by the addition of another anti-Zika virus antibody that is linked to a detectable label. This type of ELISA is a simple “sandwich ELISA.” Detection may also be achieved by the addition of a second anti-Zika virus antibody, followed by the addition of a third antibody that has binding affinity for the second antibody, with the third antibody being linked to a detectable label.

20 In another exemplary ELISA, the samples suspected of containing the Zika virus or Zika virus antigen are immobilized onto the well surface and then contacted with the anti- Zika virus antibodies of the disclosure. After binding and washing to remove non-specifically bound immune complexes, the bound anti-Zika virus antibodies are detected. Where the initial anti-Zika virus antibodies are linked to a detectable label, the immune complexes may be detected
25 directly. Again, the immune complexes may be detected using a second antibody that has binding affinity for the first anti-Zika virus antibody, with the second antibody being linked to a detectable label.

 Irrespective of the format employed, ELISAs have certain features in common, such as coating, incubating and binding, washing to remove non-specifically bound species, and
30 detecting the bound immune complexes. These are described below.

 In coating a plate with either antigen or antibody, one will generally incubate the wells of the plate with a solution of the antigen or antibody, either overnight or for a specified period of hours. The wells of the plate will then be washed to remove incompletely adsorbed material. Any remaining available surfaces of the wells are then “coated” with a nonspecific protein that

is antigenically neutral with regard to the test antisera. These include bovine serum albumin (BSA), casein or solutions of milk powder. The coating allows for blocking of nonspecific adsorption sites on the immobilizing surface and thus reduces the background caused by nonspecific binding of antisera onto the surface.

5 In ELISAs, it is probably more customary to use a secondary or tertiary detection means rather than a direct procedure. Thus, after binding of a protein or antibody to the well, coating with a non-reactive material to reduce background, and washing to remove unbound material, the immobilizing surface is contacted with the biological sample to be tested under conditions effective to allow immune complex (antigen/antibody) formation. Detection of the immune
10 complex then requires a labeled secondary binding ligand or antibody, and a secondary binding ligand or antibody in conjunction with a labeled tertiary antibody or a third binding ligand.

“Under conditions effective to allow immune complex (antigen/antibody) formation” means that the conditions preferably include diluting the antigens and/or antibodies with solutions such as BSA, bovine gamma globulin (BGG) or phosphate buffered saline
15 (PBS)/Tween. These added agents also tend to assist in the reduction of nonspecific background.

The “suitable” conditions also mean that the incubation is at a temperature or for a period of time sufficient to allow effective binding. Incubation steps are typically from about 1 to 2 to 4 hours or so, at temperatures preferably on the order of 25°C to 27°C or may be
20 overnight at about 4°C or so.

Following all incubation steps in an ELISA, the contacted surface is washed so as to remove non-complexed material. A preferred washing procedure includes washing with a solution such as PBS/Tween, or borate buffer. Following the formation of specific immune complexes between the test sample and the originally bound material, and subsequent washing,
25 the occurrence of even minute amounts of immune complexes may be determined.

To provide a detecting means, the second or third antibody will have an associated label to allow detection. Preferably, this will be an enzyme that will generate color development upon incubating with an appropriate chromogenic substrate. Thus, for example, one will desire to contact or incubate the first and second immune complex with a urease, glucose oxidase,
30 alkaline phosphatase or hydrogen peroxidase-conjugated antibody for a period of time and under conditions that favor the development of further immune complex formation (*e.g.*, incubation for 2 hours at room temperature in a PBS-containing solution such as PBS-Tween).

After incubation with the labeled antibody, and subsequent to washing to remove unbound material, the amount of label is quantified, *e.g.*, by incubation with a chromogenic

substrate such as urea, or bromocresol purple, or 2,2'-azino-di-(3-ethyl-benzthiazoline-6-sulfonic acid (ABTS), or H₂O₂, in the case of peroxidase as the enzyme label. Quantification is then achieved by measuring the degree of color generated, *e.g.*, using a visible spectra spectrophotometer.

5 In another embodiment, the present disclosure contemplates the use of competitive formats. This is particularly useful in the detection of Zika virus antibodies in sample. In competition-based assays, an unknown amount of analyte or antibody is determined by its ability to displace a known amount of labeled antibody or analyte. Thus, the quantifiable loss of a signal is an indication of the amount of unknown antibody or analyte in a sample.

10 Here, the inventor proposes the use of labeled Zika virus monoclonal antibodies to determine the amount of Zika virus antibodies in a sample. The basic format would include contacting a known amount of Zika virus monoclonal antibody (linked to a detectable label) with Zika virus antigen or particle. The Zika virus antigen or organism is preferably attached to a support. After binding of the labeled monoclonal antibody to the support, the sample is
15 added and incubated under conditions permitting any unlabeled antibody in the sample to compete with, and hence displace, the labeled monoclonal antibody. By measuring either the lost label or the label remaining (and subtracting that from the original amount of bound label), one can determine how much non-labeled antibody is bound to the support, and thus how much antibody was present in the sample.

20

B. Western Blot

The Western blot (alternatively, protein immunoblot) is an analytical technique used to detect specific proteins in a given sample of tissue homogenate or extract. It uses gel electrophoresis to separate native or denatured proteins by the length of the polypeptide
25 (denaturing conditions) or by the 3-D structure of the protein (native/ non-denaturing conditions). The proteins are then transferred to a membrane (typically nitrocellulose or PVDF), where they are probed (detected) using antibodies specific to the target protein.

Samples may be taken from whole tissue or from cell culture. In most cases, solid tissues are first broken down mechanically using a blender (for larger sample volumes), using
30 a homogenizer (smaller volumes), or by sonication. Cells may also be broken open by one of the above mechanical methods. However, it should be noted that bacteria, virus or environmental samples can be the source of protein and thus Western blotting is not restricted to cellular studies only. Assorted detergents, salts, and buffers may be employed to encourage lysis of cells and to solubilize proteins. Protease and phosphatase inhibitors are often added to

prevent the digestion of the sample by its own enzymes. Tissue preparation is often done at cold temperatures to avoid protein denaturing.

The proteins of the sample are separated using gel electrophoresis. Separation of proteins may be by isoelectric point (pI), molecular weight, electric charge, or a combination of these factors. The nature of the separation depends on the treatment of the sample and the nature of the gel. This is a very useful way to determine a protein. It is also possible to use a two-dimensional (2-D) gel which spreads the proteins from a single sample out in two dimensions. Proteins are separated according to isoelectric point (pH at which they have neutral net charge) in the first dimension, and according to their molecular weight in the second dimension.

In order to make the proteins accessible to antibody detection, they are moved from within the gel onto a membrane made of nitrocellulose or polyvinylidene difluoride (PVDF). The membrane is placed on top of the gel, and a stack of filter papers placed on top of that. The entire stack is placed in a buffer solution which moves up the paper by capillary action, bringing the proteins with it. Another method for transferring the proteins is called electroblotting and uses an electric current to pull proteins from the gel into the PVDF or nitrocellulose membrane. The proteins move from within the gel onto the membrane while maintaining the organization they had within the gel. As a result of this blotting process, the proteins are exposed on a thin surface layer for detection (see below). Both varieties of membrane are chosen for their non-specific protein binding properties (*i.e.*, binds all proteins equally well). Protein binding is based upon hydrophobic interactions, as well as charged interactions between the membrane and protein. Nitrocellulose membranes are cheaper than PVDF but are far more fragile and do not stand up well to repeated probings. The uniformity and overall effectiveness of transfer of protein from the gel to the membrane can be checked by staining the membrane with Coomassie Brilliant Blue or Ponceau S dyes. Once transferred, proteins are detected using labeled primary antibodies, or unlabeled primary antibodies followed by indirect detection using labeled protein A or secondary labeled antibodies binding to the Fc region of the primary antibodies.

C. Lateral Flow Assays

Lateral flow assays, also known as lateral flow immunochromatographic assays, are simple devices intended to detect the presence (or absence) of a target analyte in sample (matrix) without the need for specialized and costly equipment, though many laboratory-based applications exist that are supported by reading equipment. Typically, these tests are used as

low resources medical diagnostics, either for home testing, point of care testing, or laboratory use. A widely spread and well-known application is the home pregnancy test.

The technology is based on a series of capillary beds, such as pieces of porous paper or sintered polymer. Each of these elements has the capacity to transport fluid (*e.g.*, urine) spontaneously. The first element (the sample pad) acts as a sponge and holds an excess of sample fluid. Once soaked, the fluid migrates to the second element (conjugate pad) in which the manufacturer has stored the so-called conjugate, a dried format of bio-active particles (see below) in a salt-sugar matrix that contains everything to guarantee an optimized chemical reaction between the target molecule (*e.g.*, an antigen) and its chemical partner (*e.g.*, antibody) that has been immobilized on the particle's surface. While the sample fluid dissolves the salt-sugar matrix, it also dissolves the particles and in one combined transport action the sample and conjugate mix while flowing through the porous structure. In this way, the analyte binds to the particles while migrating further through the third capillary bed. This material has one or more areas (often called stripes) where a third molecule has been immobilized by the manufacturer. By the time the sample-conjugate mix reaches these strips, analyte has been bound on the particle and the third 'capture' molecule binds the complex. After a while, when more and more fluid has passed the stripes, particles accumulate and the stripe-area changes color. Typically there are at least two stripes: one (the control) that captures any particle and thereby shows that reaction conditions and technology worked fine, the second contains a specific capture molecule and only captures those particles onto which an analyte molecule has been immobilized. After passing these reaction zones, the fluid enters the final porous material – the wick – that simply acts as a waste container. Lateral Flow Tests can operate as either competitive or sandwich assays. Lateral flow assays are disclosed in U.S. Patent 6,485,982.

25 **D. Immunohistochemistry**

The antibodies of the present disclosure may also be used in conjunction with both fresh-frozen and/or formalin-fixed, paraffin-embedded tissue blocks prepared for study by immunohistochemistry (IHC). The method of preparing tissue blocks from these particulate specimens has been successfully used in previous IHC studies of various prognostic factors and is well known to those of skill in the art (Brown *et al.*, 1990; Abbondanzo *et al.*, 1990; Allred *et al.*, 1990).

Briefly, frozen-sections may be prepared by rehydrating 50 ng of frozen “pulverized” tissue at room temperature in phosphate buffered saline (PBS) in small plastic capsules; pelleting the particles by centrifugation; resuspending them in a viscous embedding medium

(OCT); inverting the capsule and/or pelleting again by centrifugation; snap-freezing in -70°C isopentane; cutting the plastic capsule and/or removing the frozen cylinder of tissue; securing the tissue cylinder on a cryostat microtome chuck; and/or cutting 25-50 serial sections from the capsule. Alternatively, whole frozen tissue samples may be used for serial section cuttings.

5 Permanent-sections may be prepared by a similar method involving rehydration of the 50 mg sample in a plastic microfuge tube; pelleting; resuspending in 10% formalin for 4 hours fixation; washing/pelleting; resuspending in warm 2.5% agar; pelleting; cooling in ice water to harden the agar; removing the tissue/agar block from the tube; infiltrating and/or embedding the block in paraffin; and/or cutting up to 50 serial permanent sections. Again, whole tissue
10 samples may be substituted.

E. Immunodetection Kits

 In still further embodiments, the present disclosure concerns immunodetection kits for use with the immunodetection methods described above. As the antibodies may be used to
15 detect Zika virus or Zika virus antigens, the antibodies may be included in the kit. The immunodetection kits will thus comprise, in suitable container means, a first antibody that binds to Zika virus or Zika virus antigen, and optionally an immunodetection reagent.

 In certain embodiments, the Zika virus antibody may be pre-bound to a solid support, such as a column matrix and/or well of a microtiter plate. The immunodetection reagents of the
20 kit may take any one of a variety of forms, including those detectable labels that are associated with or linked to the given antibody. Detectable labels that are associated with or attached to a secondary binding ligand are also contemplated. Exemplary secondary ligands are those secondary antibodies that have binding affinity for the first antibody.

 Further suitable immunodetection reagents for use in the present kits include the two-
25 component reagent that comprises a secondary antibody that has binding affinity for the first antibody, along with a third antibody that has binding affinity for the second antibody, the third antibody being linked to a detectable label. As noted above, a number of exemplary labels are known in the art and all such labels may be employed in connection with the present disclosure.

 The kits may further comprise a suitably aliquoted composition of the Zika virus or
30 Zika virus antigens, whether labeled or unlabeled, as may be used to prepare a standard curve for a detection assay. The kits may contain antibody-label conjugates either in fully conjugated form, in the form of intermediates, or as separate moieties to be conjugated by the user of the kit. The components of the kits may be packaged either in aqueous media or in lyophilized form.

The container means of the kits will generally include at least one vial, test tube, flask, bottle, syringe or other container means, into which the antibody may be placed, or preferably, suitably aliquoted. The kits of the present disclosure will also typically include a means for containing the antibody, antigen, and any other reagent containers in close confinement for commercial sale. Such containers may include injection or blow-molded plastic containers into which the desired vials are retained.

F. Vaccine and Antigen Quality Control Assays

The present disclosure also contemplates the use of antibodies and antibody fragments as described herein for use in assessing the antigenic integrity of a viral antigen in a sample. Biological medicinal products like vaccines differ from chemical drugs in that they cannot normally be characterized molecularly; antibodies are large molecules of significant complexity and have the capacity to vary widely from preparation to preparation. They are also administered to healthy individuals, including children at the start of their lives, and thus a strong emphasis must be placed on their quality to ensure, to the greatest extent possible, that they are efficacious in preventing or treating life-threatening disease, without themselves causing harm.

The increasing globalization in the production and distribution of vaccines has opened new possibilities to better manage public health concerns but has also raised questions about the equivalence and interchangeability of vaccines procured across a variety of sources. International standardization of starting materials, of production and quality control testing, and the setting of high expectations for regulatory oversight on the way these products are manufactured and used, have thus been the cornerstone for continued success. But it remains a field in constant change, and continuous technical advances in the field offer a promise of developing potent new weapons against the oldest public health threats, as well as new ones - malaria, pandemic influenza, and HIV, to name a few - but also put a great pressure on manufacturers, regulatory authorities, and the wider medical community to ensure that products continue to meet the highest standards of quality attainable.

Thus, one may obtain an antigen or vaccine from any source or at any point during a manufacturing process. The quality control processes may therefore begin with preparing a sample for an immunoassay that identifies binding of an antibody or fragment disclosed herein to a viral antigen. Such immunoassays are disclosed elsewhere in this document, and any of these may be used to assess the structural/antigenic integrity of the antigen. Standards for

finding the sample to contain acceptable amounts of antigenically correct and intact antigen may be established by regulatory agencies.

Another important embodiment where antigen integrity is assessed is in determining shelf-life and storage stability. Most medicines, including vaccines, can deteriorate over time.

