COMPOSITIONS COMPRISING AAV EXPRESSING DUAL ANTIBODY CONSTRUCTS AND USES THEREOF

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED IN ELECTRONIC FORM

Applicant hereby incorporates by reference the Sequence Listing material filed in electronic form herewith. This file is labeled "14-7032PCT_Seq Listing_ST25.txt".

BACKGROUND OF THE INVENTION

Monoclonal antibodies have been proven as effective therapeutics for cancer and other diseases. Current antibody therapy often involves repeat administration and long term treatment regimens, which are associated with a number of disadvantages, such as inconsistent serum levels and limited duration of efficacy per administration such that frequent re-administration is required and high cost. The use of antibodies as diagnostic tools and therapeutic modalities has found increasing use in recent years. The first FDA-approved monoclonal antibody for cancer treatment, Rituxan® (Rituximab) was approved in 1997 for the treatment of patients with non-Hodgkin's lymphoma and soon thereafter in 1995, Herceptin®, a humanized monoclonal antibody for treatment of patients with metastatic breast cancer, was approved. Numerous antibody-based therapies that are in various stages of clinical development are showing promise. Given the success of various monoclonal antibody therapies, it has been suggested the next generation of biopharmaceuticals will involve cocktails, *i.e.,* mixtures, of antibodies.

One limitation to the widespread clinical application of antibody technology is that typically large amounts of antibody are required for therapeutic efficacy and the costs associated with production are significant. Chinese Hamster Ovarian (CHO) cells, SP20 and NSO2 myeloma cells are the most commonly used mammalian cell lines for commercial scale production of glycosylated human proteins such as antibodies. The yields obtained from mammalian cell line production typically range from 50-250 mg/L for 5-7 day culture in a batch fermenter or 300-1000 mg/L in 7-12 days in fed batch fermenters.

Adeno associated virus (AAV) is a desirable vector for delivering therapeutic genes due to its safety profile and capability of long term gene expression in vivo. Recombinant AAV vectors (rAAV) have been previously used to express single chain and full length

antibodies in vivo. Due to the limited transgene packaging capacity of AAV, it has been a technical challenge to have a tightly regulated system to express heavy and light chains of an antibody using a single AAV vector in order to generate full length antibodies

There remains a need in the art for delivering two antibodies in a single composition for therapeutic use.

SUMMARY OF THE INVENTION

A recombinant adeno-associated virus (AAV) having an AAV capsid which has packaged therein a heterologous nucleic acid which expresses two functional antibodies in a cell is provided herein. In one embodiment, the recombinant AAV contains an ORF encoding an immunoglobulin light chain, a second ORF encoding a first immunoglobulin heavy chain and a third ORF encoding a second heavy chain, whereby the expressed functional antibody constructs have two different heavy chains with different specificities which share a light chain. In one embodiment, the two antibodies with different specificities are co-expressed, with a third, bispecific antibody having the specificities of the two monospecific antibodies.

In one embodiment, the rAAV comprises: a 5' AAV inverted terminal repeat (ITR); a first expression cassette which encodes at least a first open reading frame (ORF) for a first immunoglobulin under the control of regulatory control sequences which direct expression thereof; a second expression cassette which comprises a second ORF, a linker, and a third ORF under the control of regulatory control sequences which direct expression thereof, wherein the second and third ORF encode for a second and third immunoglobulin construct; and a 3' AAV ITR.

A pharmaceutical composition is provided which comprises a recombinant AAV which expresses at least two functional antibody constructs and pharmaceutically acceptable carrier. In one embodiment, the at least two functional antibodies have different specificities. Optionally, also co-expressed is a bispecific antibody.

A composition comprising at least two functional antibodies having different specificities is provided, wherein each of the antibodies has the same light chain and a different heavy chain. The light chain is from a different source than the heavy chain for one or both of the antibodies. In one embodiment, two functional monospecific antibodies and a bifunctional antibody are expressed. In one embodiment, the ratio of antibodies is about 25: about 50: about 25, homodimeric: bispecific: homodimeric.

A method of delivering two functional antibodies to a subject is provided which comprises administering a recombinant AAV to the subject.

Still other aspects and advantages of the invention will be readily apparent from the following detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A is a cartoon illustrating an exemplary arrangement for a vector expressing two monospecific antibody constructs containing a first and a second heavy chain and a light chain, which may be from an antibody heterologous to one or both of the antibodies from which the first and second heavy chain originate, and a third, bispecific antibody. This arrangement utilizes a shared enhancer which is bidirectional and which separates a first expression cassette and a second expression cassette. Three open reading frames (ORF) are illustrated. L refers to a linker. pA1 refers to a first polyA and pA2 refers to a second polyA. MP1 refers to a first minimal promoter and MP2 refers to a second minimal promoter. The polyA and the MP may be the same or different for each expression cassette.

FIG. 1B is a cartoon illustrating an alternative exemplary arrangement for a vector expressing two antibody constructs containing a first and a second heavy chain and a light chain, which may be from an antibody heterologous to one or both of the antibodies from which the first and second heavy chain originate, and a third, bispecific antibody. This arrangement utilizes a shared polyA. E1 refers to a first enhancer and E2 refers to a second enhancer. These may be same or different enhancers for each of the expression cassettes. Similarly MP1 and MP2 may the same or different.

FIG. 2 illustrates a nucleic acid molecule carried by a plasmid for packaging into an AAV capsid, which is used for co-expression of an anti-TSG 101 heavy chain, FI6 influenza heavy chain, and FI6 light chain. These antibody chains utilize heterologous leader from interleukin 2 (IL2). The human CMV enhancer was used in conjunction with CMV promoters. The bicistronic expression cassette contains a furin recognition site and a 2A linker sequence separating the ORF containing the FI6 VL and CL regions from the ORF containing the FI6 heavy chain. The polyA for the expression cassette on the right is a shortened thymidine kinase polyA. The polyA for the expression cassette on the left is a synthetic polyA sequence.

FIG. 3 illustrates the binding ability of an FI6v3k2 antibody co-expressed with a C05 antibody from a recombinant AAV8 prepared as described herein. The results demonstrate

the expected binding to full-length HA and the HA stem characteristic of FI6 and binding to HA and HA head only (no stem) characteristic of C05.

FIGs. 4A-4B illustrates the binding ability of an FI6v3k2 antibody co-expressed with a 1A6 antibody (anti-TSG 101) from a recombinant AAV8 prepared as described herein. FIG. 4A is a bar chart showing binding to protein A captures total monoclonal antibody in the mixture (negative control is represented by the bar on the left, antibody mixture by the bar on the right). FIG. 4B is a graph showing that binding to the TSG101 peptide captures only the MAB containing 1A6 heavy chain (upper line). These data demonstrate that when co-expressed with FI6v3k2, 1A6 antibody retained the binding specificity of antibody from which its heavy chains originated.

FIG. 5 illustrates systemic expression levels in mice administered FI6 co-expressed from an AAV vector with a second antibody at doses of 1 x 10^{11} genome copies (GC) or 1 x 10^{10} GC.

FIGs. 6A-6B illustrate the evaluation of the AAV9.BiD.FI6v3_CR8033mAb delivered intramuscularly (IM) at 1 x 10^{11} GC for protection against challenge with influenza strain PR8. FIG. 6A is a line graph showing percent change in weight. The circle represents the AAV9 construct with a bidirectional promoter expressing synthetic FI6v3 and CR8033 monoclonal antibodies having the same heterologous light chain. The square represents a positive control, i.e., AAV9 expressing a single antibody type FI6 also delivered at 1 x 10^{11} GC, and the triangle represents naïve animals. FIG. 6B shows survival post-challenge.

FIGs. 7A-7B illustrate the evaluation of the AAV9.BiD.FI6v3_CR8033mAb delivered intramuscularly (IM) at 1 x 10^{11} GC for protection against challenge with influenza strain B/Lee/40. FIG. 7A is a line graph showing percent change in weight. The circle represents the AAV9 construct with a bidirectional promoter expressing synthetic FI6 and CR8033 monoclonal antibodies having the same heterologous light chain. The square represents a positive control, i.e., AAV9 expressing a single antibody type CR8033 also delivered at 1 x 10^{11} GC, and the triangle represents naïve animals. FIG. 7B shows survival post-challenge.

FIG 8A is a chart showing protection in a mouse model following administration of an AAV which expresses both FI6v3 and TCN monoclonal antibodies, as expressed by weight of the mouse over days. The top line (diamonds) represents a dose of 25 micrograms (μg/mL) and the bottom line represents 0.4 μg/mL.

FIG 8B is a chart showing protection in a mouse model following administration of an AAV which expresses both FI6v3 and IA6 monoclonal antibodies, as expressed by weight of the mouse over days. The top line (diamonds) represents a dose of 263.2 micrograms (μg/mL) and the bottom line represents 36.5 μg/mL.

FIG 8C is a chart showing protection in a mouse model following administration of an AAV which expresses both FI6v3 and CR8033 monoclonal antibodies, as expressed by weight of the mouse over days. The top line (diamonds) represents a dose of 126.3 micrograms (μg/mL) and the bottom line represents 6.9 μg/mL.

DETAILED DESCRIPTION OF THE INVENTION

A vector is provided herein which delivers at least two functional antibodies by co-expressing two different heavy chains and single light chain which when expressed in a cell form two functional antibodies with different specificities, i.e., which recognize different antigens (or ligands). A third functional antibody may also be expressed and is bispecific, having the heavy chain of each of the two monospecific antibodies. Typically, the third antibody is expressed at a lower level than the two monospecific antibodies. A vector may be used in vivo for efficient production of compositions which will utilize the at least two antibodies or an antibody-producing host cell may be engineered to contain the expression cassettes for the two, different heavy chains and a single type of light chain. Thus, the invention also encompasses a host cell expressing a mixture of two monospecific antibodies, wherein each antibody has a distinct specificity but contains the same light chain, and a third antibody which is bispecific. In one desired embodiment, the vector is designed to deliver the three different antibody constructs in a subject to which the vector is administered.

In one embodiment, the vector is a recombinant AAV which has packaged within an AAV capsid a nucleic acid molecule containing sequences encoding two different heavy chains and a single light chain, which when co-expressed forms two functional monospecific antibodies, *i.e.*, first antibody with a first heavy chain and the light chain and a second antibody with the second heavy chain and the light chain, and a third antibody that has one of each of the heavy chains and the same light chain to make a bispecific antibody.

A "functional antibody" may be an antibody or immunoglobulin which binds to a selected target (*e.g.,* an antigen on a cancer cell or a pathogen, such as a virus, bacteria, or parasite) with sufficient binding affinity to effect a desired physiologic result, which may be protective (e.g., passive immunization) or therapeutic.

The AAV vector provided herein may contain 1, 2, or 3 open reading frames (ORF) for up to ten immunoglobulin domains. As used herein, an "immunoglobulin domain" refers to a domain of an antibody heavy chain or light chain as defined with reference to a conventional, full-length antibody. More particularly, a full-length antibody contains a heavy (H) chain polypeptide which contains four domains: one N-terminal variable (VH) region and three C-terminal constant (CH1, CH2 and CH3) regions and a light (L) chain polypeptide which contains two domains: one N- terminal variable (VL) region and one C-terminal constant (CL) region. An Fc region contains two domains (CH2 - CH3). A Fab region may contain one constant and one variable domain for each the heavy and light chains.

In an AAV vector described herein, two full-length heavy chain polypeptides may be expressed (4 domains each) and a light chain polypeptide (two domains). In one desirable embodiment, the two heavy chain polypeptides have different specificities, i.e., are directed to different targets. Thus, the vectors are useful alone or in combination, for expressing mixtures of antibodies.

As used herein, "different specificities" indicates that the referenced immunoglobulin constructs (e.g., a full-length antibody, a heavy chain, or other construct capable of binding a specific target) bind to a different target site. Suitably, in a dual expressed antibody construct, the two specificities are non-overlapping and/or non-interfering, and may optionally enhance each other. Two antibody (immunoglobulin) constructs as described herein confer different specificity by binding to a different target site on the same pathogen or target site (e.g., a virus protein or tumor). Such different target antigens may be different strains of the same viral type (e.g., two different influenza strains), or two different antigens (e.g., an antiviral and anti-cancer, two different anti-cancer constructs, amongst others). For example, a first heavy chain polypeptide may combine with the light chain to form an antibody construct having a first specificity, the second heavy chain polypeptide may combine with the light chain to form a second antibody construct having a second specificity, and the first and second heavychain may combine with the light chain to form a bispecific antibody. The antibodies may optionally both be directed to different antigenic sites (epitopes) on a single target (e.g., different target sites on a selected viral, bacterial, fungal or parasite pathogen) or to different targets. For example, heavy chains from the two antibodies may be directed to the influenza virus, and may be co-expressed to form two monospecific antibodies (*e.g.,* heavy chains from influenza viruses FI6, CR8033 and CO5

may be selected) and expressed with a selected light chain, and a bispecific antibody. Examples of suitable influenza anitbodies and other anti-airborne pathogen antibody constructs and a method for delivering same are described in, e.g., WO 2012/145572A1. The antibodies may also be directed to different targets (e.g., an anti-viral antibody, including chronic viral infections, viral infections associated with cancers, or different anti-neoplastic cell surface proteins or other targets. Examples of suitable viral targets include the influenza hemaglutinin protein or other viral proteins, human immunodeficiency virus (HIV), human papilloma virus (HPV), Epstein-Barr virus, human herpes virus, respiratory syncytial virus, amongst others. Thus, the invention is particularly well suited for use in therapeutics and passive prophylaxis for which combinations of antibodies are desired.

The term "immunoglobulin" is used herein to include antibodies, and functional fragments thereof. Antibodies may exist in a variety of forms including, for example, polyclonal antibodies, monoclonal antibodies, camelized single domain antibodies, intracellular antibodies ("intrabodies"), recombinant antibodies, multispecific antibody (bispecific), antibody fragments, such as, Fv, Fab, $F(ab)_2$, $F(ab)_3$, Fab', Fab'-SH, $F(ab')_2$, single chain variable fragment antibodies (scFv), tandem/bis-scFv, Fc, pFc', scFvFc (or scFv-Fc), disulfide Fv (dsfv), bispecific antibodies (bc-scFv) such as BiTE antibodies; camelid antibodies, resurfaced antibodies, humanized antibodies, fully human antibodies, single-domain antibody (sdAb, also known as NANOBODY®), chimeric antibodies, chimeric antibodies comprising at least one human constant region, and the like. "Antibody fragment" refers to at least a portion of the variable region of the immunoglobulin that binds to its target, *e.g.*, the tumor cell. In one embodiment, immunoglobulin is an IgG. However, other types of immunoglobulin may be selected. In another embodiment, the IgG subtype selected is an IgG1. However, other isotypes may be selected. Further, any of the IgG1 allotypes may be selected.

The term "heterologous" when used with reference to a protein or a nucleic acid indicates that the protein or the nucleic acid comprises two or more sequences or subsequences which are not found in the same relationship to each other in nature. For instance, the nucleic acid is typically recombinantly produced, having two or more sequences from unrelated genes arranged to make a new functional nucleic acid. For example, in one embodiment, the nucleic acid has a promoter from one gene arranged to direct the expression of a coding sequence from a different gene. Thus, with reference to the coding sequence, the promoter is heterologous. The term "heterologous light chain" is a light chain containing a

variable domain and/or constant domain from an antibody which has a different target specificity from the specificity of the heavy chain.

The two or more ORF(s) carried by the nucleic acid molecule packaged within the vector may be expressed from two expression cassettes, one or both of which may be bicistronic. Because the expression cassettes contain heavy chains from two different antibodies, it is desirable to introduce sequence variation between the two heavy chain sequences to minimize the possibility of homologous recombination. Typically there is sufficient variation between the variable domains of the two antibodies (VH-Ab1 and VH-Ab2). However, it is desirable to ensure there is sufficient coding sequence variation between the constant regions of the first antibody (Ab1) and the second antibody (Ab2), most preferably in each of the CH1, CH2, and CH3 regions. For example, in one embodiment, the heavy chain constant regions of a first antibody may have the sequence of nt 1 to 705 of SEQ ID NO: 1 (which encodes amino acids 1 - 233 of SEQ ID NO:2) or a sequence which is about 95% to about 99% identical thereto without any introducing any amino acid changes. In one embodiment, variation in the sequence of these regions is introduced in the form of synonymous codons (*i.e.,* variations of the nucleic acid sequence are introduced without any changes at the amino acid level). For example, the second heavy chain may have constant regions which are at least 15%, at least about 25%, at least about 35%, divergent (i.e., about 65% to about 85% identical) over CH1, CH2 and/or CH3.

Once the target and immunoglobulin are selected, the coding sequences for the selected immunoglobulin (*e.g.,* heavy and/or light chain(s)) may be obtained and/or synthesized. Methods for sequencing a nucleic acid (e.g., RNA and DNA) are known to those of skill in the art. Once the sequence of a nucleic acid is known, the amino acid can be deduced and subsequently, there are web-based and commercially available computer programs, as well as service based companies which back translate the amino acids sequences to nucleic acid coding sequences. See, *e.g.*, backtranseq by EMBOSS, http://www.ebi.ac.uk/Tools/st/ ; Gene Infinity (http://www.geneinfinity.org/sms/sms_backtranslation.html); ExPasy (http://www.expasy.org/tools/). In one embodiment, the RNA and/or cDNA coding sequences are designed for optimal expression in human cells. Methods for synthesizing nucleic acids are known to those of skill in the art and may be utilized for all, or portions, of the nucleic acid constructs described herein.

Codon-optimized coding regions can be designed by various different methods. This optimization may be performed using methods which are available on-line (*e.g.*, GeneArt,), published methods, or a company which provides codon optimizing services, *e.g.,* as DNA2.0 (Menlo Park, CA). One codon optimizing algorithm is described, *e.g.,* in US Patent Application No. WO 2015/012924, which is incorporated by reference herein. *See also, e.g.,* US Patent Publication No. 2014/0032186 and US Patent Publication No. 2006/0136184. Suitably, the entire length of the open reading frame (ORF) for the product is modified. However, in some embodiments, only a fragment of the ORF may be altered. By using one of these methods, one can apply the frequencies to any given polypeptide sequence, and produce a nucleic acid fragment of a codon-optimized coding region which encodes the polypeptide.

A number of options are available for performing the actual changes to the codons or for synthesizing the codon-optimized coding regions designed as described herein. Such modifications or synthesis can be performed using standard and routine molecular biological manipulations well known to those of ordinary skill in the art. In one approach, a series of complementary oligonucleotide pairs of 80-90 nucleotides each in length and spanning the length of the desired sequence are synthesized by standard methods. These oligonucleotide pairs are synthesized such that upon annealing, they form double stranded fragments of 80-90 base pairs, containing cohesive ends, *e.g.,* each oligonucleotide in the pair is synthesized to extend 3, 4, 5, 6, 7, 8, 9, 10, or more bases beyond the region that is complementary to the other oligonucleotide in the pair. The single-stranded ends of each pair of oligonucleotides are designed to anneal with the single-stranded end of another pair of oligonucleotides. The oligonucleotide pairs are allowed to anneal, and approximately five to six of these double-stranded fragments are then allowed to anneal together via the cohesive single stranded ends, and then they ligated together and cloned into a standard bacterial cloning vector, for example, a TOPO® vector available from Invitrogen Corporation, Carlsbad, Calif. The construct is then sequenced by standard methods. Several of these constructs consisting of 5 to 6 fragments of 80 to 90 base pair fragments ligated together, *i.e.*, fragments of about 500 base pairs, are prepared, such that the entire desired sequence is represented in a series of plasmid constructs. The inserts of these plasmids are then cut with appropriate restriction enzymes and ligated together to form the final construct. The final construct is then cloned into a standard bacterial cloning vector, and sequenced. Additional methods would be

immediately apparent to the skilled artisan. In addition, gene synthesis is readily available commercially.

Optionally, amino acid substitutions may be introduced into a heavy chain constant region in order to increase sequence diversity between the two antibody heavy chains and/or for another purpose. Methods and computer programs for preparing such alignments are available and well known to those of skill in the art. Substitutions may also be written as (amino acid identified by single letter code)-position #- (amino acid identified by single letter code) whereby the first amino acid is the substituted amino acid and the second amino acid is the substituting amino acid at the specified position. The terms "substitution" and "substitution of an amino acid" and "amino acid substitution" as used herein refer to a replacement of an amino acid in an amino acid sequence with another one, wherein the latter is different from the replaced amino acid. Methods for replacing an amino acid are well known to the skilled in the art and include, but are not limited to, mutations of the nucleotide sequence encoding the amino acid sequence. Methods of making amino acid substitutions in IgG are described, *e.g.*, for WO 2013/046704, which is incorporated by reference for its discussion of amino acid modification techniques.

The term "amino acid substitution" and its synonyms described above are intended to encompass modification of an amino acid sequence by replacement of an amino acid with another, substituting amino acid. The substitution may be a conservative substitution. The term conservative, in referring to two amino acids, is intended to mean that the amino acids share a common property recognized by one of skill in the art. The term non-conservative, in referring to two amino acids, is intended to mean that the amino acids which have differences in at least one property recognized by one of skill in the art. For example, such properties may include amino acids having hydrophobic nonacidic side chains, amino acids having hydrophobic side chains (which may be further differentiated as acidic or nonacidic), amino acids having aliphatic hydrophobic side chains, amino acids having aromatic hydrophobic side chains, amino acids with polar neutral side chains, amino acids with electrically charged side chains, amino acids with electrically charged acidic side chains, and amino acids with electrically charged basic side chains. Both naturally occurring and non-naturally occurring amino acids are known in the art and may be used as substituting amino acids in embodiments. Thus, a conservative amino acid substitution may involve changing a first amino acid having a hydrophobic side chain with a different amino acid having a hydrophobic side chain; whereas a non-conservative amino acid substitution may involve

changing a first amino acid with an acidic hydrophobic side chain with a different amino acid having a different side chain, *e.g.,* a basic hydrophobic side chain or a hydrophilic side chain. Still other conservative or non-conservative changes change be determined by one of skill in the art. In still other embodiments, the substitution at a given position will be to an amino acid, or one of a group of amino acids, that will be apparent to one of skill in the art in order to accomplish an objective identified herein.

In order to express a selected immunoglobulin domain, a nucleic acid molecule may be designed which contains codons which have been selected for optimal expression of the immunoglobulin polypeptides in a selected mammalian species, e.g., humans. Further, the nucleic acid molecule may include a heterologous leader sequence for each heavy chain and light chain of the selected antibody, which encodes the wild-type or a mutated IL-2 signal leader peptide fused upstream of the heavy and chain polypeptides composed of the variable and constant regions. However, another heterologous leader sequence may be substituted for one or both of the IL-2 signal peptide. Signal/leader peptides may be the same or different for each the heavy chain and light chain immunoglobulin constructs. These may be signal sequences which are natively found in an immunoglobulin *(e.g.,* IgG), or may be from a heterologous source. Such heterologous sources may be a cytokine (*e.g.,* IL-2, IL12, IL18, or the like), insulin, albumin, β-glucuronidase, alkaline protease or the fibronectin secretory signal peptides, amongst others.