5 Therefore, it is critical to determine whether, over time, the degree to which an antigen, such as in a vaccine, degrades or destabilizes such that it is no longer antigenic and/or capable of generating an immune response when administered to a subject. Again, standards for finding the sample to contain acceptable amounts of antigenically intact antigen may be established by regulatory agencies.

10 In certain embodiments, viral antigens may contain more than one protective epitope. In these cases, it may prove useful to employ assays that look at the binding of more than one antibody, such as 2, 3, 4, 5 or even more antibodies. These antibodies bind to closely related epitopes, such that they are adjacent or even overlap each other. On the other hand, they may represent distinct epitopes from disparate parts of the antigen. By examining the integrity of
15 multiple epitopes, a more complete picture of the antigen's overall integrity, and hence ability to generate a protective immune response, may be determined.

Antibodies and fragments thereof as described in the present disclosure may also be used in a kit for monitoring the efficacy of vaccination procedures by detecting the presence of protective Zika virus antibodies. Antibodies, antibody fragment, or variants and derivatives
20 thereof, as described in the present disclosure may also be used in a kit for monitoring vaccine manufacture with the desired immunogenicity.

VI. Examples

The following examples are included to demonstrate preferred embodiments. It should
25 be appreciated by those of skill in the art that the techniques disclosed in the examples that follow represent techniques discovered by the inventor to function well in the practice of embodiments, and thus can be considered to constitute preferred modes for its practice. However, those of skill in the art should, in light of the present disclosure, appreciate that many changes can be made in the specific embodiments which are disclosed and still obtain a like or
30 similar result without departing from the spirit and scope of the disclosure.

Example 1 - Memory B Cell Sorting and Antibody Genes Sequencing

The frequency of Zika E2-specific memory B cells in human immune donors is estimated to be low. Therefore, the inventors first assessed B cell response to ZIKV in PBMCs from a cohort of 11 donors with previous exposure to the ZIKV Asian lineage to identify donors with the highest response. Using African ZIKV lineage soluble recombinant E2 protein, the antigen that was used previously used to identify potent ZIKV mAbs, the inventors enumerated the frequency of ZIKV-specific B cells from PBMCs of the 11 donors. Briefly, B cells were purified magnetically and stained with phenotyping antibodies, a viability dye, and biotinylated E2. Antigen-labeled class-switched memory B cell-E2 complexes (CD19+IgM-IgD-IgA-E2+DAPI-) were detected with fluorescently-labeled streptavidin and quantified using a four-color flow cytometric approach (FIG. 1A). This study revealed that E2-specific B cells were readily detected in PBMCs in 7 of 11 ZIKV-immune donors with frequencies that ranged from 0.4 to 2.5% of IgG class-switched memory B cells (data not shown); the background staining of ZIKV non-immune PBMCs was 0.2%. After identification of the seven donors with the highest B cell response against ZIKV, the inventors used FACS to isolate E2-specific memory B cells from pooled PBMCs of these donors. Sorting with a biotinylated E2 antigen has been used successfully used for isolation of human neutralizing ZIKV mAbs; however, the inventors considered that this approach might miss identification of mAbs with some specificities if those antigenic sites are altered by the chemical nature of biotin coupling to proteins. To increase the diversity of the inventors' mAb panel for epitope specificities, they employed two labeling approaches (FIG. 1B), and also applied different E2-specific B cell gating strategies, which resulted in the generation of three independent sub-panels of mAbs. The first labeling approach included sorting with biotinylated E2 (sub-panel 1). The second labeling approach identified the subset of B cells that were fusion loop (FL)-specific mAbs, which dominate in the response to ZIKV but typically poorly neutralize the virus. The inventors use competition binding of their previously identified FL-specific mAb ZIKV-88 to identify such clones. The inventors labeled with intact E2 and then applied the new ZIKV followed by ZIKV-88. If the new mAb blocked ZIKV-88 binding, these FL-specific B cells were eliminated from the panel. To diversify the panel further, the inventors sorted all labeled B cells (as in sub-panel 2) and a particular subset of high-affinity B cells (high E2 labeling clones, sub-panel 3) separately.

Overall, from $> 5 \times 10^8$ PBMCs, $> 5,000$ E2-specific B cells were sorted and subjected to further analysis.

To rescue the paired heavy and light chain antibody sequences, the inventors used a commercial single-cell gene expression automated system (10x Genomics Chromium sequencing technology). This sequencing approach has an advantage over other existing mAb gene rescuing methods because, in addition to chains pairing, it also allows identification of heavy chain subclass/isotype, as well as, accurate sequencing of the framework 1 and 4 regions. Another desirable feature of this platform is the unprecedented scale of paired antibody analysis, with up to 100,000 individual cells/mAb sequences per single experiment. In addition, because each mAb sequence has a unique molecular identifier, it can be expressed and tested individually without the need to generate a library. This feature also eliminates the need to perform repeated selection sequencing to identify the desired mAb. The inventors' previous work with other viral targets (unpublished data) has shown relatively low recovery (~10%) of antibody variable gene sequences, which is likely attributed to the low levels of IgG mRNA in memory B cells and the challenging nature of single cell amplification. In this study, the inventors assessed two methods for the preparation of sorted B cells for sequencing. Approximately 800 sorted cells were subjected to direct sequencing right after flow cytometric sorting (sub-panel 3). The remaining cells were bulk-expanded in culture for 8 days in the presence of irradiated 3T3 feeder cells (FIG. 1C) that were engineered to express human CD40L, IL-21, and BAFF. The expanded lymphoblastoid cell lines (LCLs) secreted high levels of E2-specific mAbs, as confirmed by ELISA from culture supernatants and had at least 10-fold higher number of cells when compared to the input cells (data not shown). Expanded LCLs then were sequenced using 10x Genomics' technology.

Using bioinformatics sieving, the inventors down-selected the total pool of possible sequences to choose just 598 paired sequences for further study (FIG. 1D). The down-selection was carried out in two phases. In the first phase all paired heavy and light chain nucleotide sequences obtained that contained a single heavy and light chain sequence were processed using the inventors' PyIR tool (github.com/crowelab/PyIR). All heavy and light chain pairs that did not contain a stop codon, had an intact CDR3 and contained a productive junction region were considered productive and retained for additional downstream processing.

The second phase of processing reduced all heavy chain nucleotide sequences to their V3J clonotypes [PMID: 30760926] (clones sharing a common inferred VH and JH gene and identical amino acids in the CDR3). This step was accomplished by first determining all heavy chain V3J clonotypes shared between samples A, B and C. The somatic variants associated

with each heavy chain V3J clonotype then were rank-ordered, and only the most mutated heavy chain sequence was kept for downstream expression and characterization. Any somatic variant that was not of the IgG isotype (based on the sequence and assignment by the Chromium Cell Ranger analysis pipelines) was removed from consideration. All heavy-light chain nucleotide sequences were translated, and redundant entries removed to avoid expressing identical mAbs.

Previous ZIKV-specific mAb discovery efforts have identified a public clonotype for domain III-specific antibodies, for instance the VH3-23*04/D3-10*01/JH4*02 (heavy chain) + VK1-5*03/J1*01 (light chain) clonotype of mAb ZIKV-116 (*Nature*, 2016 Dec 15; 540(7633): 443–447) and antibodies subsequently reported from independent donors (*Cell*, 2017 May 4; 169(4): 597–609.e11.) Comparison of the new antibody variable gene sequences obtained to those previously reported for human ZIKV mAbs did not identify any members of public clonotypes. These results suggested that the new panel of ZIKV mAbs identified a unique collection of clonotypes. Sequences of all 598 selected ZIKV mAb candidates were synthesized using a high-throughput cDNA synthesis platform (Twist Bioscience) and cloned into an IgG1 expression vector for mammalian cell culture mAb secretion.

In summary, the inventors obtained hundreds of human mAb sequences from B cells of ZIKV immune donors that were ready for recombinant expression and functional validation with unprecedented speed, scale and efficiency. The data demonstrated the inventors' capabilities for the customized target-specific B cell selection and large-scale human antibody discovery when viral antigen is available.

Example 2 - High-Throughput mAb Expression and Screening for Binding and Neutralizing Activities

To characterize the mAb panel and identify lead candidates for *in vivo* protection studies, the inventors expressed all 598 ZIKV mAb candidates recombinantly. They adopted and optimized several high-throughput techniques that allowed rapid production and analysis of mAbs from small sample volumes (0.1 to 1 mL) in a 96-well plate format (defined as “micro-scale”). As an example, >1,000 individual recombinant mAbs can be produced, purified, and quantified starting from plasmid DNA in less than five days (FIG. 2A, left panel)—with enough purified protein to fully characterize the activity of individual mAbs and identify lead candidates for *in vivo* study. To produce individual mAbs in a high-throughput manner, the inventors performed microscale transient transfection of Chinese hamster ovary (CHO) cell cultures. High-throughput and semi-automated IgG quantification analysis by the iQue Screener Plus (Intellicyt Corp) flow cytometer showed detectable production levels (> 5

microgram mAb/mL CHO culture) for most mAbs in the panel when culture supernatants were assessed as early as day 3 after transfection (data not shown). 475 of 598 mAbs were expressed successfully and affinity purified in the micro-scale format. The mAb yield from micro-scale transfected CHO cultures (1 mL per transfection) ranged from 0.5 microgram (the detection
5 limit for the IgG quantification assay) to 300 g, with a median of 29 g per purified antibody (FIG. 2A, right panel). This result shows the high utility of micro-scale methods for rapid isolation of purified mAbs.

For rapid identification of neutralizing mAbs within the large panel, the inventors used a real-time cell analysis (RTCA) cellular impedance assay and an xCelligence (Acea
10 Biosciences) analyzer. RTCA is based on microelectronic biosensor technology, which monitors kinetic changes in cell physiology, including virus-induced cytopathic effect (CPE) (FIG. 2B, top and middle panels). One xCelligence unit has the capacity for mid-throughput CPE kinetics analysis: up to 576 individual mAbs can be assessed simultaneously and monitored in a real-time perwell basis for neutralizing activity, and multiple units can be used
15 (6 x 96 well E-plates per unit) (FIGS. 3Ba-c). From a comparative side-by-side study, the inventors found that impedance-based CPE kinetics assay performed similarly to a conventional focus-reduction neutralization test (FRNT) for ZIKV. In summary, both assays identified the same neutralizing mAbs from the panel, and neutralizing mAbs were ranked similarly by their potency from half-maximal inhibitory concentration (IC₅₀) measurements in
20 each assay (data not shown). However, the xCelligence platform offered a clear advantage for the large mAb panel analysis due to its' speed— 24 to 36 hours for the initial qualitative identification of neutralizing activity (vs. 5 to 6 days for the conventional FRNT assay), and about 60 hours for full CPE kinetics and IC₅₀ values determination for ZIKV mAbs. As an example, in seven days the inventors performed three subsequent rounds of mAb testing against
25 ZIKV. These included (1) initial analysis for identification of neutralizing mAb activity from unpurified CHO culture supernatants, (2) repeated analysis with a single concentration of each purified mAb against two viruses (ZIKV Brazil and Dakar to confirm activity of those identified in (1) and to check for neutralization breadth), and (3) ranking of identified neutralizing mAbs by their potency (estimated IC₅₀ values) against both viruses using a dose-response curves analysis. The inventors' previous work with the H3N2 influenza virus and a
30 larger panel of 1,100 mAbs that were isolated from plasmablasts by a similar 10x Genomics' sequencing approach indicated that with a faster-replicating virus, potentially neutralizing antibodies can be identified, fully characterized, and ranked by their potency in less than three days using an RTCA assay (unpublished and data not shown).

To characterize the panel of 598 micro-scale purified human mAbs, the inventors assessed their binding to recombinant E2 antigen via ELISA, along with their neutralizing activity via RTCA. Approximately 15% percent (92/598) of the mAbs bound strongly to E2 and 8% (48/598) of the mAbs possessed neutralizing activity against at least one ZIKV strain when tested at a single dilution from a purified sample (FIGS. 2C-D). Interestingly, 14 strongly neutralizing mAbs did not show detectable binding to the recombinant E2 antigen by ELISA (OD₄₅₀ nm <0.4 at 2 microgram/mL of mAb), giving a total of 106 ZIKV-specific mAbs from the panel (92 E2-reactive plus 14 E2-non-reactive neutralizing). This finding suggested that the conformation of the plate-bound E2 antigen differs from that of the conformation of the E2 antigen in solution, which is how it was presented during the B cell labeling procedure for sorting. This finding also may explain the relatively low observed frequency of E2-reactive mAbs among the ZIKV panel (about 15%) when compared to the inventors' previous data with a similar sorting strategy using ebolavirus glycoprotein antigen (unpublished and data not shown).

Our subjects had been infected with an Asian strain ZIKV during the recent outbreak in South America. Twenty-nine mAbs of the panel neutralized both antigenically homologous (Brazil strain; Asian lineage) and heterologous (Dakar strain; African lineage) viruses (data not shown). Twenty mAbs that fully neutralized at least one of two tested viruses (as determined from a single sample dilution panel screen) were considered as lead candidates for *in vivo* protection studies and were characterized further. Dose-response neutralization curves showed potent neutralization of Dakar or Brazil viruses or both viruses, with RTCA estimated IC₅₀ values ranging from about 7 to 1,100 ng/mL (FIG. 2E). The three most potent mAbs (ZIKV-491, -350, and -538) cross-neutralized Brazil and Dakar with IC₅₀ values below 100 ng/mL but exhibited differential binding to recombinant E2. ZIKV-350 bound strongly, ZIKV-538 bound weakly, and binding of ZIKV-491 was not detected at the highest mAb concentration tested (10 microgram/mL) (FIGS. 3Aa-Bc). Competition-binding analysis with reference ZIKV E2-specific human mAbs ZIKV-117 (recognizing the dimer-dimer interface), ZIKV-116 (domain III), and ZIKV-88 (FL) from the inventors' previous work, showed that the three newly identified neutralizing ZIKV-491, -350, and -538 recognized distinct, non-overlapping epitopes. This conclusion was supported by epitope mapping data from binding analysis to an alanine mutant library of cell surface-displayed E2 antigen, which revealed three distinct epitopes for ZIKV-491, -350, and -538 (FIGS. 3Ca-c). Remarkably, these mAbs were identified from different E2-antigen sorting strategies, where ZIKV-491 was from sub-panel 2, and ZIKV-350 and -538 were from sub-panels 1 or 3, respectively. This finding highlighted

the importance of study design in the antibody discovery workflow, which may rely on several independent strategies for B cell isolation to identify potent mAbs of diverse epitope specificity, and also has high relevance for the discovery of mAbs for therapeutic cocktails with complementary specificity and activity.