As used herein, an "expression cassette" refers to a nucleic acid sequence which comprises at least a first open reading frame (ORF) and optionally a second ORF. An ORF may contain two, three, or four antibody domains. For example, the ORF may contain a full-length heavy chain. Alternatively, an ORF may contain one or two antibody domains. For example, the ORF may contain a heavy chain variable domain and a single heavy chain constant domain. In another example, the ORF may contain a light chain variable and a light chain constant region. Thus, an expression cassette may be designed to be bicistronic, i.e., to contain regulatory sequences which direct expression of the ORFs thereon from shared regulatory sequences. In this instance, the two ORFs are typically separated by a linker. Suitable linkers, such as an internal ribozyme binding site (IRES) and/or a furin-2a self-cleaving peptide linker (F2a), [*see, e.g.,* Radcliffe and Mitrophanous, Gene Therapy (2004), 11, 1673-1674] are known in the art. Suitably, the ORF are operably linked to regulatory control sequences which direct expression in a target cell. Such regulatory control sequences may include a polyA, a promoter, and an enhancer. In order to facilitate co-expression from

an AAV vector, at least one of the enhancer and/or polyA sequence may be shared by the first and second expression cassettes.

In one embodiment, the rAAV has packaged within the selected AAV capsid, a nucleic acid molecule comprising: a 5' ITR, a first expression cassette, a bidirectional enhancer, and a second expression cassette, where the bidirectional enhancer separates the first and second expression cassettes, and a 3' ITR. FIG. 1A is provided herein as an example of this embodiment. For example, in such an embodiment, a first promoter for a first expression cassette is located to the left of the bidirectional enhancer, followed by at least a first open reading frame, and a polyA sequence, and a second promoter. Further, a second promoter for the second expression cassette is located to the right of the bidirectional enhancer, followed by at least a second open reading frame and a polyA. The first and second promoters and the first and second polyA sequences may be the same or different. A minimal promoter and/or a minimal polyA may be selected in order to conserve space. Typically, in this embodiment, each promoter is located either adjacent (either to the left or the right (or 5' or 3')) to the enhancer sequence and the polyA sequences are located adjacent to the ITRs, with the ORFs there between. While FIG. 1A is illustrative, the order of the ORFs may be varied, as may the immunoglobulin domains encoded thereby. For example, the light chain constant and variable sequences may be located to the left of the enhancer and the two heavy chains may be encoded by ORFs located to the right of the enhancer. Alternatively, one of the heavy chains may be located to the left of the enhancer and the ORFs to the right of the enhancer by encode a second heavy chain and a light chain. Alternatively, the opposite configuration is possible, and the expression cassette to the left of the enhancer may be bicistronic. Alternatively, depending upon what domains are encoded, both expression cassettes may be monocistronic (e.g., encoding two immunoadhesins), or both can be bicistronic (e.g., encoding two complete FABs).

In another embodiment, the rAAV has packaged within the selected AAV capsid, a nucleic acid molecule comprising: a 5' ITR, a first expression cassette, a polyA which functions bidirectionally, and a second expression cassette, where the bidirectional polyA separates and functions for both the first and the second expression cassettes, and a 3' ITR. FIG. 1B is provided herein as an example of this embodiment. In this embodiment, a first enhancer and a first promoter (or enhancer/promoter combination) is located to the right of the 5' ITR, followed by the ORF(s) and the bidirectional polyA. The second expression cassette is separated from the first expression cassette by the bidirectional polyA and is

transcribed in the opposite orientation. In this expression cassette, the enhancer and promoter (or promoter/enhancer combination) is located adjacent to the 3' ITR and the ORF(s) are adjacent to the bidirectional polyA. While FIG. 1B is illustrative, the order of the ORFs may be varied, as may the immunoglobulin domains encoded thereby. For example, the light chain constant and variable sequences may be located to the left of the polyA and the two heavy chains may be encoded by ORF(s) located to the right of the polyA. Alternatively, one of the heavy chains may be located to the left of the polyA and the ORFs to the right of the polyA encode a second heavy chain and a light chain. Alternatively, the opposite configuration is possible, and the expression cassette to the left of the polyA may be bicistronic. Alternatively, depending upon what domains are encoded, both expression cassettes may be monocistronic (*e.g.,* encoding two immunoadhesins), or both can be bicistronic.

Optionally, the expression configuration exemplified in FIGS 1A and 1B and described herein may be used to co-express other immunoglobulin constructs. For example, two immunoadhesins (IA) may be expressed from two monocistronic expression cassettes. An immunoadhesin includes a form of antibody that is expressed as single open reading frame containing a single chain variable fragment (scFv) unit (i.e., VH linked to VL or VL linked to VH) fused to an Fc domain (CH2-CH3), (e.g., VH-VL-CH2-CH3 or VL-VH-CH2-CH3). Alternatively, up to four scFvs could be expressed from two bicistronic expression cassettes. In another alternative, an IA may be co-expressed with a full-length antibody. In another alternative, one complete FABS may be co-expressed with a full-length antibody or two complete FABs may be co-expressed. In still another embodiment, other combinations of full-length antibody, IA, or FAB fragment may be co-expressed.

Suitable regulatory control sequences may be selected and obtained from a variety of sources. In one embodiment, a minimal promoter and/or a minimal polyA may be utilized to conserve size.

As used herein, the term "minimal promoter" means a short DNA sequence comprised of a TATA-box and other sequences that serve to specify the site of transcription initiation, to which regulatory elements are added for control of expression. In one embodiment, a promoter refers to a nucleotide sequence that includes a minimal promoter plus regulatory elements that is capable of controlling the expression of a coding sequence or functional RNA. This type of promoter sequence consists of proximal and more distal upstream elements, the latter elements often referred to as enhancers. In one

embodiment, the minimal promoter is a Cytomegalovirus (CMV) minimal promoter. In another embodiment, the minimal promoter is derived from human CMV (hCMV) such as the hCMV immediate early promoter derived minimal promoter (see, US 20140127749, and Gossen and Bujard (Proc. Natl. Acad. Sci. USA, 1992, 89: 5547-5551), which are incorporated herein by reference). In another embodiment, the minimal promoter is derived from a viral source such as, for example: SV40 early or late promoters, cytomegalovirus (CMV) immediate early promoters, or Rous Sarcoma Virus (RSV) early promoters; or from eukaryotic cell promoters, for example, beta actin promoter (Ng, Nuc. Acid Res. 17:601-615, 1989; Quitsche et al., J. Biol. Chem. 264:9539-9545, 1989), GADPH promoter (Alexander, M. C. et al., Proc. Nat. Acad. Sci. USA 85:5092-5096, 1988, Ercolani, L. et al., J. Biol. Chem. 263:15335-15341, 1988), TK-1 (thymidine kinase) promoter, HSP (heat shock protein) promoters, UbB or UbC promoter, PGK, Ef1-alpha promoter or any eukaryotic promoter containing a TATA box (US Published Application No. 2014/0094392). In another embodiment, the minimal promoter includes a mini-promoter, such as the CLDN5 mini-promoter described in US Published Application No. 2014/0065666. In another embodiment, the minimal promoter is the Thymidine Kinase (TK) promoter. In one embodiment, the minimal promoter is tissue specific, such as one of the muscle-cell specific promoters minimal TnISlow promoter, a minimal TnIFast promoter or a muscle creatine kinase promoter (US Published Application No. 2012/0282695). Each of these documents is incorporated herein by reference.

In one embodiment, the polyadenylation (poly(A)) signal is a minimal poly(A) signal, i.e., the minimum sequence required for efficient polyadenylation. In one embodiment, the minimal poly(A) is a synthetic poly(A), such as that described in Levitt et al, Genes Dev., 1989 Jul, 3(7):1019-25; and Xia et al, Nat Biotechnol. 2002 Oct; 20(10):1006-10. Epub 2002 Sep 16. In another embodiment, the poly(A) is derived from the rabbit beta-globin poly(A). In one embodiment, the polyA acts bidirectionally (An et al, 2006, PNAS, 103(49): 18662–18667. In one embodiment, the poly(A) is derived from the SV40 early poly A signal sequence. Each of these documents is incorporated herein by reference.

As described herein, in one embodiment, a single enhancer, or the same enhancer, may regulate the transcription of multiple heterologous genes in the plasmid construct. Various enhancers suitable for use in the invention are known in the art and include, for example, the CMV early enhancer, Hoxc8 enhancer, nPE1 and nPE2. Additional enhancers

useful herein are described in Andersson et al, Nature, 2014 March, 507(7493):455-61, which is incorporated herein by reference. Still other enhancer elements may include, *e.g.,* an apolipoprotein enhancer, a zebrafish enhancer, a GFAP enhancer element, and tissue specific enhancers such as described in WO 2013/1555222, woodchuck post hepatitis post-transcriptional regulatory element. Additionally, or alternatively, other , *e.g.,* the hybrid human cytomegalovirus (HCMV)-immediate early (IE)-PDGR promoter or other promoter - enhancer elements may be selected. To enhance expression the other elements can be introns (like promega intron or chimeric chicken globin-human immunoglobulin intron). Other promoters and enhancers useful herein can be found in the Mammalian Promoter/Enhancer Database found at http://promoter.cdb.riken.jp/.

The constructs described herein may further contain other expression control or regulatory sequences such as, e.g., include appropriate transcription initiation, termination, promoter and enhancer sequences; efficient RNA processing signals such as splicing and polyadenylation (polyA) signals; sequences that stabilize cytoplasmic mRNA; sequences that enhance translation efficiency (*i.e.*, Kozak consensus sequence); sequences that enhance protein stability; and when desired, sequences that enhance secretion of the encoded product. A promoter may be selected from amongst a constitutive promoter, a tissue-specific promoter, a cell-specific promoter, a promoter responsive to physiologic cues, or an regulatable promoter [*see, e.g.,* WO 2011/126868 and WO 2013/049492].

These control sequences are "operably linked" to the immunoglobulin construct gene sequences. As used herein, the term "operably linked" refers to both expression control sequences that are contiguous with the gene of interest and expression control sequences that act in trans or at a distance to control the gene of interest.

Examples of constitutive promoters suitable for controlling expression of the antibody domains include, but are not limited to chicken β-actin (CB) or beta actin promoters from other species, human cytomegalovirus (CMV) promoter, the early and late promoters of simian virus 40 (SV40), U6 promoter, metallothionein promoters, EFlα promoter, ubiquitin promoter, hypoxanthine phosphoribosyl transferase (HPRT) promoter, dihydrofolate reductase (DHFR) promoter (Scharfmann *et al.*, Proc. Natl. Acad. Sci. USA 88:4626-4630 (1991), adenosine deaminase promoter, phosphoglycerol kinase (PGK) promoter, pyruvate kinase promoter phosphoglycerol mutase promoter, the β-actin promoter (Lai *et al.*, Proc. Natl. Acad. Sci. USA 86: 10006-10010 (1989), UbB, UbC, the long terminal repeats (LTR) of Moloney Leukemia Virus and other retroviruses, the thymidine

kinase promoter of Herpes Simplex Virus and other constitutive promoters known to those of skill in the art. Examples of tissue- or cell-specific promoters suitable for use in the present invention include, but are not limited to, endothelin-I (ET -I) and Flt-I, which are specific for endothelial cells, FoxJ1 (that targets ciliated cells).

Inducible promoters suitable for controlling expression of the antibody domains include promoters responsive to exogenous agents (*e.g.*, pharmacological agents) or to physiological cues. These response elements include, but are not limited to a hypoxia response element (HRE) that binds HIF-Iα and *β,* a metal-ion response element such as described by Mayo *et al.* (1982, Cell 29:99-108); Brinster *et al.* (1982, Nature 296:39-42) and Searle *et al.* (1985, Mol. Cell. Biol. 5:1480-1489); or a heat shock response element such as described by Nouer *et al.* (in: Heat Shock Response, ed. Nouer, L., CRC, Boca Raton, Fla., ppI67-220, 1991)

In one embodiment, expression of an open reading frame is controlled by a regulatable promoter that provides tight control over the transcription of the ORF (gene), *e.g.,* a pharmacological agent, or transcription factors activated by a pharmacological agent or in alternative embodiments, physiological cues. Examples of regulatable promoters which are ligand-dependent transcription factor complexes that may be used include, without limitation, members of the nuclear receptor superfamily activated by their respective ligands (e.g., glucocorticoid, estrogen, progestin, retinoid, ecdysone, and analogs and mimetics thereof) and rTTA activated by tetracycline. Examples of such systems, include, without limitation, the ARGENT™ Transcriptional Technology (ARIAD Pharmaceuticals, Cambridge, Mass.). Examples of such promoter systems are described, e.g., in WO 2012/145572, which is incorporated by reference herein.

Still other promoters may include, e.g., human cytomegalovirus (CMV) immediate-early enhancer/promoter, the SV40 early enhancer/promoter, the JC polymovirus promoter, myelin basic protein (MBP) or glial fibrillary acidic protein (GFAP) promoters, herpes simplex virus (HSV-1) latency associated promoter (LAP), rouse sarcoma virus (RSV) long terminal repeat (LTR) promoter, neuron-specific promoter (NSE), platelet derived growth factor (PDGF) promoter, hSYN, melanin-concentrating hormone (MCH) promoter, CBA, glial fibriallary acidic protein (GFAP) promoter, matrix metalloprotein promoter (MPP), and the chicken beta-actin promoter. The promoters may the same or different for each expression cassette.

For use in producing an AAV viral vector (*e.g.*, a recombinant (r) AAV), the expression cassettes can be carried on any suitable vector, *e.g.*, a plasmid, which is delivered to a packaging host cell. The plasmids useful in this invention may be engineered such that they are suitable for replication and packaging in prokaryotic cells, mammalian cells, or both. Suitable transfection techniques and packaging host cells are known and/or can be readily designed by one of skill in the art.

Methods for generating and isolating AAVs suitable for use as vectors are known in the art. *See* generally, *e.g.,* Grieger & Samulski, 2005, "Adeno-associated virus as a gene therapy vector: Vector development, production and clinical applications," *Adv. Biochem. Engin/Biotechnol.* 99: 119-145; Buning *et al.,* 2008, "Recent developments in adeno-associated virus vector technology," *J. Gene Med.* 10:717-733; and the references cited below, each of which is incorporated herein by reference in its entirety. For packaging a transgene into virions, the ITRs are the only AAV components required in *cis* in the same construct as the nucleic acid molecule containing the expression cassettes. The cap and rep genes can be supplied in *trans.*

As described above, the term "about" when used to modify a numerical value means a variation of ±10%, unless otherwise specified.

As used throughout this specification and the claims, the terms "comprise" and "contain" and its variants including, "comprises", "comprising", "contains" and "containing", among other variants, is inclusive of other components, elements, integers, steps and the like. The term "consists of" or "consisting of" are exclusive of other components, elements, integers, steps and the like.

The terms "identical" or percent "identity," in the context of two or more nucleic acids or polypeptide sequences, refer to two or more sequences or subsequences that are the same or have a specified percentage of amino acid residues or nucleotides that are the same (i.e., about 70% identity, preferably 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or higher identity over a specified region (*e.g.*, any one of the modified ORFs provided herein when compared and aligned for maximum correspondence over a comparison window or designated region) as measured using a BLAST or BLAST 2.0 sequence comparison algorithms with default parameters described below, or by manual alignment and visual inspection (see, *e.g.*, NCBI web site or the like). As another example, polynucleotide sequences can be compared using Fasta, a program in GCG Version 6.1. Fasta provides alignments and percent sequence identity of the regions of the best overlap

between the query and search sequences. For instance, percent sequence identity between nucleic acid sequences can be determined using Fasta with its default parameters (a word size of 6 and the NOPAM factor for the scoring matrix) as provided in GCG Version 6.1, herein incorporated by reference. Generally, these programs are used at default settings, although one skilled in the art can alter these settings as needed. Alternatively, one of skill in the art can utilize another algorithm or computer program that provides at least the level of identity or alignment as that provided by the referenced algorithms and programs. This definition also refers to, or can be applied to, the compliment of a sequence. The definition also includes sequences that have deletions and/or additions, as well as those that have substitutions. As described below, the preferred algorithms can account for gaps and the like. Preferably, identity exists over a region that is at least about 25, 50, 75, 100, 150, 200 amino acids or nucleotides in length, and oftentimes over a region that is 225, 250, 300, 350, 400, 450, 500 amino acids or nucleotides in length or over the full-length of an amino acid or nucleic acid sequences.

Typically, when an alignment is prepared based upon an amino acid sequence, the alignment contains insertions and deletions which are so identified with respect to a reference AAV sequence and the numbering of the amino acid residues is based upon a reference scale provided for the alignment. However, any given AAV sequence may have fewer amino acid residues than the reference scale. In the present invention, when discussing the parental sequence, the term "the same position" or the "corresponding position" refers to the amino acid located at the same residue number in each of the sequences, with respect to the reference scale for the aligned sequences. However, when taken out of the alignment, each of the proteins may have these amino acids located at different residue numbers. Alignments are performed using any of a variety of publicly or commercially available Multiple Sequence Alignment Programs. Sequence alignment programs are available for amino acid sequences, *e.g.*, the "Clustal X", "MAP", "PIMA", "MSA", "BLOCKMAKER", "MEME", and "Match-Box" programs. Generally, any of these programs are used at default settings, although one of skill in the art can alter these settings as needed. Alternatively, one of skill in the art can utilize another algorithm or computer program which provides at least the level of identity or alignment as that provided by the referenced algorithms and programs. *See, e.g.*, J. D. Thomson *et al*, *Nucl. Acids. Res.*, "A comprehensive comparison of multiple sequence alignments", 27(13):2682-2690 (1999).

In one embodiment, the expression cassettes described herein are engineered into a genetic element (*e.g.,* a shuttle plasmid) which transfers the immunoglobulin construct sequences carried thereon into a packaging host cell for production a viral vector. In one embodiment, the selected genetic element may be delivered to a an AAV packaging cell by any suitable method, including transfection, electroporation, liposome delivery, membrane fusion techniques, high velocity DNA-coated pellets, viral infection and protoplast fusion. Stable AAV packaging cells can also be made. Alternatively, the expression cassettes may be used to generate a viral vector other than AAV, or for production of mixtures of antibodies in vitro. The methods used to make such constructs are known to those with skill in nucleic acid manipulation and include genetic engineering, recombinant engineering, and synthetic techniques. *See, e.g.,* Molecular Cloning: A Laboratory Manual, ed. Green and Sambrook, Cold Spring Harbor Press, Cold Spring Harbor, NY (2012).

AAV Vectors

A recombinant AAV vector (AAV viral particle) may comprise, packaged within an AAV capsid, a nucleic acid molecule containing a 5' AAV ITR, the expression cassettes described herein and a 3' AAV ITR. As described herein, an expression cassette may contain regulatory elements for an open reading frame(s) within each expression cassette and the nucleic acid molecule may optionally contain additional regulatory elements.

The AAV vector may contain a full-length AAV 5' inverted terminal repeat (ITR) and a full-length 3' ITR. A shortened version of the 5' ITR, termed ΔITR, has been described in which the D-sequence and terminal resolution site (trs) are deleted. The abbreviation "sc" refers to self-complementary. "Self-complementary AAV" refers a construct in which a coding region carried by a recombinant AAV nucleic acid sequence has been designed to form an intra-molecular double-stranded DNA template. Upon infection, rather than waiting for cell mediated synthesis of the second strand, the two complementary halves of scAAV will associate to form one double stranded DNA (dsDNA) unit that is ready for immediate replication and transcription. *See, e.g.,* D M McCarty *et al*, "Self-complementary recombinant adeno-associated virus (scAAV) vectors promote efficient transduction independently of DNA synthesis", Gene Therapy, (August 2001), Vol 8, Number 16, Pages 1248-1254. Self-complementary AAVs are described in, *e.g.,* U.S. Patent Nos. 6,596,535; 7,125,717; and 7,456,683, each of which is incorporated herein by reference in its entirety.

Where a pseudotyped AAV is to be produced, the ITRs are selected from a source which differs from the AAV source of the capsid. For example, AAV2 ITRs may be selected for use with an AAV capsid having a particular efficiency for a selected cellular receptor, target tissue or viral target. In one embodiment, the ITR sequences from AAV2, or the deleted version thereof (ΔITR), are used for convenience and to accelerate regulatory approval. However, ITRs from other AAV sources may be selected. Where the source of the ITRs is from AAV2 and the AAV capsid is from another AAV source, the resulting vector may be termed pseudotyped. However, other sources of AAV ITRs may be utilized.

A variety of AAV capsids have been described. Methods of generating AAV vectors have been described extensively in the literature and patent documents, including, *e.g.*, WO 2003/042397; WO 2005/033321, WO 2006/110689; US 7588772 B2. The source of AAV capsids may be selected from an AAV which targets a desired tissue. For example, suitable AAV may include, e.g., AAV9 [US 7,906,111; US 2011-0236353-A1], rh10 [WO 2003/042397] and/or hu37 [see, *e.g.*, US 7,906,111; US 2011-0236353-A1]. However, other AAV, including, *e.g.,* AAV1, AAV2, AAV3, AAV4, AAV5, AAV6, AAV7, AAV8, [US Patent 7790449; US Patent 7282199] and others. However, other sources of AAV capsids and other viral elements may be selected, as may other immunoglobulin constructs and other vector elements.

A single-stranded AAV viral vector is provided. Methods for generating and isolating AAV viral vectors suitable for delivery to a subject are known in the art. *See, e.g.,* US Patent 7790449; US Patent 7282199; WO 2003/042397; WO 2005/033321, WO 2006/110689; and US 7588772 B2]. In one system, a producer cell line is transiently transfected with a construct that encodes the transgene flanked by ITRs and a construct(s) that encodes rep and cap. In a second system, a packaging cell line that stably supplies rep and cap is transiently transfected with a construct encoding the transgene flanked by ITRs. In each of these systems, AAV virions are produced in response to infection with helper adenovirus or herpesvirus, requiring the separation of the rAAVs from contaminating virus. More recently, systems have been developed that do not require infection with helper virus to recover the AAV - the required helper functions (*i.e.,* adenovirus E1, E2a, VA, and E4 or herpesvirus UL5, UL8, UL52, and UL29, and herpesvirus polymerase) are also supplied, *in trans*, by the system. In these newer systems, the helper functions can be supplied by transient transfection of the cells with constructs that encode the required helper functions, or the cells can be engineered to stably contain genes encoding the helper functions, the

expression of which can be controlled at the transcriptional or posttranscriptional level. In yet another system, the transgene flanked by ITRs and rep/cap genes are introduced into insect cells by infection with baculovirus-based vectors. For reviews on these production systems, see generally, *e.g.*, Zhang *et al.*, 2009, "Adenovirus-adeno-associated virus hybrid for large-scale recombinant adeno-associated virus production," Human Gene Therapy 20:922-929, the contents of each of which is incorporated herein by reference in its entirety. Methods of making and using these and other AAV production systems are also described in the following U.S. patents, the contents of which is incorporated herein by reference in its entirety: 5,139,941; 5,741,683; 6,057,152; 6,204,059; 6,268,213; 6,491,907; 6,660,514; 6,951,753; 7,094,604; 7,172,893; 7,201,898; 7,229,823; and 7,439,065.