5 The inventors have now identified four distinct groups of antibodies. Group 1 antibodies are presumably binding to domain III, compete with ZIKV-116 and bind to recombinant E2 strongly by ELISA. ZIKV-350 is a Group 1 antibody. Group 2 antibodies are presumably domain II, compete with ZIKV-117, and bind to recombinant E2 strongly by ELISA. ZIKV-207 and ZIKV-604 are Group 2 antibodies. Group 3 antibodies do not compete
10 with any reference mAbs including ZIKV-88(FL), ZIKV-116 (DIII) and ZIKV-117 (DII), and bind to recombinant E2 strongly by ELISA. ZIKV-538 and ZIKV-578 are Group 3 antibodies. Group 4 antibodies bind weakly to recombinant E2 by ELISA, bind unfixed cells co-expressing prM/E – furin, and are quaternary epitopes. ZIKV-491 and ZIKV-233 antibodies are Group 4 antibodies.

15 In summary, these data demonstrate the high utility of newly developed assays in an integrated workflow and demonstrated the inventors' capabilities for accelerated production and analysis of large panels of recombinant human antibodies to identify lead candidates for *in vivo* studies.

20 **Example 3 - Protective Efficacy of Identified mAbs in Lethal ZIKV Challenge Mouse Model**

 The inventors next used a lethal mouse challenge model for ZIKV to determine the protective capacity of the neutralizing mAbs selected as lead candidates. For prophylaxis
25 treatments, groups of four-week old C57Bl6/J (B6) mice (n=5 to 14 mice per group) were treated intra-peritoneally (i.p.) with anti-IFN-alpha receptor antibody and individual ZIKV mAbs on day -1. An irrelevant IgG1 isotype mAb (FLU-5J8, which is specific to influenza A virus hemagglutinin) served as a control. On day 0, mice were challenged subcutaneously (s.q.) with 1,000 focus-forming units (FFU) of mouse-adapted ZIKV Dakar virus (ZIKV-MA) and
30 monitored for 21 days for survival. High dose prophylaxis (about 70 microgram of mAb per mouse, which corresponded to about 5 mg/kg mAb dose for a 14 g four-week old mouse) provided complete protection from mortality by three of the five tested mAbs when compared to the control group ($p=0.049$ for ZIKV-233, -350, and -491); $p \leq 0.05$ was considered significant by log-rank test). MAb ZIKV-266 offered partial although not significant protection
35 and mAb ZIKV-32 did not protect (FIG. 4A). Given the full protection with high-dose mAb

prophylaxis, the inventors next tested a larger panel of ten neutralizing mAbs (FIGS. 4A-D) with a low-dose prophylaxis approach (using about 9 micrograms of mAb per mouse, which corresponded to about 0.65 mg/kg mAb dose for a 14 g four-week old mouse). As an early timepoint correlate of mAb-mediated protection, the inventors determined plasma virus titers from individual mice of each treatment group by real-time quantitative PCR (RT-qPCR) analysis. Remarkably, all groups that were treated with ZIKV mAbs showed significantly reduced plasma titers by 2 dpi (median viral load ranged from 3 to 3.7 log₁₀ genome equivalents (GEQ) per mL) when compared to the control mAb FLU-5J8-treated group that developed high viremia in all animals with a median viral load of 6.4 log₁₀ genome equivalents (GEQ) per mL of plasma (FIG. 4B). Of note, virus was undetectable in the plasma of many animals in the ZIKV mAb treatment groups (limit of detection = 2.9 log₁₀ (GEQ/mL), suggesting efficient inhibition of the viremia by a low dose of antibody in prophylaxis settings. Consistent with the reduced viral load in plasma, all tested mAbs conferred significant protection against disease, as judged by reduced and/or delayed mortality when compared to the mAb FLU-5J8-treated group in which all mice succumbed to the disease by 10 dpi ($p \leq 0.05$ was considered significant by log-rank test) (FIG. 4C). Three of ten tested cross-neutralizing mAbs (ZIKV-233, 266, and 491) conferred complete protection (100% mice survived), and the protection by the other two cross-neutralizing mAbs, ZIKV-350 and ZIKV-538, was partial but highly significant ($p < 0.001$ by log-rank test) as estimated with study of 5 to 13 animals per each group (FIG. 4C). The above results demonstrate a high level of prophylaxis efficacy for some newly identified mAbs against ZIKV.

Given the high level of protection with low-dose prophylaxis treatment for these clones, the inventors next tested therapeutic efficacy by using a low dose of mAb (about 9 micrograms of mAb per mouse, corresponding to about 0.65 mg/kg mAb dose for a 14 g four-week old mouse) that was provided to mice on 1 dpi. They chose to test three mAbs ZIKV-350, -491, and -538 because of their features, which included broad and potent neutralization of ZIKV (Brazil and Dakar; FIG. 2E, FIGS. 3Ba-c), recognition of distinct, non-overlapping epitopes of E2 (FIGS. 3Ca-c), and a high level of protection with prophylaxis treatment (FIG. 4C). Remarkably, ZIKV-491 and -538 conferred complete protection with a relatively low mAb dose in the therapeutic treatment setting (FIG. 4D). Together, these results demonstrate the high level of therapeutic efficacy for newly identified neutralizing mAbs against ZIKV and suggest new promising candidates for testing in the rhesus macaque (nonhuman primate - NHP) ZIKV challenge model.

In summary, the inventors identified many potent neutralizing and protective human mAbs against ZIKV with unprecedented speed, scale, and efficiency (Table A; FIG. 5). The inventors' data provided a roadmap for large-scale discovery of potent anti-viral human monoclonal antibody therapeutics against known viral antigens.

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Table A. Summary of binding, neutralizing, and protective properties for panel of rapidly discovered human mAbs against ZIKV

Featured mAbs properties	Number of mAbs
Panel size	598
ZIKV E2-reactive (binding)	92
ZIKV-specific (E2-reactive + neutralizers that don't bind E2)	106
ZIKV neutralizing	48
Broadly neutralizing (Brazil and Dakar)	29
Highly protective (12.5 or 100 ug IgG per mouse)*	4 (of 11 tested)

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- Offered complete protection from mortality by prophylaxis in mice as shown in FIGS. 4A-D

Table B. Correspondence chart for antibody naming/designations

ZIKV-120766-21	21	ZIKV-423
ZIKV-120763-32	32	ZIKV-434
ZIKV-120764-116	116	ZIKV-518
ZIKV-120764-206	206	ZIKV-608
ZIKV-120764-207	207	ZIKV-609
ZIKV-120765-222	222	ZIKV-624
ZIKV-120765-233	233	ZIKV-635
ZIKV-120765-250	250	ZIKV-652
ZIKV-120765-266	266	ZIKV-668
ZIKV-120765-279	279	ZIKV-681
ZIKV-120764-280	280	ZIKV-682
ZIKV-120764-282	282	ZIKV-684
ZIKV-120764-350	350	ZIKV-752
ZIKV-120764-467	467	ZIKV-869
ZIKV-120765-491	491	ZIKV-893
ZIKV-120765-520	520	ZIKV-922
ZIKV-2834-538	538	ZIKV-940
ZIKV-2834-578	578	ZIKV-980
ZIKV-2834-604	604	ZIKV-1006
ZIKV-2834-605	605	ZIKV-1007

TABLE 1 – NUCLEOTIDE SEQUENCES FOR ANTIBODY VARIABLE REGIONS

Clone	SE Q ID NO:	Chain	Variable Sequence Region
ZIKV- 120766-21	1	heavy	GAAGTGCAGTTGTTGGAGTCGGGGAGGGCTTGGTACAGCCTGGGGTCCCTGAGACTCTCATGTGCAG CCTCTGGATTACCTTTAGCAACTATGGCGTGGGCTGGTCCGCCAGGCTCCAGGTTCGGGACTTGAATGG GTCTCATCTATTAAACAGGCTGGTGACAGCACATACTACGCCGGCTCGTGAAGGCCGCTTACCACATCTCC AGAGACAACCTCCAAGAACACACTATTTCTGCAATGAACAGCCTGAGAGACGAAGACACGGCCGTATATTT CTGTGCGAAAAGATCGGACGTGAGGGGGTTTCGGGGAGTTATTCAAACACTGGGGACAGGGAAACCCCTGGTC ACCGTCTCCTCA
		light	GACATCCAGATGACCCAGTCTCCTCCACCCTGTCTGTCATCTGTAGGAGACAGAGTCACCATCACTTGCCGG GCCAGTCAGAGTATTAA TAGCTGGTGGCTGGTTTTCAGCAGAAAGCCAGGAAAGCCCTAAACTCCTGATC CACAAAGGCTCAAGTTAGAAAGTGGGTCCCATTTAGTTTCAGCGCAGTGGATCTGGGACAGAAATTCAC TCTCACCATCAACAGCCTGCAGCCTGATGACTTTGCAACTTACTACTGCCAACACTATCATAGTTATCCGTGG ACGTTCGGCCAAGGGACCAAGGTGGAATCAAA
		heavy	GAGGTCCAACCTGTTGGAGTCTGGGGAGGCTTGGTTCTCCTGGGGGTCCCTGAGACTCTCCTGTGCAGC CTCTGGATTCACCTTCAGTAGTTATGAAATGAACCTGGGTCCGCCAGGCTCCAGGGAGGGGCTGGAGTGGG TTTCACACATTAGTCTAGTGGTTAGCAAAGACTATTTCAGACTCTGTGAAGGGCCGATTACCATCTTCAG AGACAACGCCAAGGACTTGTATCTACAAATGAACGGCTGAGAGCCGACGACACGGCTGTTTATTACT GTGCGAGAGATCGGTACGATTTTGGAGTGGTGACCCCATGGGTACTTTGACTACTGGGGCCAGGGAACC CTGGTCACCGTCTCCTCA
ZIKV- 120763-32	4	light	GACATCCAGATGACCCAGTCTCCATCCTCCTCTGTCATCTGTAGGAGACAGAGTCACCATCACTTGCCAG GCGAGTCAGGACATTACCAACTATTTAAATGGTATCAGCAGAAACCCAGGAAAGCCCTAAACTCCTGATC TATAAGGCGTCTAGTTAGAAAGTGGGTCCCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAAATTCAC TCTCACCATCAGCAGCCTGCAGCCTGATGATTTTGCAACTTATTACTGCCAACAGTATAATAGAGGTTCTGTGG ACGTTTCGGCCAAGGGACCAAGGTGGAATCAAA
		heavy	GAGGTGCAGCTGGTGCAGTCTGGAGCAGAGGTGAAAAAGCCCGGGGAGTCTCTGAGGATCTCCTGTGAGA GTTTTGGATACACCTTTAGCAACTACTGGATCACCTGGGTGCGCAGGTGCCCCGGAAGGCGCTGGAATGG
		heavy	GAGGTGCAGCTGGTGCAGTCTGGAGCAGAGGTGAAAAAGCCCGGGGAGTCTCTGAGGATCTCCTGTGAGA GTTTTGGATACACCTTTAGCAACTACTGGATCACCTGGGTGCGCAGGTGCCCCGGAAGGCGCTGGAATGG

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			ATGGGGAAGATTGATCCTAATGACCCCTTATCAACTACAGTCGCGCCTCCGTGGGACGTTATCATCTCAG TTGACAAAGTCCATCAAGACTGCCTACTTGAGTGAGCAGCCTGAAGGCCTCGGACACCGCCATGTATTACT GTGCGAGAGCGACATATAGTAGTTCGTATGACTACTGTGTAATCGATGTCTGGGCGCGTGGCACCCCTGGTC ACTGTCTCCTCA
	6	light	TCCTATGTGCTGACTCAGCCACCCTCGGTGTAGTGGCCCCCAGACAGCGCCAGGATCACCTGTGGGGG AAACAACATTGGAAGTAAAGTGTGAGTGCCAGCAGAGCCAGGCCAGGCCCTGTGCTGGTCTGTCT ATGATGATAGCGACCGCCCTCAGGGATCCCTGAGCGATTCTGTGCTCCAACTCTGGAAACACGGCCACC CTGACCATCAGCAGGGTCGAAGCCGGGATGAGGCCGACTATTACTGTCAAGTGTGGGATGATAGTAGTG ATCAATGGGTGTTCCGGGAGGGACCAAGGTGACCGTCCTA
ZIKV- 120764-206	7	heavy	GAGGTGCTTTTGGTGAGTCTGGGGAGGCTGTACAGCCTGGGGGTCCCTGAGACTCTCCTGTGAAG CCTCTGGATTCTCCTTTAGTAGATATGCCATGAACTGGTCCGCCAGCGCCAGGAAGGACTGGAGTGG GTCTCAACCATTAACCGTTGATGGGGCAGCACATACTACGAGGCTCCGTGAGGGCCGATTCAACCATCTCC AGAGACAAATCCAAGAAACAACTGTATCTGCAATGAACAGCTGAGAGCCGAGACACGGCCCTATATTA CTGTGCGAAAAGATCGGCCCTCTCTGGGGTGGGGAGTTATATGACTACTGGGTGAGGGAACGCTGGTC ACCGTCTCTCA
	8	light	GACATCCAGATGACCCAGTCTCCTCCACCCTGTCTGCATCTGTGGGAGACAGATCACCATCACTTGCCGG GCCAGTCAGAGTATTAGTAGTGGTTGGCTGGTATCAGCAGAAACAGGGAAGCCCTAAGCTCCTGAT CTATAAGGCGTCTAGTTAGAAAGTGGGTCCCATCAAGGTTCAAGCGGAGTGGATCTGGGACAGAATTCA CTCTCACCATCAGCAGCCTGCAGCCTGATGATTTTGCAACTTATTACTGCCAACAGTATAATAGTTATCCGTG GACGTTCCGCAAGGGACCAAGGTGGAAATCAAA
ZIKV- 120764-207	9	heavy	GAGGTGCATCTCTTGGAGTCTGGGGAGGCTTGGTGAAGTCTGGGGGTCCCTGAGACTCTCCTGTGCAGC CTCTGGATTACCTTTACCACCTATCCCATGAGCTGGTCCGCCGGCTCCAGGGAAGGGCTGGAGTGGG TCTCAACTATTAGTAATAGTGGTGGTGACACATACTACGAGACTCCGTGAAGGCCGTTCAACCATCTCCA GAGACAATTCGAAGAACATCTGTATCTGCAATGAACAGCCTGAGAGCCGAGGACACGGCCATTTATTACT GTGCCAAAGATCACCCACAGTGGCTGGGATCGCATGAGTGGGGCCAGGGAGCCCGTCAACCGTCTCCTCA
	10	light	TCCTATGTGCTGACTCAGCCACCCTCGGTGTAGTGGCCCCCAGACAGACGGCCAGGATTACCTGTGGGG AAACAACATTGGAAGAAACAAATTGTCACTGGTACAGCAGAGCCAGGCCAGGCCCTGTGCTGGTCTCT ACGATGATAGCGACCGCCCTCAGGGATCCCTGAGCGATTCTGTGCTCCAACTCTGGGAAACACGGCCACC CTGACCATCAGCAGGGTCGAAGCCGGGATGAGCGGACTTTTACTGTCAAGTGTGGGATAGTACTCGTGA TCAATATGTCTTCGGAACCTGGGACCAGCGGTCAACCGTCCTA