USES AND REGIMENS

The rAAV, preferably suspended in a physiologically compatible carrier, may be administered to a human or non-human mammalian patient. Suitable carriers may be readily selected by one of skill in the art in view of the indication for which the transfer virus is directed. For example, one suitable carrier includes saline, which may be formulated with a variety of buffering solutions (*e.g.*, phosphate buffered saline). Other exemplary carriers include sterile saline, lactose, sucrose, maltose, and water. The selection of the carrier is not a limitation of the present invention. Optionally, the compositions of the invention may contain, in addition to the rAAV and carrier(s), other conventional pharmaceutical ingredients, such as preservatives, or chemical stabilizers.

Methods for using these rAAV, e.g., for passive immunization are described, e.g., in WO 2012/145572. Other methods of delivery and uses will be apparent to one of skill in the art. For example, a regimen as described herein may comprise, in addition to one or more of the combinations described herein, further combination with one or more of a biological drug, a small molecule drug, a chemotherapeutic agent, immune enhancers, radiation, surgery, and the like. A biological drug as described herein, is based on a peptide, polypeptide, protein, enzyme, nucleic acid molecule, vector (including viral vectors), or the like.

In a combination therapy, the AAV-delivered immunoglobulin construct described herein is administered before, during, or after commencing therapy with another agent, as well as any combination thereof, *i.e.*, before and during, before and after, during and after, or before, during and after commencing the therapy. For example, the AAV can be

administered between 1 and 30 days, preferably 3 and 20 days, more preferably between 5 and 12 days before commencing radiation therapy. In another embodiment of the invention, chemotherapy is administered concurrently with or, more preferably, subsequent to AAV-mediated immunoglobulin (antibody) therapy. In still other embodiments, the compositions of the invention may be combined with other biologics, *e.g.*, recombinant monoclonal antibody drugs, antibody-drug conjugates, or the like. Further, combinations of different AAV-delivered immunoglobulin constructs such as are discussed above may be used in such regimens.

Any suitable method or route can be used to administer AAV-containing compositions as described herein, and optionally, to co-administer other active drugs or therapies in conjunction with the AAV-mediated antibodies described herein. Routes of administration include, for example, systemic, oral, intravenous, intraperitoneal, subcutaneous, or intramuscular administration.

Targets for the immunoglobulin constructs described herein may be selected from a variety of pathogens, including, e.g., bacterial, viral, fungal and parasitic infectious agents. Suitable targets may further include cancer or cancer-associated antigens, or the like. Still other targets may include an autoimmune condition such as rheumatoid arthritis (RA) or multiple sclerosis (MS).

Examples of viral targets include influenza virus from the orthomyxovirudae family, which includes: Influenza A, Influenza B, and Influenza C. The type A viruses are the most virulent human pathogens. The serotypes of influenza A which have been associated with pandemics include, H1N1, which caused Spanish Flu in 1918, and Swine Flu in 2009; H2N2, which caused Asian Flu in 1957; H3N2, which caused Hong Kong Flu in 1968; H5N1, which caused Bird Flu in 2004; H7N7; H1N2; H9N2; H7N2; H7N3; and H10N7.

Broadly neutralizing antibodies against influenza A have been described. As used herein, a "broadly neutralizing antibody" refers to a neutralizing antibody which can neutralize multiple strains from multiple subtypes. For example, CR6261 [The Scripps Institute/ Crucell] has been described as a monoclonal antibody that binds to a broad range of the influenza virus including the 1918 "Spanish flu" (SC1918/H1) and to a virus of the H5N1 class of avian influenza that jumped from chickens to a human in Vietnam in 2004 (Viet04/H5). CR6261 recognizes a highly conserved helical region in the membrane-proximal stem of hemagglutinin, the predominant protein on the surface of the influenza virus. This antibody is described in WO 2010/130636, incorporated by reference herein.

Another neutralizing antibody, F10 [XOMA Ltd] has been described as being useful against H1N1 and H5N1. [Sui *et al,* Nature Structural and Molecular Biology (Sui, et al. 2009, 16(3):265-73)] Other antibodies against influenza, *e.g.*, Fab28 and Fab49, may be selected. See, e.g., WO 2010/140114 and WO 2009/115972, which are incorporated by reference. Still other antibodies, such as those described in WO 2010/010466, US Published Patent Publication US/2011/076265, and WO 2008/156763, may be readily selected.

Other target pathogenic viruses include, arenaviruses (including funin, machupo, and Lassa), filoviruses (including Marburg and Ebola), hantaviruses, picornoviridae (including rhinoviruses, echovirus), coronaviruses, paramyxovirus, morbillivirus, respiratory synctial virus, togavirus, coxsackievirus, parvovirus B19, parainfluenza, adenoviruses, reoviruses, variola (Variola major (Smallpox)) and Vaccinia (Cowpox) from the poxvirus family, and varicella-zoster (pseudorabies).

Viral hemorrhagic fevers are caused by members of the arenavirus family (Lassa fever) (which family is also associated with Lymphocytic choriomeningitis (LCM)), filovirus (ebola virus), and hantavirus (puremala). The members of picornavirus (a subfamily of rhinoviruses), are associated with the common cold in humans. The coronavirus family, which includes a number of non-human viruses such as infectious bronchitis virus (poultry), porcine transmissible gastroenteric virus (pig), porcine hemagglutinatin encephalomyelitis virus (pig), feline infectious peritonitis virus (cat), feline enteric coronavirus (cat), canine coronavirus (dog). The human respiratory coronaviruses, have been putatively associated with the common cold, non-A, B or C hepatitis, and sudden acute respiratory syndrome (SARS). The paramyxovirus family includes parainfluenza Virus Type 1, parainfluenza Virus Type 3, bovine parainfluenza Virus Type 3, rubulavirus (mumps virus, parainfluenza Virus Type 2, parainfluenza virus Type 4, Newcastle disease virus (chickens), rinderpest, morbillivirus, which includes measles and canine distemper, and pneumovirus, which includes respiratory syncytial virus (RSV). The parvovirus family includes feline parvovirus (feline enteritis), feline panleucopeniavirus, canine parvovirus, and porcine parvovirus. The adenovirus family includes viruses (EX, AD7, ARD, O.B.) which cause respiratory disease.

A neutralizing antibody construct against a bacterial pathogen may also be selected for use in the present invention. In one embodiment, the neutralizing antibody construct is directed against the bacteria itself. In another embodiment, the neutralizing antibody construct is directed against a toxin produced by the bacteria. Examples of airborne bacterial

pathogens include, *e.g., Neisseria meningitidis* (meningitis), *Klebsiella pneumonia* (pneumonia), *Pseudomonas aeruginosa* (pneumonia), *Pseudomonas pseudomallei* (pneumonia), *Pseudomonas mallei* (pneumonia), Acinetobacter (pneumonia), *Moraxella catarrhalis, Moraxella lacunata, Alkaligenes, Cardiobacterium, Haemophilus influenzae* (flu), *Haemophilus parainfluenzae, Bordetella pertussis* (whooping cough), *Francisella tularensis* (pneumonia/fever), *Legionella pneumonia* (Legionnaires disease), *Chlamydia psittaci* (pneumonia), *Chlamydia pneumoniae (*pneumonia), *Mycobacterium tuberculosis* (tuberculosis (TB)), *Mycobacterium kansasii (*TB*), Mycobacterium avium* (pneumonia), *Nocardia asteroides* (pneumonia), *Bacillus anthracis* (anthrax), *Staphylococcus aureus* (pneumonia), *Streptococcus pyogenes* (scarlet fever), *Streptococcus pneumoniae* (pneumonia), *Corynebacteria diphtheria* (diphtheria), *Mycoplasma pneumoniae* (pneumonia).

The causative agent of anthrax is a toxin produced by *Bacillius anthracis*. Neutralizing antibodies against protective agent (PA), one of the three peptides which form the toxoid, have been described. The other two polypeptides consist of lethal factor (LF) and edema factor (EF). Anti-PA neutralizing antibodies have been described as being effective in passively immunization against anthrax. *See, e.g.,* US Patent number 7,442,373; R. Sawada-Hirai et al, J Immune Based Ther Vaccines. 2004; 2: 5. (on-line 2004 May 12). Still other anti-anthrax toxin neutralizing antibodies have been described and/or may be generated. Similarly, neutralizing antibodies against other bacteria and/or bacterial toxins may be used to generate an AAV-delivered anti-pathogen construct as described herein.

Other infectious diseases may be caused by airborne fungi including, *e.g., Aspergillus* species, *Absidia corymbifera*, *Rhixpus stolonifer*, *Mucor plumbeaus*, *Cryptococcus neoformans*, *Histoplasm capsulatum*, *Blastomyces dermatitidis*, *Coccidioides immitis*, *Penicillium* species, *Micropolyspora faeni*, *Thermoactinomyces vulgaris*, *Alternaria alternate*, *Cladosporium* species, *Helminthosporium*, and *Stachybotrys* species.

In addition, passive immunization may be used to prevent fungal infections (*e.g.,* athlete's foot), ringworm, or viruses, bacteria, parasites, fungi, and other pathogens which can be transmitted by direct contact. In addition, a variety of conditions which affect household pets, cattle and other livestock, and other animals. For example, in dogs, infection of the upper respiratory tract by canine sinonasal aspergillosis causes significant disease. In cats, upper respiratory disease or feline respiratory disease complex originating in the nose causes morbidity and mortality if left untreated. Cattle are prone to infections by the

infectious bovine rhinotracheitis (commonly called IBR or red nose) is an acute, contagious virus disease of cattle. In addition, cattle are prone to Bovine Respiratory Syncytial Virus (BRSV) which causes mild to severe respiratory disease and can impair resistance to other diseases. Still other pathogens and diseases will be apparent to one of skill in the art. *See, e.g.*, US 5,811,524, which describes generation of anti-respiratory syncytial virus (RSV) neutralizing antibodies. The techniques described therein are applicable to other pathogens. Such an antibody may be used intact or its sequences (scaffold) modified to generate an artificial or recombinant neutralizing antibody construct. Such methods have been described [see, e.g., WO 2010/13036; WO 2009/115972; WO 2010/140114].