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ZIKV- 120765-222	11	heavy	CAGGTGCAGCTGGTGGAGTCTGGGGAGGCTTGTTCAAGCCTGGAGGGTCCCTGAGACTCTCTTGTGCAG CCTCTGGATTACCTTCAGTGACTACTACATGAGTTGGATCCGCCAGGCTCCAGGGAAGGGCTGGAGTGG GTTTCATACATTAGTGGTATTAGTAGTTTCAAACTACGAGACTCTGTGAAGGCCGATTACCATCTCCA GAGACAACGCCAAGAACTCACTGTATCTGCAATGAACAGCCTGAGAGCCGAGACACGGCCGTGTATTAC TGTGGAGAGATAGAAGGCTCTATACCCCTACTACCACTACTACATGAGCGTCTGGGGCAAAAGGGACAC GGTACCGTCTCCTCA
	12	light	CAGTCTGTGCTGACTCAGCCACCTCAGCGTCTGGGACCCCGGGCAGAGGGTCACCATCTTTTGTCTGGA AGCAGCTCCAGCATCCGAAGTAACTCTGTAACTGGTACCAGCAGCTCCAGGAACGGCCCAAACTCCTC ATTCATAGTAATGATCAGCGGCCCTCAGGGGTCCCTGACCGATTCTCTGGCTCAAAGTCTGGCACCTCAGCC TCCCTGGCCATCAGTGGGCTCCAGTCTGAGGATGAGGCTGATTATTACTGTGAGCATGGGATGACAGCCT GAATGGTCGAGTGTTCGGCGAGGGACCAAGCTGACCGTCTCA
ZIKV- 120765-233	13	heavy	CAGGTGCAGCTGGTGGAGTCTGGGGAGGCGTGGTCCAGCCTGGGGGTCCCTGAGACTCTCCTGTGCAG CCTCTGGATTACCTTCAGTGACTATGGCATTCACCTGGTCCGCCAGGCTCCAGGAAGGGCTGGAGTGG GTGGCAGTTATATCATATGATGGAAGTAATAATACTATGCCGACTCCGTGAAGGCCGATTACCATCTCC AGAGACAAATCCAGAACACTCTGTATCTGCAATGAACAGCCTGAGACCTGAGGACACGGCTGTGTATTAC TGTGCGAAAGATTCCGGGGGAGGCGGTGGCAGCAGCTCTCGGAGGTATCTGGGGCCAAGGGACAATG GTACCGTCTCTTCA
	14	light	GATATTGTGATGACTCAGTCTCCTCTCCCTGCCCCGTACCCCTGGAGAGCCGGCCTCCATCTCCTGCAGGT CTAGTCAGAGCCTCCTGCATAGTAATGGATACAACTTTTGGATTGGTACCTGCAGAAGCCGGGCGAGTCTC CACAGCTCCTCATCTATTGGTCTTATCGGGCTCCGGGTCCCTGACAGGTTCAAGTGGCAGTGGATCAG GCACAGATTTTACACTGAAATCAGCAGAGTGGAGGCTGAGGATGTTGGGGTTTATTACTGCATGCAAGCT CTACAACTCCGTGGACGTTCCGGCCAAGGGACCAAGGTGGAATCAAA
ZIKV- 120765-250	15	heavy	GAGGTGCAGCTGTTGGAGTCTGGGGGAACTTGGTACAGCCTGGGGGTCCCTGAGACTCTCCTGTGTAGC CTCTGGATTCACCTTTAGTGGCTATGCCATGAGCTGGTCCGCCAGGCTCCAGGGAAGGGGCTAGAGTGGG TCTCAGCTATTAGTGGTAGTGGTAGACATACACTACGCAGACTCCGTGAAGGCCGTTACCATCTCCA GAGACAATCCAAAGAACACGCTGTTTTGCAATGAACAGCCTGAGAGCGGAGACACGGCCGTATATTAC TGTGCGAAAGTAATTGACCAAGTGGCTGGATTGACTACTGGGGCCAGGGAACTCTGTCACCGTCTCCTCA
	16	light	TCCTATGTGCTGACTCAGCCACCTCGGTGTAGTGGCCCCCAGGACAGACGGCCAGGATTACCTGTGGGGG AAACAACATTGGAAGGATAACTGTGCACTGTGTAACAGCAGAGGACGGCCAGGCCCTGTGTGTGCTGTCT ATGATGATAGCGACCGGCCCTCAGGGATCCCTGAGCGATTCTCTGGCTCCAACTCTGGGAACACGGGCCACC

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ZIKV- 120765-266			CTGACCATCAGCAGGGTGAAGCCGGGATGAGGCCGACTATTACTGTGAGGTGTGGGATAGTAGTAGTG ATCAGTGGGTGTCGGCGGAGGGACCAAGCTGACCGTCCTA
	17	heavy	GAGGTGCAGCTGGTGGAGTCTGGGGAGGCTTGGTAAAGCCAGGGCGGTCCCTGAGACTCTCCTGTTTCTCAG CTTCTGGATTGAGCTTTGGTGATTATGCTATGAGCTGTTCCGCCAGGCTCCAGGGAAGGACTGGAGTGG GTAGGTATCATTAAGCAAGCTTTTGGTGGGACACAAGATACGCCGCTCTGTGAAAGGCAGATTAC CATCTCAAGAGATGATTCCAAAGCATCGCTATCTGCAATGAACAGCTGAAATCGAGGACACAGCCG TGTAATCTGTACTAGAGACTTCAACGATTTTGGACTGGTCAACCCCACTGGTTCGACCCCTGGGGCCA GGGAACCTGGTCAACCGTCTCTCA
	18	light	GACATCCAGATGACCCAGGCTCCCTCTGCTGCTGCTGAGGACAGAGTCAACATCACTTGCCTGG GCAAGTCAGAGCATTAGCAACTATTTAAATTGGTATCAGCAGAAACAGGGAAAGCCCTAAGCTCCTGAT CTATGCTGCATCCAGTTTGCAAAGTGGGTCCCATCAAGGTTCAAGTGGAGTGGATCTGGGACAGATTTAC TCTCACCATCAGCAGTCTGCAACCTGAAGATTTTGCAACTTACTACTGTCAACAGAGTTACAGTATCCCTCGA ACGTTCCGCAAGGGACCAAGGTGGAAATCAAA
ZIKV- 120765-279	19	heavy	GAGGTGCGGCTGGTGCAATCTGGGGAGGCTTGTACAGCTGGGGGTCACTGAGACTCTCCTGTGTAA CCCTCTGGATTCTCCTTACCAGCCATGCGATGAGTTGGTCCGCCAGGCTCCAGGGAAGGGCTGGAGTGG GTCTCATCTCTTGGTTTGGTGATAGCACACTACGCAGACTCTGTGAAGGGCCGCTTACCATCTCCA GAGACAGTTCACGAACACTCTCTACCTTCAAATGAGGAGCCTGAGAGGCGAGACACGGCCATTTTATTACT GTGCGAAAGATCGTGTGTCGCGGGGTGCGGGGAGAACCTTGACCACCTGGGGCCCCGGGAACGCTGGTCAC CGTCTCTTCA
	20	light	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGGGTCTGTCGGAGACAGAGTCAACATCACTTGCCGG GCGAGTCAGGGTATTAGCGATTATTAGCCTGGTATCAGCAGAAAGCCAGGCAAGTTCTCTATACTCCTGATC TATAGAGCATCCACTTTGCAATCGGGGTCCGTCGCGTTCCGTGGCAGTGGTCTGGCAGAGATTTCACT CTCACCATCACCGGCTGCAGCCTGAAGATGTTGGAACCTTATTCTGTGAGAGTATAACAGTGTCCCGTGG ACGTTCCGCCAGGGACCAAGGTGACCGTCCTA
	21	heavy	CAGGTGCAGCTGGTGGAGTCTGGGGAGGCGTGGTCCAGCTGGGAGGTCCCTGAGACTCTCCTGTGCAG CCTCTGGATTACCTTCAGTAACTATGGCATACTGGGTCCGCCAGGCTCCAGGCAAGGGCTGGAGTGG CTGGCAATTATTTTCATATGATGAAGTACTAAATATTATGAGACTCCGTGAAGGGCCGAATCACCATCTCC AGAGACAAATTCAGAACACGCTGTATCTGCAATGAACAGCTGAGACCTGAGGACACGGCTGTGTATTA CTGTGCGAAAGAGAGAGAGTGGGAGGTACGGGACGGAGGTTTGTACTACTGGGGCCAGGGAGCCCTGGT CACCGTCTCTCTCA

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ZIKV- 120764-282	22	light	TCCTATGTGCTGACTCAGCCACCTCGGTGTCAGTGGCCCCCAGGACAGACGGCCAGGATTACCTGTGGGG AAACAACATTGGAAGTAAAGTGTGCACTGGTACCAGCAGAAGCCAGGCCAGGCCCTCGCTGGTCTCT ATGATGATAGCGCCCGCTCAGGGATCCCTGAGCGATTCTCTGGCTCCAACTCTGGAAACACGGCCACCC TGACCATCACCAGGGTCGAAGCCGGGATGAGGCCGACTATTACTGTAGGTGTGGCATAGTAATACTGAT CATGTGTATTGCGCGAGGGACCAAGCTGACCGTCCTA
	23	heavy	GAGGTGCAGCTGGTGGAGTCTGGGGAGGCTTGGTCCAGCTGGGGGTCCCTGAAACTCTCCTGTGCAG CCTCTGGGTTCACTTTCAGTACTGCTGATGCACTGGTCCGCCAGGCTCCGGGAAAGGCTGGAGTGG GTTGGCGTATTAGAGGCAAGGTAACGATTACGCGACAGCATATGATGCGTCGGTGAAGGCAGGTTTAC CATCTCAGAGATGATTCAAAGAACAACGCGTATCTGCAATGAACAGCCTGAAACCCGAGGACACGGCCG TCTATTATTGATTAGACAGGGGGTTACTATGAGAGTAGCGAGTTTGACTACTGGGGCCGGGAAACCTG GTCACCGTCTCCTCA
	24	light	CAGTCTGTGCTGACGACGCCCTCAGTGTCTGGGGCCCGCCAGGGCAGAGGTCACCATCTCCTGCACTGG GAGCAGCTCCAACATCGGGGAGGTTATGATGTCCACTGTACCAGCAGCTTCCAGGAACAGCCCCAAAC TCCTCATCTATGTTAAACAACATCGGCCCTCAGGGTCCCTGGCGGATTCTCTGGCTCCAACTGTGGCACCTC AGCCTCCCTGGCCATCACTGGGCTCCAGGCTGAGGATGAGGCTGATTATTTCTGCCAGTCTCTATGACAGCAG CCTGACTGTCCATGTGTATTGCGGGAGGGACCAAGCTGACCGTCCTA
ZIKV- 120764-350	25	heavy	GACGTGCAGCTGGTGGAGTCTGGGGTGGTGTGATCCAGCCTGGGGGTCCCTGAGACTCTCCTGTGCAGC CTCTGGGTTACCGCCAGAACCACTACATGACCTGGTCCGCCAGGCTCCAGGGAAGGGCTGGAGTGG GTCTCAGTATTTATAGCGGTGTAGCACAATCTACGCAGACTCCGTGAAGGGCCGATTACCCTCTCCAGA GACAACGCCAAGAACTCACTGTATCTGCAAAATGAACAGCCTGAGAGCCGAGGACACGGCTGTGTTACTG TGCGAGAGATCGAGGGTATCTTGACCACTGGGGCCAGGGAACCTGGTCACCGTCTCCTCA
	26	light	GAAATTGTGTTGACACAGTCTCCAGCCACCTGTCTTTGTCTCCAGGGGAAGACCCCTCTCCTGCAGG GCCAGTCAGAGTGTACCAACTACTTCGCTGGTACCAACAGAGACCTGGCCAGGCTCCAGGCTCCTCATC TATGATGTATCCAACAGGGCCACTGGCATCCAGCCAGGTTCACTGGCAGTGGTCTGGGACAGACTTCAC TCTCACCATCAGCAGCCTAGAGCCTGAAGATTTTGCAGTTTATTACTGTCAACAGCGTAGCAACTGGCCGTA CACTTTTGGCCAGGGGACCAAGGTGGAGATCAAA
ZIKV- 120764-467	27	heavy	GAGGTGCAGCTGGTGGAGTCTGGGGAGGCTTGGTACAGCCTGGGGGTCCCTGAGACTCTCCTGCGCAG CCTCTGGATTCACTTTCAGTAGCTACGACATGCACTGGTCCGCCAAGCTACAGGAAAGGCTCGGAGTGG GTCTCAGGTATTGGTACTGCTGATGACACATACTATCCAGGCTCCGTGAAGGGCCGATTACAGCATCTCCAGA GAGAAATGCCAAGCATCTCTTGTATCTTCAAATGAACAGCCTGAGAGCCGGAGACACGGCTGTCTATTACTGT