Anti-neoplastic immunoglobulins as described herein may target a human epidermal growth factor receptor (HER), such as HER2. For example, trastuzumab is a recombinant IgG1 kappa, humanized monoclonal antibody that selectively binds with high affinity in a cell-based assay (Kd = 5 nM) to the extracellular domain of the human epidermal growth factor receptor protein. The commercially available product is produced in CHO cell culture. *See, e.g.*, http://www.drugbank.ca/drugs/DB00072. The amino acid sequences of the trastuzumab light chains 1 and 2 and heavy chains 1 and 2, as well as sequences obtained from a study of the x-tray structure of trastuzumab, are provided on this database at accession number DB00072, which sequences are incorporated herein by reference. See, also, 212-Pb-TCMC-trastuzumab [Areva Med, Bethesda, MD]. Another antibody of interest includes, *e.g.*, pertuzumab, a recombinant humanized monoclonal antibody that targets the extracellular dimerization domain (Subdomain II) of the human epidermal growth factor receptor 2 protein (HER2). It consists of two heavy chains and two lights chains that have 448 and 214 residues respectively. FDA approved June 8, 2012. The amino acid sequences of its heavy chain and light chain are provided, *e.g.*, in www.drugbank.ca/drugs/DB06366 (synonyms include 2C4, MOAB 2C4, monoclonal antibody 2C4, and rhuMAb-2C4) on this database at accession number DB06366. In addition to HER2, other HER targets may be selected.

For example, MM-121/SAR256212 is a fully human monoclonal antibody that targets the HER3 receptor [Merrimack's Network Biology] and which has been reported to be useful in the treatment of non-small cell lung cancer (NSCLC), breast cancer and ovarian cancer. SAR256212 is an investigational fully human monoclonal antibody that targets the HER3 (ErbB3) receptor [Sanofi Oncology]. Another anti-Her3/EGFR antibody is RG7597 [Genentech], described as being useful in head and neck cancers. Another antibody,

margetuximab (or MGAH22), a next-generation, Fc-optimized monoclonal antibody (mAb) that targets HER [MacroGenics], may also be utilized.

Alternatively, other human epithelial cell surface markers and/or other tumor receptors or antigens may be targeted. Examples of other cell surface marker targets include, *e.g.*, 5T4, CA-125, CEA (*e.g.,* targeted by labetuzumab), CD3, CD19, CD20 (*e.g.*, targeted by rituximab), CD22 (*e.g.,* targeted by epratuzumab or veltuzumab), CD30, CD33, CD40, CD44, CD51 (also integrin $\alpha_v\beta_3$), CD133 (*e.g.,* glioblastoma cells), CTLA-4 (*e.g.,* Ipilimumab used in treatment of , *e.g.,* neuroblastoma)) , Chemokine (C-X-C Motif) Receptor 2 (CXCR2) (expressed in different regions in brain; *e.g.*, Anti-CXCR2 (extracellular) antibody #ACR-012 (Alomene Labs)); EpCAM, fibroblast activation protein (FAP) [*see, e.g.,* WO 2012020006 A2, brain cancers], folate receptor alpha (*e.g.*, pediatric ependymal brain tumors, head and neck cancers), fibroblast growth factor receptor 1 (FGFR1) (*see, et al*, WO2012125124A1 for discussion treatment of cancers with anti-FGFR1 antibodies), FGFR2 (*see, e.g.,* antibodies described in WO2013076186A and WO2011143318A2), FGFR3 (*see, e.g.*, antibodies described in US8187601 and WO2010111367A1), FGFR4 (*see, e.g.,* anti-FGFR4 antibodies described in WO2012138975A1), hepatocyte growth factor (HGF) (*see, e.g.,* antibodies in WO2010119991A3), integrin $\alpha_5\beta_1$, IGF-1 receptor, gangioloside GD2 (*see, e.g.*, antibodies described in WO2011160119A2), ganglioside GD3, transmembrane glycoprotein NMB (GPNMB) (associated with gliomas, among others and target of the antibody glembatumumab (CR011), mucin, MUC1, phosphatidylserine (*e.g.,* targeted by bavituximab, Peregrine Pharmaceuticals, Inc], prostatic carcinoma cells, PD-L1 (*e.g.,* nivolumab (BMS-936558, MDX-1106, ONO-4538), a fully human gG4, *e.g.,* metastatic melanoma], platelet-derived growth factor receptor, alpha (PDGFR α) or CD140, tumor associated glycoprotein 72 (TAG-72), tenascin C, tumor necrosis factor (TNF) receptor (TRAIL-R2), vascular endothelial growth factor (VEGF)-A (*e.g.*, targeted by bevacizumab) and VEGFR2 (*e.g.,* targeted by ramucirumab).

Other antibodies and their targets include, *e.g.,* APN301 (hu14.19-IL2), a monoclonal antibody [malignant melanoma and neuroblastoma in children, Apeiron Biolgics, Vienna, Austria]. S*ee, also, e.g.,* monoclonal antibody, 8H9, which has been described as being useful for the treatment of solid tumors, including metastatic brain cancer. The monoclonal antibody 8H9 is a mouse IgG1 antibody with specificity for the B7H3 antigen [United Therapeutics Corporation]. This mouse antibody can be humanized. Still

other immunoglobulin constructs targeting the B7-H3 and/or the B7-H4 antigen may be used in the invention. Another antibody is S58 (anti-GD2, neuroblastoma). Cotara™ [Perregrince Pharmaceuticals] is a monoclonal antibody described for treatment of recurrent glioblastoma. Other antibodies may include, *e.g.*, avastin, ficlatuzumab, medi-575, and olaratumab. Still other immunoglobulin constructs or monoclonal antibodies may be selected for use in the invention. *See, e.g.*, Medicines in Development Biologics, 2013 Report, pp. 1 - 87, a publication of PhRMA's Communications & Public Affairs Department. (202) 835-3460, which is incorporated by reference herein.

For example, immunogens may be selected from a variety of viral families. Example of viral families against which an immune response would be desirable include, the picornavirus family, which includes the genera rhinoviruses, which are responsible for about 50% of cases of the common cold; the genera enteroviruses, which include polioviruses, coxsackieviruses, echoviruses, and human enteroviruses such as hepatitis A virus; and the genera apthoviruses, which are responsible for foot and mouth diseases, primarily in non-human animals. Within the picornavirus family of viruses, target antigens include the VP1, VP2, VP3, VP4, and VPG. Another viral family includes the calcivirus family, which encompasses the Norwalk group of viruses, which are an important causative agent of epidemic gastroenteritis. Still another viral family desirable for use in targeting antigens for inducing immune responses in humans and non-human animals is the togavirus family, which includes the genera alphavirus, which include Sindbis viruses, RossRiver virus, and Venezuelan, Eastern & Western Equine encephalitis, and rubivirus, including Rubella virus. The flaviviridae family includes dengue, yellow fever, Japanese encephalitis, St. Louis encephalitis and tick borne encephalitis viruses. Other target antigens may be generated from the Hepatitis C or the coronavirus family, which includes a number of non-human viruses such as infectious bronchitis virus (poultry), porcine transmissible gastroenteric virus (pig), porcine hemagglutinating encephalomyelitis virus (pig), feline infectious peritonitis virus (cats), feline enteric coronavirus (cat), canine coronavirus (dog), and human respiratory coronaviruses, which may cause the common cold and/or non-A, B or C hepatitis. Within the coronavirus family, target antigens include the E1 (also called M or matrix protein), E2 (also called S or Spike protein), E3 (also called HE or hemagglutin-elterose) glycoprotein (not present in all coronaviruses), or N (nucleocapsid). Still other antigens may be targeted against the rhabdovirus family, which includes the genera vesiculovirus (*e.g.*, Vesicular Stomatitis Virus), and the general lyssavirus (*e.g.*, rabies).

Within the rhabdovirus family, suitable antigens may be derived from the G protein or the N protein. The family filoviridae, which includes hemorrhagic fever viruses such as Marburg and Ebola virus, may be a suitable source of antigens. The paramyxovirus family includes parainfluenza Virus Type 1, parainfluenza Virus Type 3, bovine parainfluenza Virus Type 3, rubulavirus (mumps virus), parainfluenza Virus Type 2, parainfluenza virus Type 4, Newcastle disease virus (chickens), rinderpest, morbillivirus, which includes measles and canine distemper, and pneumovirus, which includes respiratory syncytial virus. The influenza virus is classified within the family orthomyxovirus and is a suitable source of antigen (*e.g.*, the HA protein, the N1 protein). The bunyavirus family includes the genera bunyavirus (California encephalitis, La Crosse), phlebovirus (Rift Valley Fever), hantavirus (puremala is a hemahagin fever virus), nairovirus (Nairobi sheep disease) and various unassigned bungaviruses. The arenavirus family provides a source of antigens against LCM and Lassa fever virus. The reovirus family includes the genera reovirus, rotavirus (which causes acute gastroenteritis in children), orbiviruses, and cultivirus (Colorado Tick fever, Lebombo (humans), equine encephalosis, blue tongue).

The retrovirus family includes the sub-family oncorivirinal which encompasses such human and veterinary diseases as feline leukemia virus, HTLVI and HTLVII, lentivirinal (which includes human immunodeficiency virus (HIV), simian immunodeficiency virus (SIV), feline immunodeficiency virus (FIV), equine infectious anemia virus, and spumavirinal). Among the lentiviruses, many suitable antigens have been described and can readily be selected as targets. Examples of suitable HIV and SIV antigens include, without limitation the gag, pol, Vif, Vpx, VPR, Env, Tat, Nef, and Rev proteins, as well as various fragments thereof. For example, suitable fragments of the Env protein may include any of its subunits such as the gp120, gp160, gp41, or smaller fragments thereof, *e.g.*, of at least about 8 amino acids in length. Similarly, fragments of the tat protein may be selected. [See, US Patent 5,891,994 and US Patent 6,193,981.] See, also, the HIV and SIV proteins described in D.H. Barouch et al, J. Virol., 75(5):2462-2467 (March 2001), and R.R. Amara, et al, *Science*, **292**:69-74 (6 April 2001). In another example, the HIV and/or SIV immunogenic proteins or peptides may be used to form fusion proteins or other immunogenic molecules. See, *e.g.*, the HIV-1 Tat and/or Nef fusion proteins and immunization regimens described in WO 01/54719, published August 2, 2001, and WO 99/16884, published April 8, 1999. The invention is not limited to the HIV and/or SIV immunogenic proteins or peptides described herein. In addition, a variety of modifications to these proteins has been described or could

readily be made by one of skill in the art. See, *e.g.*, the modified gag protein that is described in US Patent 5,972,596.

The papovavirus family includes the sub-family polyomaviruses (BKU and JCU viruses) and the sub-family papillomavirus (associated with cancers or malignant progression of papilloma). The adenovirus family includes viruses (EX, AD7, ARD, O.B.) which cause respiratory disease and/or enteritis. The parvovirus family feline parvovirus (feline enteritis), feline panleucopeniavirus, canine parvovirus, and porcine parvovirus. The herpesvirus family includes the sub-family alphaherpesvirinae, which encompasses the genera simplexvirus (HSVI, HSVII), varicellovirus (pseudorabies, varicella zoster) and the sub-family betaherpesvirinae, which includes the genera cytomegalovirus (HCMV, muromegalovirus) and the sub-family gammaherpesvirinae, which includes the genera lymphocryptovirus, EBV (Burkitts lymphoma), infectious rhinotracheitis, Marek's disease virus, and rhadinovirus. The poxvirus family includes the sub-family chordopoxvirinae, which encompasses the genera orthopoxvirus (Variola (Smallpox) and Vaccinia (Cowpox)), parapoxvirus, avipoxvirus, capripoxvirus, leporipoxvirus, suipoxvirus, and the sub-family entomopoxvirinae. The hepadnavirus family includes the Hepatitis B virus. One unclassified virus which may be suitable source of antigens is the Hepatitis delta virus. Still other viral sources may include avian infectious bursal disease virus and porcine respiratory and reproductive syndrome virus. The alphavirus family includes equine arteritis virus and various Encephalitis viruses.

Other pathogenic targets for antibodies may include, *e.g.,* bacteria, fungi, parasitic microorganisms or multicellular parasites which infect human and non-human vertebrates, or from a cancer cell or tumor cell. Examples of bacterial pathogens include pathogenic gram-positive cocci include pneumococci; staphylococci; and streptococci. Pathogenic gram-negative cocci include meningococcus; gonococcus. Pathogenic enteric gram-negative bacilli include enterobacteriaceae; pseudomonas, acinetobacteria and eikenella; melioidosis; salmonella; shigella; haemophilus; moraxella; *H. ducreyi* (which causes chancroid); brucella; *Franisella tularensis* (which causes tularemia); yersinia (pasteurella); streptobacillus moniliformis and spirillum; Gram-positive bacilli include listeria monocytogenes; erysipelothrix rhusiopathiae; *Corynebacterium diphtheria* (diphtheria); cholera; *B. anthracis* (anthrax); donovanosis (granuloma inguinale); and bartonellosis. Diseases caused by pathogenic anaerobic bacteria include tetanus; botulism; other clostridia; tuberculosis; leprosy; and other mycobacteria. Pathogenic spirochetal diseases include syphilis;

treponematoses: yaws, pinta and endemic syphilis; and leptospirosis. Other infections caused by higher pathogen bacteria and pathogenic fungi include actinomycosis; nocardiosis; cryptococcosis, blastomycosis, histoplasmosis and coccidioidomycosis; candidiasis, aspergillosis, and mucormycosis; sporotrichosis; paracoccidiodomycosis, petriellidiosis, torulopsosis, mycetoma and chromomycosis; and dermatophytosis. Rickettsial infections include Typhus fever, Rocky Mountain spotted fever, Q fever, and Rickettsialpox. Examples of mycoplasma and chlamydial infections include: mycoplasma pneumoniae; lymphogranuloma venereum; psittacosis; and perinatal chlamydial infections. Pathogenic eukaryotes encompass pathogenic protozoa and helminthes and infections produced thereby include: amebiasis; malaria; leishmaniasis; trypanosomiasis; toxoplasmosis; *Pneumocystis carinii*; *Trichans*; *Toxoplasma gondii*; babesiosis; giardiasis; trichinosis; filariasis; schistosomiasis; nematodes; trematodes or flukes; and cestode (tapeworm) infections.

Many of these organisms and/or toxins produced thereby have been identified by the Centers for Disease Control [(CDC), Department of Health and Human Services, USA], as agents which have potential for use in biological attacks. For example, some of these biological agents, include, *Bacillus anthracis* (anthrax), *Clostridium botulinum* and its toxin (botulism), *Yersinia pestis* (plague), variola major (smallpox), *Francisella tularensis* (tularemia), and viral hemorrhagic fevers [filoviruses (*e.g.*, Ebola, Marburg], and arenaviruses [*e.g.*, Lassa, Machupo]), all of which are currently classified as Category A agents; *Coxiella burnetti* (Q fever); Brucella species (brucellosis), *Burkholderia mallei* (glanders), *Burkholderia pseudomallei* (meloidosis), *Ricinus communis* and its toxin (ricin toxin), *Clostridium perfringens* and its toxin (epsilon toxin), *Staphylococcus* species and their toxins (enterotoxin B), *Chlamydia psittaci* (psittacosis), water safety threats (*e.g.*, *Vibrio cholerae*, *Crytosporidium parvum*), Typhus fever (*Richettsia powazekii*), and viral encephalitis (alphaviruses, *e.g.*, Venezuelan equine encephalitis; eastern equine encephalitis; western equine encephalitis); all of which are currently classified as Category B agents; and Nipan virus and hantaviruses, which are currently classified as Category C agents. In addition, other organisms, which are so classified or differently classified, may be identified and/or used for such a purpose in the future. It will be readily understood that the viral vectors and other constructs described herein are useful to target antigens from these organisms, viruses, their toxins or other by-products, which will prevent and/or treat infection or other adverse reactions with these biological agents.

The following examples are illustrative only and are not a limitation on the invention described herein.

EXAMPLE 1: GENERATION OF VECTORS CONTAINING FULL-LENGTH ANTIBODY CO-EXPRESSION CASSETTES

A series of cis-plasmids were prepared for use in generating an AAV viral particle containing a nucleic acid molecule for delivery to a host target cell. The nucleic acid molecules comprise AAV2 5' and 3' ITR sequences at each terminus, a shared CMV enhancer flanked by two expression cassettes in opposite orientations, where a first expression cassette is controlled by a first minimal CMV promoter and a second expression cassette is controlled by a second minimal CMV promoter. All sequences located between AAV2 ITRs were de novo synthesized by a commercial vendor (GeneArt). All coding sequences for immunoglobulin variable domains were flanked with the unique restriction enzymes to allow convenient shuttling of the desired variable domains. To create constructs with heterologous light chain sequence (kgl), a coding sequence encoding germline light chain (IGKV4-1*01) was de novo synthesized and used to replace FI6 variable light sequence.

An exemplary antibody co-expression shuttle is illustrated in FIG. 2. This shuttle contains to the left of the enhancer a first expression cassette which contains, from right to left, a CMV minimal promoter, a heterologous IL2 leader sequence linked to an anti-TSG101 antibody (1A6) variable heavy (VH) domain, a CH'1 domain, and a CH'2-3 domain which has been optimized for expression in humans, and a synthetic polyA. To the right of the enhancer is located a CMV minimal promoter, a heterologous IL2 leader sequence, a FI6k2 (anti-influenza antibody) light chain variable domain and a light chain constant domain, furin cleavage site, the 2a linker from the foot-and-mouth disease virus, an IL2 leader sequence, the FI6v3 VH, CH1, CH2-3, and a thymidine kinase short polyA sequence. CH designations refer to the known antibody allotype G1m17,1.

SEQ ID NO: 1 provides sequences of the FI6 constant regions. The amino acid sequences of the FI6 amino acid light chain is provided in SEQ ID NO: 2.

The cis-plasmid of FIG2 was used in a triple transfection method as previously described in, e.g., in US Patent Application No. 12/226,558, to generate AAV8 and AAV9 vectors which were used in subsequent studies described herein. The resulting plasmid, pN509_ACE Fi6-1A6 MAB_p3160, is 7722 bp in length, the sequence of which is

provided in SEQ ID NO: 3, which is incorporated herein by reference together with its features. The encoded sequences for the FI6 variable light (VL) chain [SEQ ID NO:4], FI6 variable heavy [SEQ ID NO: 5], CH1 (SEQ ID NO: 6), CH2-3 [SEQ ID NO: 7] are also provided.

Similar antibody co-expression cis-plasmids were generated by subcloning a seasonal flu antibody (CR8033) or a pandemic flu antibody (C05), or an anti-M2e antibody (TCN-032) in the place of 1A6 heavy variable domain in FIG. 2 using pre-positioned unique restriction sites that allow easy shuffling of the variable domains. These cis-plasmids were in turn used in triple transfection (e.g., performed as described in US Patent Application No. 12/226,588) to generate AAV8 and AAV9 vectors used for subsequent studies. Sequences for the pN510_ACE Fi6-C05 MAB shuttle are provided in SEQ ID NO:8; the amino acids sequence of the variable light chain is provided in SEQ ID NO: 9, the constant light is provided in SEQ ID NO: 10, the FI6 variable heavy chain is provided in SEQ ID NO: 11, the CH1 is provided in SEQ ID NO:12 and the CH2-3 is provide in SEQ ID NO: 13. Sequences for the pN514_ACE Fi6-C05 MAB shuttle are provided in SEQ ID NO:19; the amino acids sequence of the constant light is provided in SEQ ID NO: 20, the FI6 variable heavy chain is provided in SEQ ID NO: 21, the CH1 is provided in SEQ ID NO:22 and the CH2-3 is provide in SEQ ID NO: 23. These shuttles were in turn used to generate AAV8 and AAV9 vectors which were used for subsequent studies.

EXAMPLE 2: CHARACTERIZATION OF PRODUCTS EXPRESSED FROM AAV8 VECTORS CO-EXPRESSING F16 MONOCLONAL ANTIBODY (MAB) AND IA6 MAB

A series of ELISA assays were performed to characterize expression levels and to assess binding of the FI6 MAB co-expressed with the IA6 MAB from the cis plasmid generated as described in Example 1 after transfection into HEK 293 cells. TSG101 peptide was synthesized using f-Moc chemistry by Mimotopes. All flu antigens were procured from a commercial supplier, ImmuneTechnologies, Inc. ProteinA was purchased from Sigma-Aldrich and was used to monitor expression of total human IgG1. Detection of human IgG1 in tissue culture supernatants was measured by either antigen-specific or proteinA capture ELISA. High binding ELISA plates were coated with 2 µg/ml of HA proteins or peptides, or with 5 µg/ml proteinA diluted in PBS and incubated overnight at 4°C. Wells

were washed 5-8 times and blocked with 1 mM EDTA, 5% heat inactivated PBS, 0.07% Tween 20 in PBS for one hour at room temperature. Tissue culture supernatants were added to the plates at various dilutions in duplicates and incubated at 37°C for one hour. Plates were washed, blocked, and Bio-SP-conjugated Affinipures Goat Anti-Human IgG antibody (Jackson ImmunoResearch Laboratories, Inc., West Grove, PA, USA) was added at a 1:10,000 dilution. After one hour, plates were washed and strepdavidin-conjugated horseradish peroxidase (HRP) was added at a 1:30,000 dilution. After one hour, plates were washed 3,3′,5,5′-tetramethylbenzidine (TMB) was added. The reaction was stopped after 30 minutes at room temperature using 2N sulfuric acid and plates were read at 450 nm using a BioTek μQuant plate reader (Winooski, VT, USA).

As expected, no binding is observed of FI6 to the TSG101 peptide, the HA (B/Malaysia/2506/2/004), or the HA (Head region only of influenza strain A/Brisbane/59/2007). FI6 binding is observed for this same strain of influenza when the full-length HA is present, as well as for influenza strain HA(dTM)(A/Beijing/01/2009, H1N1)). As expected, FI6 binding is also observed for Protein A.

According to published reports, FI6 produced according to prior art methods binds to full-length HA and to HA stem, but not to the head only region. These data demonstrate that the co-expressed FI6 monoclonal antibody retains its characteristic binding profile.

EXAMPLE 3: CHARACTERIZATION OF PRODUCTS EXPRESSED FROM AAV8 VECTORS CO-EXPRESSING F16 MONOCLONAL ANTIBODY (MAB) AND PANDEMIC FLU MAB C05

The possibility of differential detection of two different monoclonal antibodies was assessed in a capture assay. Monoclonal antibodies FI6 and C05 co-expressed from a cis-plasmid prepared as described in Example 1 and transfected into HEK293 cells were assessed for binding. FI6 is expected to bind to full-length HA and to HA stem, but not to the head only region. The results of the binding study illustrated in FIG. 3 demonstrate that the co-expressed antibodies retain their characteristic binding. More particularly, binding to full-length HA and the HA stem characteristic of FI6 is observed and binding to HA and HA head only (no stem) characteristic of C05 is also observed. ELISA assays were performed as described in Example 2.