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ZIKV- 120765-491			GCAAGAGTGGCGCACCATTCGGAGTACCACCTGTTATATATGCCTCACGGTATGGACGTCTGGGGCCAAAGG GACCACGGTCAACGGTCTCCTCA
	28	light	CAGTCTGCCCTGACTCAGCCTCGCTCCGTGTCTGGGTCTCCTGGACAGTCGATCACCATCTCCTGCACTGGAA CCAGCAGTGATGTTGGAGTTATAATTTGTCTCTGGTACGACAGACCCAGGCAAGCCCCCAAACCTGA TGATTTATAGGGCAGTAAGCGCCCTCAGGGGTTTCTAATCGCTTCTCTGGCTCAAGTCTGGCAACACGG CTCCCTGACAATCTCTGGCTCAGGCTCAGGCTGAGGACGAGGCTGATTATTACTGCTCTCATATACAGATAATA GTCTTATGTCTGTTCGGCGGAGGACCAAGCTGACCGTCCTA
	29	heavy	GAGGTGCAGCTGGTGGAGTCTGGGGAGGCTTGGTACAGCCTGGGGGTCCCTGAGACTCTCCTGTGCAG CCTCTGGATTACCTTTATCAGATATGCCATGAGCTGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAGTGG GTCTCAGATATTAGTGGTAGTGGTAGTACATTCTACGCAGACTCCGTGAAGGGCCGGTTACCATCTCC AGAGACAAATCCAAAGAACACGCTGTATCTGCAATGAACAGCTGAGAGCCGAGGACACGGCTGTCTATTA CTGTGCGAGAGATGACGAGGTTATACCACCAACTGGTACGATGCTTATGATATCTGGGGCCCAAGGGACAA TGGTCACCGTCTCTTCA
ZIKV- 120765-520	30	light	GACATCCAGATGACCCAGTCTCCATCCTCCCTGTCTGTCATCTGTAGGACAGAGTCACCATCACTTGCCGG GCAAGTCAGAGCATTGGCAGCTATTTAAATGGTATCAGCAGAGACCAGGGAAGGCCCTAAACTCCTGAT CTATACTGCATCCAGTTTGCAAAGTGGGTCCCATCAAGTTCACTGGCAGTGGATCTGGGACAGATTTTCAT TCTCACCATCAGCAGTCTGCAACCTGAAGATTTTGCAACTTACTACTGTCAACAGAAATACAATATCCCTCAG GTCACCTTCGGCCCTGGGACCAAAAGTGGATATCAAA
	31	heavy	GAGGTGCAGCTGGTGGAGTCTGGGGGAGACTTGGTACAGCCGGGGGGTCCCTGAGACTCTCCTGTGCAG CCTCTGGTTTACCTTTAGCATCTATGCCATGAGCTGGGTCCGTCCAGGCTCCAGGGAAGGGGCTGGAGTGG GTCTCTGCAATTACTCATGACTCTGGAAGCACATATTACGCAAACTCCGTGAAGGGCCGGTTACCATCTCCA GAGACAAATCCAAAGAACACGGTGATTTTGCAGATGAACCGCTGAGAGCCGAGGACACGGCCACATATTAT TGTGCGAAAGATCGGCCCTCTCGGGGGGTGCGGGAATTATGACTATTGGGGCCAGGGTGGCTGGTCA CCGTCTCCTCA
	32	light	GACATCCAGATGACCCAGTCTCCTTCCACCCTGTCTGTCATCTGTAGGACAGAGTCACCATCACTTGCCGG GCCAGTCAGAGTATTAGTTCCCTGGTTGGCTGGTATCAGCAGAAACAGGGAAGCCCCCTAAGCTCCTCATC AATACGGCGTCTAAATTAGAAACTGGGTCCCATCAAGGTTCAAGGTTCAAGGTCAGTCTGGGACAGATTTTCA TCTCACCATCAGCAGCCTGCAGCCTGATGATTTTGCACCTTATTACTGCCAACAAATATCTTAGTTATCCGTGG ACATTGGGCCAAGGGACCAAGGTGGAAATCAAA

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ZIKV-2834-538	33	heavy	CAGGTGCAACTGCAGGAGTCCGGGCCAGGACTGGTGAAGCCTTCGGAGACCCTGTCCCTCACATGCACGTCTCTGGTCCCTCAGTAATAAATACTGGAGTTGGATCCGGCAGCCCCAGGGAAGGACTGGAGTGGA TTGGGTATATCTATTAACACTGGGACCAACCACTAACCCCTCCCTCAAGAGTCGAGTCACCATATCAGTTGA CACGTCCAAGAACAGTTCTCCCTGAAGCTGAACCTGTGACCGCTGCGGACACGCGCTCTATTACTGTGC GAGAGATTGGCCAGTGGCTGGAGCGGATGTGACTTCTGGGGCCAGGGAACCCCTGGTCACCGTCTCCTCA CAGTCTGTGCTGACTCAGCCACCCTCAGCGTCTGGGACCCCCGGGCAGAGGGTCACCGTCTCTTTGTTCTGGA AGCAGCTCCAACATCGGAAGTAATACTGTAACTGGTACCAGCAGCTCCAGGAACGGCCCCCAAACTCCTC ATCCACAGTACTAATCAGCGGCCCTCAGGGGTCCCTGACCGATTCTCTGGCTCCAAGTCTGGCACCTCAGCC TCCTGGCCATCAGTGGGCTCCAGTCTGAGGATGAGGCTGATTATTACTGTGCAGCATGGGATGACAGCCT GAATGGTTATGTCTTCGGAACTGGGACCAAGGTCACCGTCTCTA
	34	light	CAGTCTGTGCTGACTCAGCCACCCTCAGCGTCTGGGACCCCCGGGCAGAGGGTCACCGTCTCTTTGTTCTGGA AGCAGCTCCAACATCGGAAGTAATACTGTAACTGGTACCAGCAGCTCCAGGAACGGCCCCCAAACTCCTC ATCCACAGTACTAATCAGCGGCCCTCAGGGGTCCCTGACCGATTCTCTGGCTCCAAGTCTGGCACCTCAGCC TCCTGGCCATCAGTGGGCTCCAGTCTGAGGATGAGGCTGATTATTACTGTGCAGCATGGGATGACAGCCT GAATGGTTATGTCTTCGGAACTGGGACCAAGGTCACCGTCTCTA
ZIKV-2834-578	35	heavy	CAGGTGCAAGTGTGGAGGCTGGGGAGGCGTGGTCCAGCCTGGGAGGTCCTGAGAGTCTCCTGTGCAG CCTCTGGATTACCTTCAGTAGTTATGTCTATGCACTGGGTCCGCCAGGCTCCAGGCAAGGGGCTGGAGTGG ATGGGAATTATATCATATGAAGGAAGTAACAAATATTACTCAGACTCCGTGAAGGGCCGATTACCATCTCC AGAGACAAITCCAAAGAACACGCTGTATCTGCAAAATGAACAGCCTGAGAGCTGAGGACACGCGCTGTATATTA CTGTGTGAGAGATCGGAAAGTGGCTGGACAAATGATCCGCCACGGTATGGACGTCTGGGGCCAAAGGGACC ACGGTACCGTCTCCTCA
	36	light	CAGACTGTGGTGACCCAGGAGCATCGTTCTCAGTGTCCCTGGAGGGACAGTCACACTCACTTGTGGCTTG AGCTCTGGCTCAGTCTCTACTAAATTACTACCCCTGTGTACCAGCAGACCCAGGCCAGGCTCCACGCACG CTCATCTACAAACAAACACTCGCTCTCTGGGGTCCCTGATCGCTTCTGTGGCTCCATCCTTGGGAACAAAG CTGCCCTCACCATCAGGGGGCCAGGAGCAGATGATGAATCTGATTATTACTGTACGCTATATATGGGTAGTG GCATTTCCGGTGTTCGGCGGAGGGACCAAGCTGACCGTCTCTA
ZIKV-2834-604	37	heavy	CAGGTGCGGCTGGTGGAGTCTGGGGAGGCGTGGTCCAGCCTGGGAGGTCCTGAGACTCTCCTGTGCAG CGTCTGGATTACCTTCACCTCACTAATATGCCATGGAATGGTCCGCCAGGCTCCAGGCAAGGGCCTGGAGTGG GTGACAAITATATGGTATGATGGGATTACTATATCTATGCTGACTCCGTGAAGGGCCGATTACCATCTCC AGAGACAAITCCAAAGAACACGCTGTATCTGCAAAATGAGCAGTCTGAGAGCCGAGGACACGCGCTATGATTA CTGTGCGAGAGTAGGGGTTCCGGGAGCCGATGATGCTTTTGATATTGGGGCCAAAGGACAAATGGTCACC GTCTCTTCA
	38	light	TCCTATGTGCTGACTCAGCCACCCTCGGTGTGAGTGGCCCCCAGGACAGACGGCCAGGATTACCTGTGGGGG ACACAAATGGAAATAAAATCTCAGTGGTACCAACAGAGCCAGGCCAGGCCCTGTGCTGGTGGTCTCTA TGATGATAGCAGCCGGCCCTCAGGGATCCCTGAGCGATTCTCTGGCTCCAACCTCTGGGAACACGGCCACCCCT

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			GACCATCAGCAGGGTCGAAGCCGGGGATGAGGCCGACTATTATTGTCAGGTGTGGGATAGTAATAGTGATCATGGGGTGTTCGGCGGAGGGACCAAGCTGACCGTCCTA
ZIKV-2834-605	39	heavy	GAAGTGCAGCTGGTGGAGTCTGGGGGAGGCTTGGTACAGCCTGGCAGGTCCCTGAGACTCTCCTGTGCAGCCTCTGGATTACCTTTGATGATTATGCCATGCACTGGGTCCGGCAAGCTCCAGGGAAGGCCCTGGAGTGGTCTCAGGTATTAGTGGGAATGGTCGTACTATAGGCTATGCGGACTCTGTGAAGGGCCGATTCAACCATCTCCAGAGACAACGCCAAGAACTCCCTGTATCTGCAAATGAACAGTCTGAGAGTTGAGGACACGGCCTTGTTATTA
	40	light	CTGTGCAAAAACCAAGGCGTACGGTGACTTCCACTTTGACTACTGGGGCCAGGGAAACCCCTGGTCACCGTCTCTCA
			TCCTATGTGTGACTCAGCCACCCTCGGTGTCAGTGGCCCCCAGGACAGACGGCCAGGATTACCTGTGGGGGAAACAACATTGGAAATAAGGCTGTGCACTGGTACCAGCGGAAGCCAGGCCAGGCCCTGTGTGGTGTCTATGATGATAGCGACCGGCCCTCAGGGATCCCTGAGCGATTCTCTGGCTCCAACTCTGGGAACACGGGCCACCCTGACCATCAGCAGGGTCTGAAGCCGGGGATGAGGCCGACTATTACTGTCAGTTATGGGATACTAGTAGTAA
			TCCCCATGTGGTATTTCGGCGGAGGGACCAAGGTGACCGTCCTA

TABLE 2 – PROTEIN SEQUENCES FOR ANTIBODY VARIABLE REGIONS

Clone	SEQ ID NO:	Chain	Variable Sequence
ZIKV-120766-21	41	heavy	EVQLLESGGGLVQPGGSLRLSCAASGFTFSNYGVGWVROAPGSGLEWVSSINTAGDSTYYAGSVKGRFTISRDNKNTLFLQMNSLRDEDTAVYFCAKDRTSGGFGELFKHWGQGTLTVSS
	42	light	DIQMTQSPSTLSASVGDRVTITCRASQSINSLAWFQQKPGKAPKLLIHKASSLESQVPSRFSGSGSGTEFTLTINSLQPDDEFATYYCQHYHSPWTFGQGTKEIK
ZIKV-120763-32	43	heavy	EVQLLESGGGLVLPGGSLRLSCAASGFTFSYEMNWVROAPGRGLEWVSHISPSGVSKDYSVKGRTIFRDNAKDSLYLQMNGLRADDTAVYYCARDRYDFWSGDPMGYFDYWGGQTLTVSS
	44	light	DIQMTQSPSSLSASVGDRVTITCQASQDITNYLNWYQQKPGKAPKLLIYKASSLESQVPSRFSGSGSGTEFTLTISLQPDDEFATYYCQQYNRGSWTFGQGTKEIK
ZIKV-120764-116	45	heavy	EVQLVQSGAEVKKPGESLRISCSFGYTFSNYWITWVRQVPGKGLWVGKIDPNDPYINYSPPFRGHVVISVDKSIKTAYLQWSSLKASDTAMYYCARATYSSSYDYWYFDVWGRGTLTVSS
	46	light	SYVLTQPPSVSVAPRQTARITCGGNNIGSKSVQWHQQKPGQAPVLVYDDSDRPSGIPERFSGSNSGNTATLTISRVEAGDEADYYCQVWD DSSDQWVFGGGTKVTVL
ZIKV-120764-206	47	heavy	EVLLESVGGGLVQPGGSLRLSCEASGFSFSRYAMNWVROAPGKGLEWVSTITVDGGSTYYAGSVRGRFTISRDNKSKNLYLQMNSLRAEDTALYYCAKDRPSLGVGELYDYWGQGTTLTVSS
	48	light	DIQMTQSPSTLSASVGDRVTITCRASQSISSWLAWYQQKPGKAPKLLIYKASSLESQVPSRFSGSGSGTEFTLTISLQPDDEFATYYCQQYNSYPWTFGQGTKEIK
ZIKV-120764-207	49	heavy	EVHLLSGLVKSGLRLSCAASGFTFTTYPMSWVRAPGKGLWVSTISNSGGDTYYADSVKGRFTISRDNKSKNLYLQMNSLRAEDTAIYYCAKDHPQWLGSHEWGQGPVTVSS
	50	light	SYVLTQPPSVSVAPGQTARITCGGNNIGRTIVHWYQQKPGQAPVLVYDDSDRPSGIPERFSGSNSGNTATLTISRVEAGDEADFCQVWDSTRDQYVFGTGTTVTVL
ZIKV-120765-222	51	heavy	QVQLVESGGGLVQPGGSLRLSCAASGFTFSYYMSWIRQAPGKGLEWVSYISGISSFTNYADSVKGRFTISRDNKNSLYLQMNSLRAEDTAVYYCARDRLTYPPYHYMDVWGKGTTVTVSS
	52	light	QSVLTQPPSASGTPGQRTVIFCSGSSSIRSNPVNWYQQLPGTAPKLLIHSNDQRPSPGVPDRFSGSKSGTSASLAISGLQSEDEADYYCAAWDDSLNLRVFGGGTKLTVL
ZIKV-120765-233	53	heavy	QVQLVESGGGVVQPGGSLRLSCAASGFTFSYGIHWVROAPGKGLEWVAVISYDGSNKYYADSVKGRFTISRDNKNTLYLQMNSLRPEDTAVYYCAKDSAGRRWQQLSAGIWGGTMTVTVSS
	54	light	DIVMTQSPSLPVTGPSPASISCRSSQSLHSNGYNFLDWYLGKPGQSPQLLIYLGYSRASGVPDRFSGSGSGTDFTLKISRVEAEDVGVYYCMQALQTPWTFGQGTKEIK

ZIKV-120765-250	55	heavy	EVQLLESGGNVLQPGGSLRLSCVASGFTFSGYAMSWVRQAPGKGL EWWSAISGSGDSTYYADSVKGRFTISRDNKNTLFLQMNSLRGEDT AVYYCAKVIDQWLGFQDYWGQGTLVTVSS
	56	light	SYVLTQPPSVSVAPGQTARITCGGNNIGRITVHWYQQKAGQAPVL VVYDDSDRPSGIPERFSGSNSGNTATLTISRVEAGDEADYYCQVWD SSSDQWVFGGGTKLTVL
ZIKV-120765-266	57	heavy	EVQLVESGGGLVQPGGSLRLSCSASGFSFGDYAMSWFRQAPGKGL EWWGIIRSKAFGGTTEYAASVKGRFTISRDDSKSIAYLQMNSLKIEDT AVYYCTRDNFDFWTGHHPNWFDPWGQGTLVTVSS
	58	light	DIQMTQAPSSLSASVGDRVITTCRASQISNYLNWYQQKTGKAPKL LIYAASSLQSGVPSRFRSGSGSGTDFTLTISLQPEDFATYYCQSYSIP RTFGQGTKEIK
ZIKV-120765-279	59	heavy	EVRLVQSGGGLVQPGGSLRLSCVTSGFSFTSHAMSWVRQAPGKGL EWWSSLAFDGDSTYYADSVKGRFTISRDSSTNTLYLQMRSLRGEDT AIYYCAKDRVVRGVGENLDHWGPGLTVTVSS
	60	light	DIQMTQSPSSLSASVGDRVITTCRASQGISDYLAHWYQQKPGRPILL IYRASTLQSGVPSRFRSGSGSGTDFTLTITGLQPEDVGTYYCQKNSV PWTFGPGLTKV
ZIKV-120764-280	61	heavy	QVQLVESGGGVVQPGGSLRLSCAASGFTFSNYGIHWVRQAPGKGL EWLAIISYDGSTKYYADSVKGRITISRDNKNTLYLQMNSLRPEDTA VYYCAKEREWVRDGGFDYWGQGLVTVSS
	62	light	SYVLTQPPSVSVAPGQTARITCGGNNIGSKSVHWYQQKPGQAPAL VVYDDSARPSGIPERFSGSNSGNTATLTITRVEAGDEADYYCQVWH SNTDHHVFGGGTKLTVL
ZIKV-120764-282	63	heavy	EVQLVESGGGLVQPGGSLRLSCAASGFSFSDSAMHWVRQASGKGL EWWGRIRGKANDYATAYDASVKGRFTISRDDSKNTAYLQMNSLKT EDTAVYYCIRQGGYSESEFDYWGRTLVTVSS
	64	light	QSVLTQPPSVSGAPGQRTISCTGSSNIGAGYDVHWYQQLPGTA PKLLIYGNNRPSGVPGRFSGSKSGTSASLAITGLQAEDEADYFCQS YDSSLTVHVFVGGGKTLTVL
ZIKV-120764-350	65	heavy	DVQLVESGGGLIQPGGSLRLSCAASGFTARTNYMTWVRQAPGKGL EWWSVIYSGGSTIYADSVKGRFTISRDNKNSLYLQMNSLRAEDTAV YYCARDRGYLDHWGQGLTVTVSS
	66	light	EIVLTQSPATLSLSPGERATLSCRASQSVTNFYAWYQQRPGQAPRL IYDVSNRATGIPARFSGSGSGTDFTLTISLQPEDFAVYYCQQRNW PYTFGQGTKEIK
ZIKV-120764-467	67	heavy	EVQLVESGGGLVQPGGSLRLSCAASGFTFSYDMHWVRQATGKGL EWWSGIGTADDTYPGSKGRFSISRENAKHLLYLQMNSLRAGDTA VYYCARVAHHSEYHLLYMPHGMDVWGQGTITVTVSS
	68	light	QSALTQPASVSGSPQSITISCTGTSSDVGSYNFVSWYRQHPGKAP KLMIYEGSKRPSGVSNRFGSGSKSGNTASLTISGLQAEDEADYYCCSY TDNSPYVLFVGGGKTLTVL
ZIKV-120765-491	69	heavy	EVQLVESGGGLVQPGGSLRLSCAASGFTFIRYAMSWVRQAPGKGL EWWSDISGSGGSTFYADSVKGRFTISRDNKNTLYLQMNSLRAEDT AVYYCARDDEGYTTNWDYDAYDIWGQGTMTVTVSS

	70	light	DIQMTQSPSSLSASVGDRVTITCRASQSIGSYLNWYQQRPGKAPKL LIYTASSLQSGVPSRFSGSGSGTDFILTISLQPEDFATYYCQQNYNIP QVTFGPGTKVDIK
ZIKV- 120765- 520	71	heavy	EVQLVESGGDLVQPGGSLRLSCAASGFTFSIYAMSWVRQAPGKGL EWVSAITHDSGSTYYANSVKGRFTISRDN SKNTVYLQMNRLRAEDT ATYYCAKDRPSRGVGEYDYWGQGALVTVSS
	72	light	DIQMTQSPSTLSASVGDRVTITCRASQSISSWLAWYQQKPGKAPKL LINTASKLETGVPSRFSGSASGTDFTLTISLQPD FATYYCQYLSYP WTFGQG TKVEIK
ZIKV- 2834-538	73	heavy	QVQLQESGPGLVKPSETLSLTCTVSGGSLSNKYWSWIRQPPGKGLE WIGYIYTGTTNYPNPSLKSRTISVDT SKNQFSLKLSVTAADTAVYY CARDCASGWDGCDFWGQGT LTVSS
	74	light	QSVLTQPPSASGTPGQRVTVSCSGSSSNIGSNTVNWYQQLPGTAP KLLIHSTNQRP SGVPDRFSGSKSGTSASLAISGLQSEADYCAAW DDSLNGYVFGTGT KVTVL
ZIKV- 2834-578	75	heavy	QVQLVEAGGGVVPGRSLRVSCAASGFTFSSYAMHWVRQAPGK GLEWMGIISYEGSNKYSDSVKGRFTISRDN SKNTLYLQMNSLRAE DTAVYYCVRDRKVAGQMIRHGMDVWGQGT TTVTVSS
	76	light	QTVVTQEPSFSVSPGGTVTLTCGLSSGSVSTNYPCWYQQTPGQA PRTLIIYNTNTRSSGVPDRFSGSILGNKAALTITGAQADDES DYCTLY MGSGISVFEGG TKLTVL
ZIKV- 2834-604	77	heavy	QVRLVESGGGVVPGRSLRLSCAASGFTFTNYAMNWWVRQAPGKG LEWVTIIWYDGITIIYADSVKGRFTISRDN SKNTVYLQMSSLRAEDT AMYYCARVGVRGADDAFDIWGQGT MVTVSS
	78	light	SYVLTQPPSVSVAPGQTARITCGGHNIGNKNLHWYQQKPGQAPVL VYDDSDRPSGIPERFSGSNSGNTATLTISRVEAGDEADYYCQVWD SNSDHGVFEGG TKLTVL
ZIKV- 2834-605	79	heavy	EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKG LEWVSGISGNRTIGYADSVKGRFTISRDN AKNSLYLQMNSLRVED TALYYCAKT KAYGDFHFDYWGQGT LTVTVSS
	80	light	SYVLTQPPSVSVAPGQTARITCGGNNIGNKAVHWYQRKPGQAPVL VYDDSDRPSGIPERFSGSNSGNTATLTISRVEAGDEADYYCQLWD TSSNPHVVFEGG TKVTVL

TABLE 3 – CDR HEAVY CHAIN SEQUENCES

Clone	CDRH1 (SEQ ID NO:)	CDRH2 (SEQ ID NO:)	CDRH3 (SEQ ID NO:)
ZIKV- 120766-21	GFTFSNYG	INTAGDST	AKDRTSGGFGELFKH
	81	82	83
ZIKV- 120763-32	GFTFSSYE	ISPSGVSK	ARDRYDFWSGDPMGYFDY
	84	85	86
ZIKV- 120764-116	GYTFSNYW	IDPNDPYI	ARATYSSSYDYWYFDV
	87	88	89
ZIKV- 120764-206	GFSFSRYA	ITVDGGST	AKDRPSLGVGELYDY
	90	91	92
ZIKV- 120764-207	GFTFTTYP	ISNSGGDT	AKDHPQWLGSHE
	93	94	95
ZIKV- 120765-222	GFTFSDYY	ISGISSFT	ARDRLTYTPYYHYMDV
	96	97	98
ZIKV- 120765-233	GFTFSDYG	ISYDGSNK	AKDSAGRRWQQLSAGI
	99	100	101
ZIKV- 120765-250	GFTFSGYA	ISGSGDST	AKVIDQWLGFYD
	102	103	104
ZIKV- 120765-266	GFSFGDYA	IRSKAFGGTT	TRDFNDFWTGHHPNWFDP
	105	106	107
ZIKV- 120765-279	GFSFTSHA	LAFDGDST	AKDRVVRGVGENLDH
	108	109	110
ZIKV- 120764-280	GFTFSNYG	ISYDGSTK	AKEREWVVRDGGFDY
	111	112	113
ZIKV- 120764-282	GFSFSDSA	IRGKANDYAT	IRQGGYESSSEFDY
	114	115	116
ZIKV- 120764-350	GFTARTNY	IYSGGST	ARDRGYLDH
	117	118	119
ZIKV- 120764-467	GFTFSSYD	IGTADDT	ARVAHHSEYHLLYMPHGMDV
	120	121	122
ZIKV- 120765-491	GFTFIYA	ISGSGGST	ARDDEGYTTNWYDAYDI
	123	124	125
ZIKV- 120765-520	GFTFSIYA	ITHDSGST	AKDRPSRGGVGEYDY
	126	127	128
ZIKV-2834- 538	GGSLSNKY	IYYTGTT	ARDCASGWDGCDF
	129	130	131
ZIKV-2834- 578	GFTFSSYA	ISYEGSNK	VRDRKVAGQMIRHGMDV
	132	133	134
ZIKV-2834- 604	GFTFTNYA	IWYDGITI	ARVGVRGADDAFDI
	135	136	137
ZIKV-2834- 605	GFTFDDYA	ISNGRTI	AKTKAYGDFHFDY
	138	139	140

TABLE 4 – CDR LIGHT CHAIN SEQUENCES

Clone	CDRL1 (SEQ ID NO:)	CDRL2 (SEQ ID NO:)	CDRL3 (SEQ ID NO:)
ZIKV-120766-21	QSINSW	KAS	QHYHSPWT
	141	142	143
ZIKV-120763-32	QDITNY	KAS	QQYNRGSWT
	144	145	146
ZIKV-120764-116	NIGSKS	DDS	QVWDDSSDQWV
	147	148	149
ZIKV-120764-206	QSISSW	KAS	QQYNSYPWT
	150	151	152
ZIKV-120764-207	NIGRTI	DDS	QVWDSTRDQYV
	153	154	155
ZIKV-120765-222	SSSIRSNP	SND	AAWDDSLNGRV
	156	157	158
ZIKV-120765-233	QSLHSNGYNF	LGS	MQALQTPWT
	159	160	161
ZIKV-120765-250	NIGRIT	DDS	QVWDSSSDQWV
	162	163	164
ZIKV-120765-266	QSISSY	AAS	QQSYSIPRT
	165	166	167
ZIKV-120765-279	QGISDY	RAS	QKYNVPWT
	168	169	170
ZIKV-120764-280	NIGSKS	DDS	QVWHSNTDHVV
	171	172	173
ZIKV-120764-282	SSNIGAGYD	GNN	QSYDSSLTVHVV
	174	175	176
ZIKV-120764-350	QSVTNY	DVS	QQRSNWPYT
	177	178	179
ZIKV-120764-467	SSDVGSYNF	EGS	CSYTDNSPYVL
	180	181	182
ZIKV-120765-491	QSIGSY	TAS	QQNYNIPQVT
	183	184	185
ZIKV-120765-520	QSISSW	TAS	QQYLSYPWT
	186	187	188
ZIKV-2834-538	SSNIGSNT	STN	AAWDDSLNGYV
	189	190	191
ZIKV-2834-578	SGSVSTNYY	NTN	TLYMGSGISV
	192	193	194
ZIKV-2834-604	NIGNKN	DDS	QVWDSNSDHGV
	195	196	197
ZIKV-2834-605	NIGNKA	DDS	QLWDTSSNPHVV
	198	199	200

* * * * *

All of the compositions and methods disclosed and claimed herein can be made and executed without undue experimentation in light of the present disclosure. While the compositions and methods of this disclosure have been described in terms of preferred
5 embodiments, it will be apparent to those of skill in the art that variations may be applied to the compositions and methods and in the steps or in the sequence of steps of the method described herein without departing from the concept, spirit and scope of the disclosure. More specifically, it will be apparent that certain agents which are both chemically and physiologically related may be substituted for the agents described herein while the same or
10 similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the disclosure as defined by the appended claims.

VII. REFERENCES

The following references, to the extent that they provide exemplary procedural or other details supplementary to those set forth herein, are specifically incorporated herein by reference.

U.S. Patent 3,817,837

U.S. Patent 3,850,752

U.S. Patent 3,939,350

U.S. Patent 3,996,345

U.S. Patent 4,196,265

U.S. Patent 4,275,149

U.S. Patent 4,277,437

U.S. Patent 4,366,241

U.S. Patent 4,472,509

U.S. Patent 4,554,101

U.S. Patent 4,680,338

U.S. Patent 4,816,567

U.S. Patent 4,867,973

U.S. Patent 4,938,948

U.S. Patent 5,021,236

U.S. Patent 5,141,648

U.S. Patent 5,196,066

U.S. Patent 5,563,250

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WHAT IS CLAIMED IS:

1. A method of detecting a Zika virus infection in a subject comprising:
 - (a) contacting a sample from said subject with an antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively; and
 - (b) detecting Zika virus in said sample by binding of said antibody or antibody fragment to a Zika] virus antigen in said sample.
2. The method of claim 1, wherein said sample is a body fluid.
3. The method of claims 1-2, wherein said sample is blood, sputum, tears, saliva, mucous or serum, semen, cervical or vaginal secretions, amniotic fluid, placental tissues, urine, exudate, transudate, tissue scrapings or feces.
4. The method of claims 1-3, wherein detection comprises ELISA, RIA, lateral flow assay or Western blot.
5. The method of claims 1-4, further comprising performing steps (a) and (b) a second time and determining a change in Zika virus antigen levels as compared to the first assay.
6. The method of claims 1-5, wherein the antibody or antibody fragment is encoded by clone-paired variable sequences as set forth in Table 1.
7. The method of claims 1-5, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1.
8. The method of claims 1-5, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1.

9. The method of claims 1-5, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
10. The method of claims 1-5, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2.
11. The method of claims 1-5, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
12. The method of claims 1-11, wherein the antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
13. A method of treating a subject infected with Zika virus or reducing the likelihood of infection of a subject at risk of contracting Zika virus, comprising delivering to said subject an antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively.
14. The method of claim 13, the antibody or antibody fragment is encoded by clone-paired light and heavy chain variable sequences as set forth in Table 1.
15. The method of claim 13-14, the antibody or antibody fragment is encoded by clone-paired light and heavy chain variable sequences having 95% identity to as set forth in Table 1.
16. The method of claim 13-14, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired sequences from Table 1.
17. The method of claim 13, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.

18. The method of claim 13, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2.
19. The method of claim 13, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
20. The method of claims 13-19, wherein the antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
21. The method of claims 13-20, wherein said antibody is an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern.
22. The method of claims 13-19, wherein said antibody is a chimeric antibody or a bispecific antibody.
23. The method of claim 13-22, wherein said antibody or antibody fragment is administered prior to infection or after infection.
24. The method of claim 13-23, wherein said subject is a pregnant female, a sexually active female, or a female undergoing fertility treatments.
25. The method of claim 13-24, wherein delivering comprises antibody or antibody fragment administration, or genetic delivery with an RNA or DNA sequence or vector encoding the antibody or antibody fragment.

26. A monoclonal antibody, wherein the antibody or antibody fragment is characterized by clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively.
27. The monoclonal antibody of claim 26, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences according to clone-paired sequences from Table 1.
28. The monoclonal antibody of claim 26, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having at least 70%, 80%, or 90% identity to clone-paired sequences from Table 1.
29. The monoclonal antibody of claim 26, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having at least 95% identity to clone-paired sequences from Table 1.
30. The monoclonal antibody of claim 26, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
31. The monoclonal antibody of claim 26, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
32. The monoclonal antibody of claims 26-31, wherein the antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
33. The monoclonal antibody of claims 26-31, wherein said antibody is a chimeric antibody, or is bispecific antibody.
34. The monoclonal antibody of claim 26-33, wherein said antibody is an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase

therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern.

35. The monoclonal antibody of claim 26-34, wherein said antibody or antibody fragment further comprises a cell penetrating peptide and/or is an intrabody.
36. A hybridoma or engineered cell encoding an antibody or antibody fragment wherein the antibody or antibody fragment is characterized by clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively.
37. The hybridoma or engineered cell of claim 36, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences according to clone-paired sequences from Table 1.
38. The hybridoma or engineered cell of claim 36, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having at least 70%, 80%, or 90% identity to clone-paired variable sequences from Table 1.
39. The hybridoma or engineered cell of claim 36, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having 95% identity to clone-paired variable sequences from Table 1.
40. The hybridoma or engineered cell of claim 36, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
41. The hybridoma or engineered cell of claim 36, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having at least 70%, 80%, or 90% identity to clone-paired variable sequences from Table 2.

42. The hybridoma or engineered cell of claim 36, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
43. The hybridoma or engineered cell of claims 36-42, wherein the antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
44. The hybridoma or engineered cell of claim 36-43, wherein said antibody is a chimeric antibody or a bispecific antibody.
45. The hybridoma or engineered cell of claim 36-43, wherein said antibody is an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern.
46. The hybridoma or engineered cell of claim 36-45, wherein said antibody or antibody fragment further comprises a cell penetrating peptide and/or is an intrabody.
47. A vaccine formulation comprising one or more antibodies or antibody fragments characterized by clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively.
48. The vaccine formulation of claim 47, wherein at least one of said antibodies or antibody fragments is encoded by light and heavy chain variable sequences according to clone-paired sequences from Table 1.
49. The vaccine formulation of claim 47, wherein at least one of said antibodies or antibody fragments is encoded by light and heavy chain variable sequences having at least 70%, 80%, or 90% identity to clone-paired sequences from Table 1.

50. The vaccine formulation of claim 47, wherein at least one of said antibodies or antibody fragments is encoded by light and heavy chain variable sequences having at least 95% identity to clone-paired sequences from Table 1.
51. The vaccine formulation of claim 47, wherein at least one of said antibodies or antibody fragments comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
52. The vaccine formulation of claim 47, wherein at least one of said antibodies or antibody fragments comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
53. The vaccine formulation of claims 47-52, wherein at least one of said antibody fragments is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
54. The vaccine formulation of claims 47-52, wherein at least one of said antibodies is a chimeric antibody or is bispecific antibody.
55. The vaccine formulation of claims 47-54, wherein said antibody is an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern.
56. The vaccine formulation of claims 47-55, wherein at least one of said antibodies or antibody fragments further comprises a cell penetrating peptide and/or is an intrabody.
57. A vaccine formulation comprising one or more expression vectors encoding a first antibody or antibody fragment according to claims 26-34.

58. The vaccine formulation of claim 57, wherein said expression vector(s) is/are Sindbis virus or VEE vector(s).
59. The vaccine formulation of claims 57-58, formulated for delivery by needle injection, jet injection, or electroporation.
60. The vaccine formulation of claim 57, further comprising one or more expression vectors encoding for a second antibody or antibody fragment, such as a distinct antibody or antibody fragment of claims 26-34.
61. A method of protecting the health of a placenta and/or fetus of a pregnant a subject infected with or at risk of infection with Zika virus comprising delivering to said subject an antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively.
62. The method of claim 61, the antibody or antibody fragment is encoded by clone-paired light and heavy chain variable sequences as set forth in Table 1.
63. The method of claim 61-62, the antibody or antibody fragment is encoded by clone-paired light and heavy chain variable sequences having 95% identity to as set forth in Table 1.
64. The method of claim 61-62, wherein said antibody or antibody fragment is encoded by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired sequences from Table 1.
65. The method of claim 61, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
66. The method of claim 61, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2.

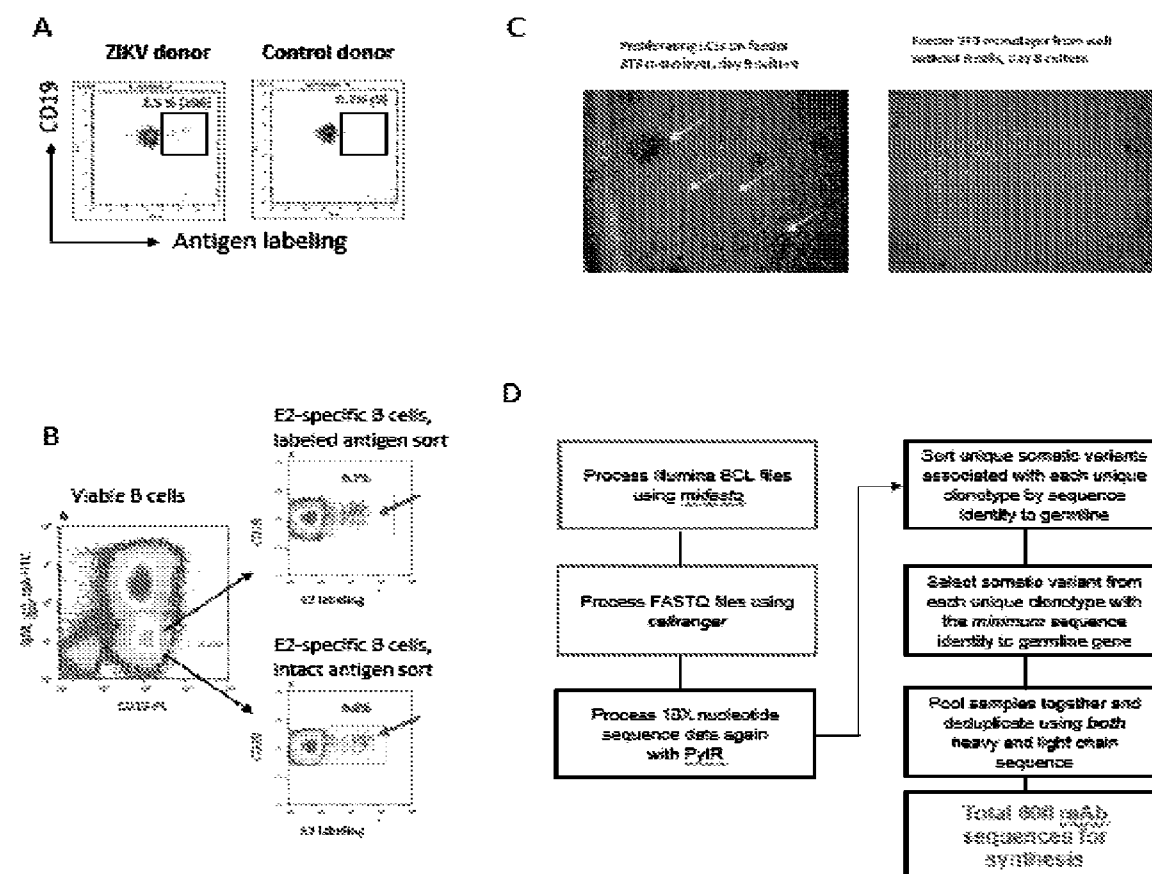
67. The method of claim 61, wherein said antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
68. The method of claims 61-67, wherein the antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
69. The method of claims 61-68, wherein said antibody is an IgG, or a recombinant IgG antibody or antibody fragment comprising an Fc portion mutated to alter (eliminate or enhance) FcR interactions, to increase half-life and/or increase therapeutic efficacy, such as a LALA, N297, GASD/ALIE, YTE or LS mutation or glycan modified to alter (eliminate or enhance) FcR interactions such as enzymatic or chemical addition or removal of glycans or expression in a cell line engineered with a defined glycosylating pattern.
70. The method of claims 61-67 wherein said antibody is a chimeric antibody or a bispecific antibody.
71. The method of claim 61-70, wherein said antibody or antibody fragment is administered prior to infection or after infection.
72. The method of claim 61-71, wherein said subject is a pregnant female, a sexually active female, or a female undergoing fertility treatments.
73. The method of claim 61-72, wherein delivering comprises antibody or antibody fragment administration, or genetic delivery with an RNA or DNA sequence or vector encoding the antibody or antibody fragment.
74. The method of claim 61, wherein the antibody or antibody fragment increases the size of the placenta as compared to an untreated control.

75. The method of claim 61, wherein the antibody or antibody fragment reduces viral load and/or pathology of the fetus as compared to an untreated control.
76. A method of determining the antigenic integrity, correct conformation and/or correct sequence of a Zika virus antigen comprising:
- (a) contacting a sample comprising said antigen with a first antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively; and
 - (b) determining antigenic integrity, correct conformation and/or correct sequence of said antigen by detectable binding of said first antibody or antibody fragment to said antigen.
77. The method of claim 76, wherein said sample comprises recombinantly produced antigen.
78. The method of claim 76, wherein said sample comprises a vaccine formulation or vaccine production batch.
79. The method of claims 76-78, wherein detection comprises ELISA, RIA, western blot, a biosensor using surface plasmon resonance or biolayer interferometry, or flow cytometric staining.
80. The method of claims 76-79, wherein the first antibody or antibody fragment is encoded by clone-paired variable sequences as set forth in Table 1.
81. The method of claims 76-79, wherein said first antibody or antibody fragment is encoded by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1.
82. The method of claims 76-79 wherein said first antibody or antibody fragment is encoded by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1.

83. The method of claims 76-79, wherein said first antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
84. The method of claims 76-79, wherein said first antibody or antibody fragment comprises light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2.
85. The method of claims 76-79, wherein said first antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
86. The method of claims 76-85, wherein the first antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
87. The method of claims 76-86, further comprising performing steps (a) and (b) a second time to determine the antigenic stability of the antigen over time.
88. The method of claims 76-87, further comprising:
- (c) contacting a sample comprising said antigen with a second antibody or antibody fragment having clone-paired heavy and light chain CDR sequences from Tables 3 and 4, respectively; and
 - (d) determining antigenic integrity of said antigen by detectable binding of said second antibody or antibody fragment to said antigen.
89. The method of claim 88, wherein the second antibody or antibody fragment is encoded by clone-paired variable sequences as set forth in Table 1.
90. The method of claim 89, wherein said second antibody or antibody fragment is encoded by light and heavy chain variable sequences having 70%, 80%, or 90% identity to clone-paired variable sequences as set forth in Table 1.

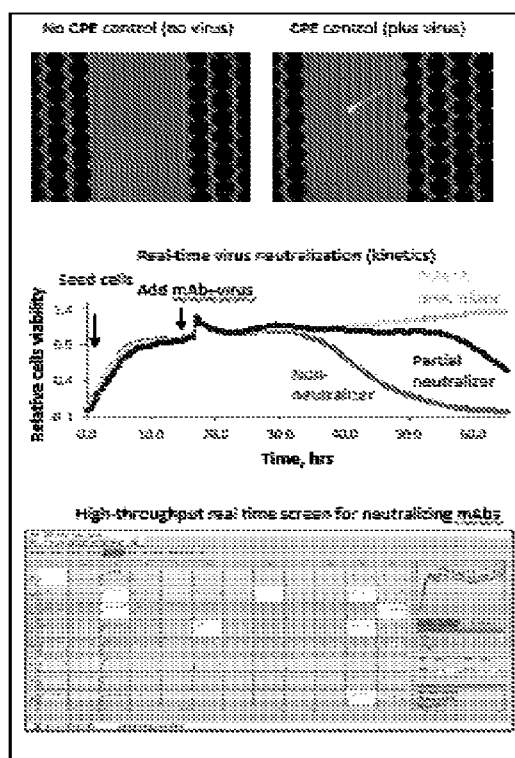
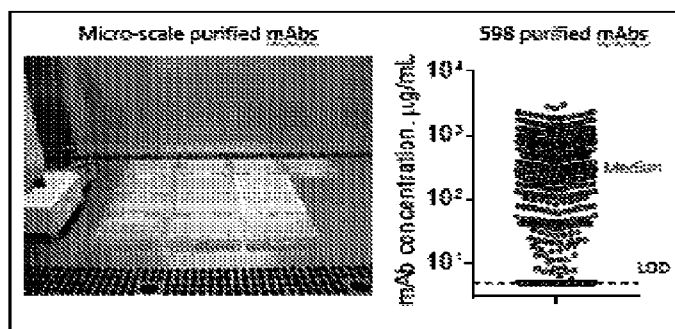
91. The method of claim 89, wherein said second antibody or antibody fragment is encoded by light and heavy chain variable sequences having 95% identity to clone-paired sequences as set forth in Table 1.
92. The method of claims 89, wherein said second antibody or antibody fragment comprises light and heavy chain variable sequences according to clone-paired sequences from Table 2.
93. The method of claim 89, wherein said second antibody or antibody fragment comprises light and heavy chain variable sequences having 70%, 80% or 90% identity to clone-paired sequences from Table 2.
94. The method of claim 89, wherein said second antibody or antibody fragment comprises light and heavy chain variable sequences having 95% identity to clone-paired sequences from Table 2.
95. The method of claim 89, wherein the second antibody fragment is a recombinant scFv (single chain fragment variable) antibody, Fab fragment, F(ab')₂ fragment, or Fv fragment.
96. The method of claim 89, further comprising performing steps (c) and (d) a second time to determine the antigenic stability of the antigen over time.
97. A human monoclonal antibody or antibody fragment, or hybridoma or engineered cell producing the same, wherein said antibody binds to a Zika virus E2 antigen, recognizes a highly quaternary epitope and recognizes one or more residues selected from D83, P222, F218 and K123.
98. The human monoclonal antibody or antibody fragment of claim 97, wherein the epitope is a domain II epitope.
99. The human monoclonal antibody or antibody fragment of claim 97 or 98, wherein the antibody or antibody fragment recognizes each of residues D83, P222, F218 and K123.

100. The human monoclonal antibody or antibody fragment of claims 97-99, wherein the antibody or antibody fragment neutralizes at least one Zika virus of African lineage and at least one Zika virus of Asian lineage.



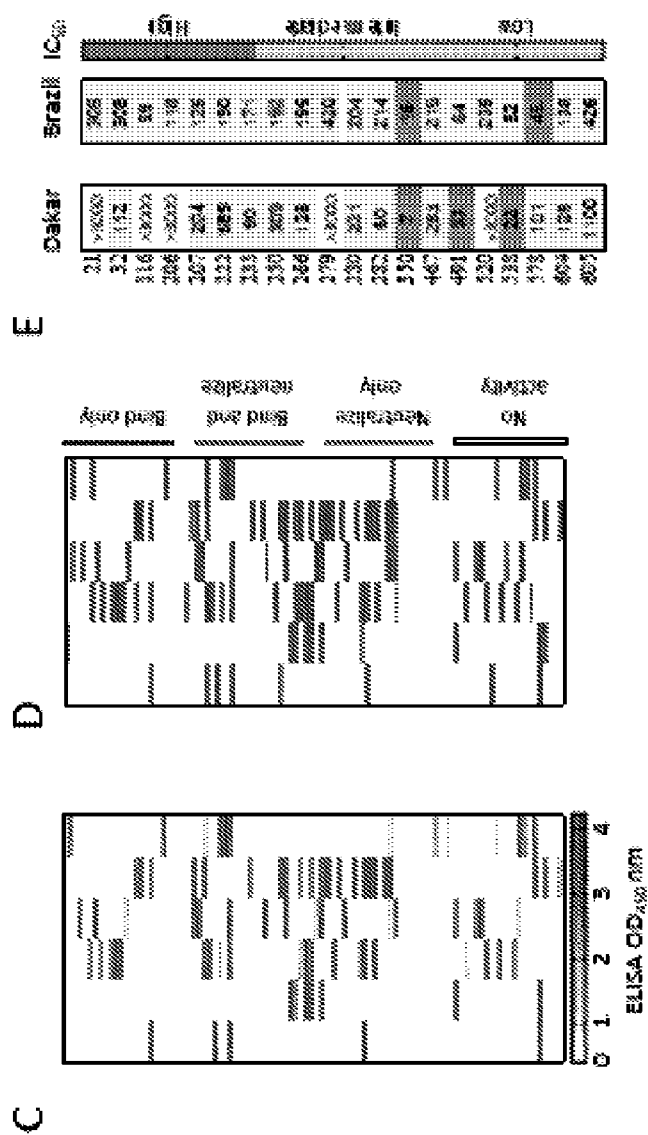
FIGS. 1A-D

A

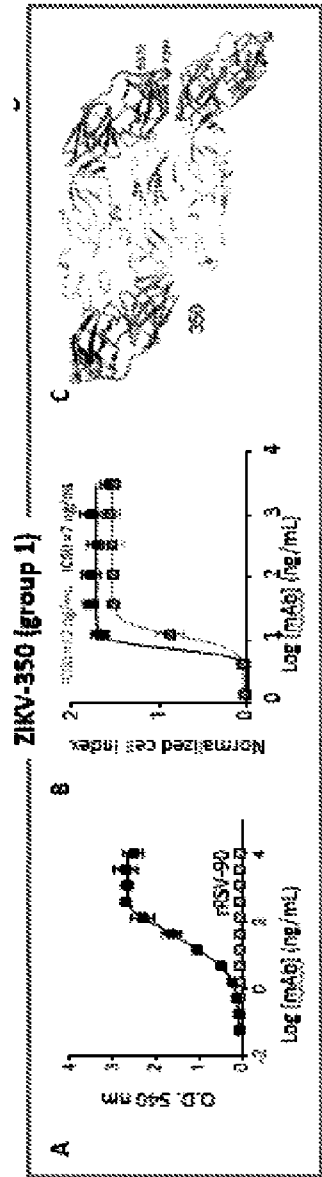


B

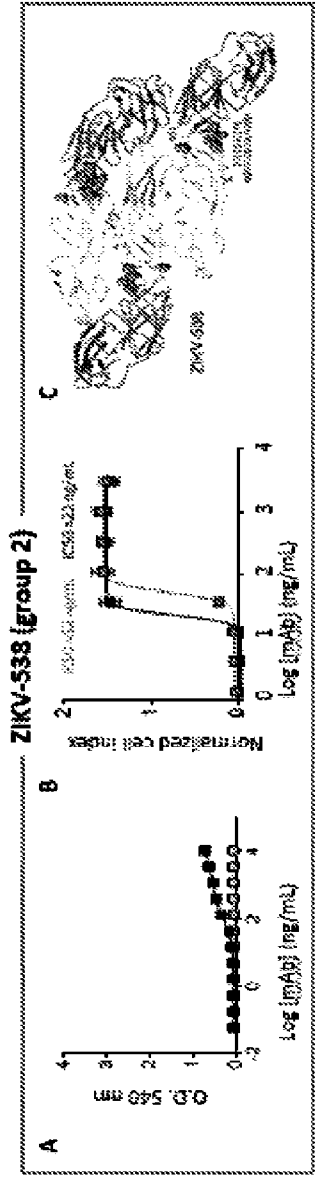
FIGS. 2A-B



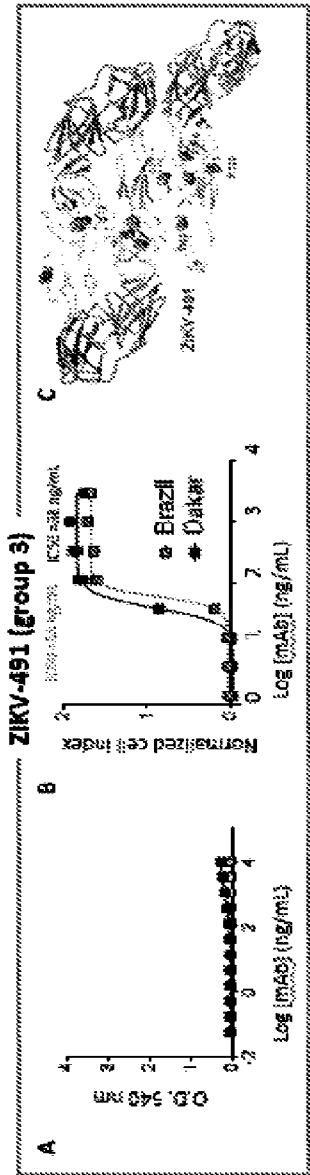
FIGS. 2C-E



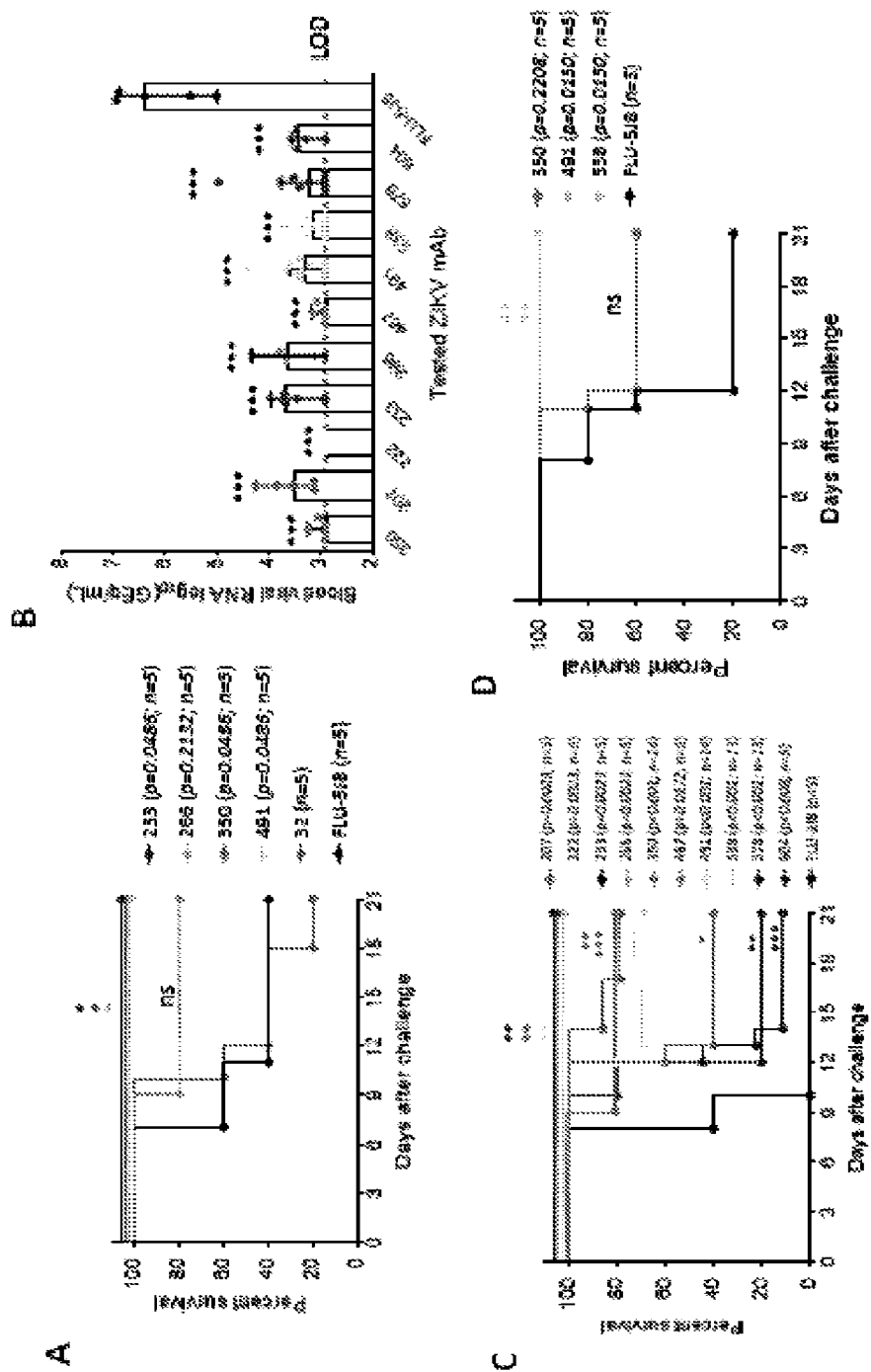
FIGS. 3Aa-c



FIGS. 3Ba-c



FIGS. 3Ca-c



FIGS. 4A-D

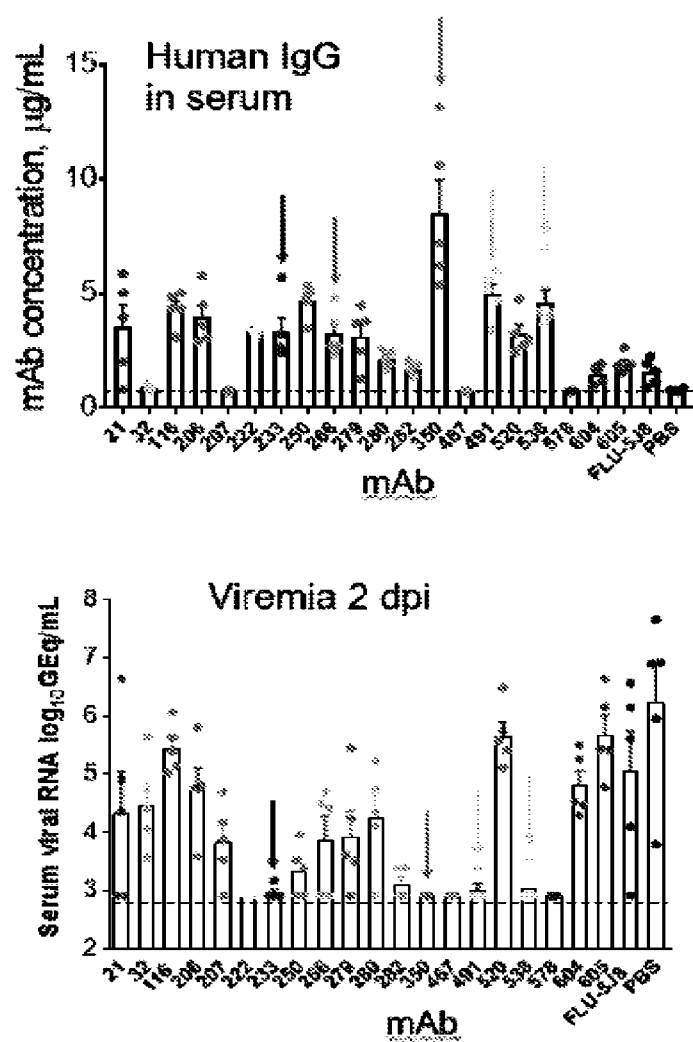


FIG. 6

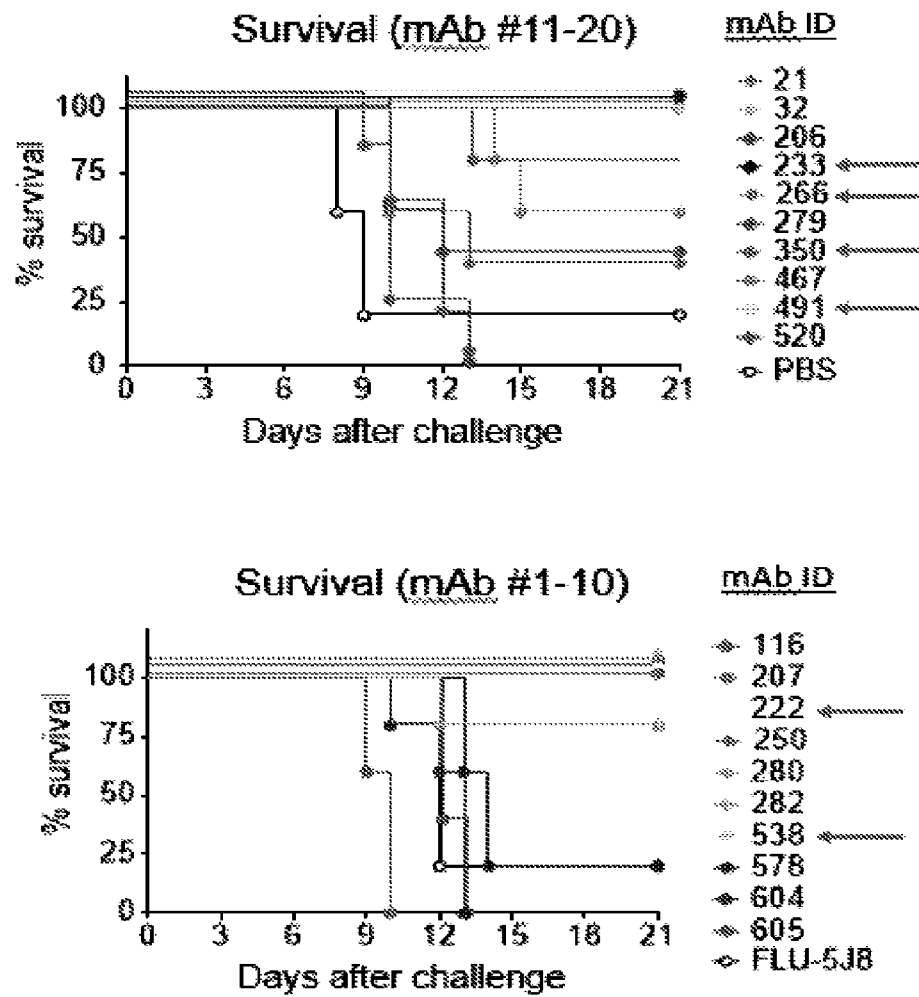


FIG. 7