EXAMPLE 4: CHARACTERIZATION OF PRODUCTS EXPRESSED FROM AAV8 VECTORS CO-EXPRESSING F16 MONOCLONAL ANTIBODY (MAB) AND A SECOND FULL-LENGTH MAB

6-8 weeks old male RAG KO mice (The Jackson Laboratory Bar Harbor, ME, USA) were housed under pathogen-free conditions at the University of Pennsylvania's Translational Research Laboratories. All animal procedures and protocols were approved by the Institutional Animal Care and Use Committee. Mice were sacrificed by carbon dioxide asphyxiation and death was confirmed by cervical dislocation. For vector administration, mice were anaesthetized with a mixture of 70 mg/kg of body weight ketamine and 7 mg/kg of body weight xylazine by intraperitoneal (IP) injection. Vectors were diluted in phosphate buffered saline (PBS) and IM injections were performed using a Hamilton syringe. Serum was collected weekly via retro-orbital bleeds.

Detection of human IgG1 in tissue culture supernatants was measured by proteinA capture ELISA. High binding ELISA plates were coated with 5 μg/ml proteinA diluted in PBS and incubated overnight at 4°C. Wells were washed 5-8 times and blocked with 1 mM EDTA, 5% heat inactivated PBS, 0.07% Tween 20 in PBS. Mouse serum samples were heat inactivated and added to the plates at various dilutions in duplicates and incubated at 37∘C for one hour. Plates were washed, blocked, and Bio-SP-conjugated Affinipures Goat Anti-Human IgG antibody (Jackson ImmunoResearch Laboratories, Inc., West Grove, PA, USA) was added at a 1:10,000 dilution. After one hour, plates were washed and incubated with strepdavidin-conjugated horseradish peroxidase (HRP) at a 1:30,000 dilution. After one hour, plates were washed 3,3′,5,5′-tetramethylbenzidine (TMB) was added. The reaction was stopped after 30 minutes at room temperature using 2N sulfuric acid and plates were read at 450 nm using a BioTek μQuant plate reader (Winooski, VT, USA).

FIG. 5 illustrates systemic expression levels for total human IgG1 in mice administered an AAV vector co-expressing FI6 with IA6 antibody. Mice were injected intramuscularly at doses of 1×10^{11} genome copies (GC) or 1×10^{10} GC. Expression levels were assessed at day 7, 15, 21, 28, 34, 42, 49 and 56 and measured at a concentration of micrograms/mL. A dose dependent increase in expression was observed.

EXAMPLE 5: CHARACTERIZATION OF PRODUCTS EXPRESSED FROM AAV8 VECTORS CO-EXPRESSING FI6 MONOCLONAL ANTIBODY (MAB) AND THREE DIFFERENT FULL-LENGTH MONOCLONAL ANTIBODIES

The tables below showing expression levels in mice administered an AAV vector co-expressing FI6 with full-length CR8033, C05, or 1A6 monoclonal antibody. RAG knock-out (KO) mice were injected intramuscularly at doses of 1 x 10^{11} genome copies (GC) or 1 x 10^{10} GC as described in the previous example. Expression levels were assessed weekly at days 7, 15, 21, 28, 34, 42, and 49 and measured at a concentration of micrograms/mL. A dose dependent increase in expression was observed for expressed antibodies. The capture antigen used for the assay is Protein A ELISA as described in the previous example.

Test Article	Fi6v3k2 mAb + CR8033 mAb			
Dose	1.00 x 10^{11}		1.00 x 10^{10}	
	average	stdev.	average	stdev.
Day 0	0.00	0.00	0.00	0.00
Day 7	2.92	0.48	0.04	0.07
Day 14	18.30	4.79	1.24	0.66
Day 21	33.69	7.45	2.09	0.88
Day 28	43.38	10.92	2.84	1.81
Day 35	66.45	16.61	4.47	1.86
Day 42	64.25	12.06	4.37	2.35
Day 49	51.36	11.90	3.57	1.52

Test Article	Fi6v3k2 mAb + CO5 mAb			
Dose	1.00×10^{11}		1.00×10^{10}	
	average	stdev.	average	stdev.
Day 0	0.00	0.00	0.00	0.00
Day 7	1.73	0.42	0.00	0.00
Day 14	9.95	3.39	0.24	0.22
Day 21	24.74	11.66	0.81	0.24
Day 28	22.32	4.77	1.11	0.17
Day 35	31.67	7.93	1.53	0.28
Day 42	34.69	14.46	1.83	0.29
Day 49	26.14	5.85	1.46	0.49

Test Article	Fi6v3k2 mAb + 1A6 mAb			
Dose	1.00×10^{11}		1.00×10^{10}	
	average	stdev.	average	stdev.
Day 0	0	0	0	0
Day 7	2.70	0.75	0	0
Day 14	5.01	0.06	1.58	.055
Day 21	30.16	13.31	1.71	0.52
Day 28	38.18	15.99	2.16	0.59
Day 35	55.18	18.52	4.09	1.53
Day 42	50.49	16.61	3.69	0.94
Day 49	46.66	15.59	3.73	1.09

EXAMPLE 6: ANTI-VIRAL EFFECT IS CONFERRED BY DUAL FULL-LENGTH ANTIBODIES EXPRESSED FROM A SINGLE AAV9 and/or AAV8 VECTOR INTRAMUSCULARLY

A. AAV9.BiD.FI6_CR8033mAb and Influenza A Challenge

BALB/c mice were injected intramuscularly with AAV9.BiD.FI6_CR8033mAb delivered was delivered intramuscularly (IM) at 1 x 10^{11} GC. Two weeks later the mice were challenged intranasally with 5LD50 of mouse adapted PR8 (influenza A). The circle represents the AAV9 construct with a bidirectional promoter expressing synthetic FI6 and CR8033 monoclonal antibodies having the same heterologous light chain. The square represents a positive control, i.e., AAV9 expressing a single antibody type FI6 also delivered at 1 x 10^{11} GC, and the triangle represents naïve animals. FIG. 6B shows survival post-challenge. Administration of the AAV9.BiD.FI6_CR8033mAb at 1011 GC/mouse dose allowed partial protection with a significant delay in the weight loss.

B. AAV9.BiD.FI6_CR8033mAb and Influenza B Challenge

For AAV9 vector injection: BALB/c female mice were anesthetized by an intramuscular injection of a 100 mg/kg ketamine/ 10 mg/kg xylazine mixture in PBS, and AAV9.BiD.FI6_CR8033mAb vector was injected intramuscularly (IM) at 1 x 10^{11} GC per mouse. BiD vector was compared to an AAV9 expressing a single antibody type CR8033 also delivered at 1 x 10^{11} GC, and a negative control (naïve animals). FIG. 7B shows survival post-challenge. For influenza challenge, two weeks after vector treatment, AAV-treated and naïve BALB/c mice were weighed and tails color-coded, anesthetized as described above, suspended by their dorsal incisors with their hind limbs supported on a platform, and administered intranasally with 5LD50 of B/Lee/40 (influenza B) in a total volume of 50µl of PBS as described above. Mice were then weighed daily and monitored for signs of disease or distress. Animals that exhibited behavioral signs of distress or lost 30% of their initial body weight were euthanized by CO2 asphyxiation

FIG. 7A is a line graph showing percent change in weight. These data show that full protective effect was conferred by the dual expressed antibodies at this dose. FIG. 7B shows survival post-challenge.

C. AAV8.FI6-TCN032, AAV8.FI6-1A6, and AAV8.FI6-CR8033 vectors administered IM and mouse adapted PR8 Influenza A challenge.

These vectors were made as described in Example 1. 6-8 weeks old male RAG KO mice (The Jackson Laboratory Bar Harbor, ME, USA) were housed under pathogen-free conditions at the University of Pennsylvania's Translational Research Laboratories. All animal procedures and protocols were approved by the Institutional Animal Care and Use Committee. For vector administration, mice were anaesthetized with a mixture of 70 mg/kg of body weight ketamine and 7 mg/kg of body weight xylazine by intraperitoneal (IP) injection. Vectors were diluted in phosphate buffered saline (PBS) and IM injections were performed using a Hamilton syringe. Serum was collected weekly via retro-orbital bleeds.

Detection of human IgG1 in tissue culture supernatants was measured by proteinA capture ELISA. High binding ELISA plates were coated with 5 µg/ml proteinA diluted in PBS and incubated overnight at 4°C. Wells were washed 5-8 times and blocked with 1 mM EDTA, 5% heat inactivated PBS, 0.07% Tween 20 in PBS. Mouse serum samples were heat inactivated and added to the plates at various dilutions in duplicates and incubated at 37◦C for one hour. Plates were washed, blocked, and Bio-SP-conjugated Affinipures Goat Anti-Human IgG antibody (Jackson ImmunoResearch Laboratories, Inc., West Grove, PA, USA) was added at a 1:10,000 dilution. After one hour, plates were washed and incubated with strepdavidin-conjugated horseradish peroxidase (HRP) at a 1:30,000 dilution. After one hour, plates were washed 3,3′,5,5′-tetramethylbenzidine (TMB) was added. The reaction was stopped after 30 minutes at room temperature using 2N sulfuric acid and plates were read at 450 nm using a BioTek µQuant plate reader (Winooski, VT, USA).

With reference to FIG 8C, on all panels, expression levels are indicated on Day 56 after vector administration. Couple days after the last orbital bleed on Day 56, mice were mice were weighed and tails color-coded, anesthetized as described above, suspended by their dorsal incisors with their hind limbs supported on a platform, and administered intranasally with $5LD_{50}$ of mouse adapted PR8 (influenza A) in a total volume of 50µl of PBS as described above. Mice were then weighed daily and monitored for signs of disease or distress. Animals that exhibited behavioral signs of distress or lost 30% of their initial body weight were euthanized by CO_2 asphyxiation and death was confirmed by cervical dislocation. FIG8A shows that systemic expression of as little as 25µg/ml of anti-influenza

antibody is sufficient to afford protection in PR8 challenge, but expression of 0.4 μg/ml is insufficient for protection.

D. AAV9. FI6_IA6 mAbs and Influenza A Challenge

An AAV9 vector expressing artificial FI6 and an anti-HIV immunoadhesin, IA6, were assessed for protection against challenge with influenzA A as described above. FIG 8B shows that expressing 36.5 μg/ml of anti-influenza antibody is sufficient to provide complete protection against challenge with PR8. FIG8C shows expressing 6.9 ug/ml of anti-influenza antibodies is not sufficient to protect against PR8 challenge.

EXAMPLE 8 - GENERATION OF VECTORS CONTAINING TWO IMMUNOADHESIN CO-EXPRESSION CASSETTES

Using a shuttle vector similar to that illustrated in FIG. 2, vectors containing two immunoadhesins have been generated.

In one embodiment, a vector containing FI6 and C05 immunoadhesins was created. The sequences from a plasmid carrying the FI6 and CO5 immunoadhesin expression cassettes are provided in SEQ ID NO: 36; with the translated encoded sequences provided in SEQ ID NO: 37 (FI6 variable heavy chain), SEQ ID NO: 38 (FI6 variable light chain), and SEQ ID NO: 39 (CH2-3). These sequences and their features are incorporated by reference.

In another embodiment, a vector containing FI6 and CR8033 immunoadhesins was created. The sequences from a plasmid containing the FI6 and CR8033 immunoadhesins are provided in SEQ ID NO:40; with the translated encoded sequences provided in SEQ ID NO: 41 (FI6 VH) and SEQ ID NO: 42 (FI6 variable light). These sequences and their features are incorporated by reference.

AAV may be generated from the immunoadhesin shuttle plasmids described above using techniques known to those of skill in the art.

Additional illustrative shuttle plasmids are as follows.

The sequence of a plasmid pN512_ACE FI6v3kgl-1A6 MAB_p3184 containing a kappa germline light chain that is heterologous to the source of both heavy chains, 1A6 and FI6v3 is provided in SEQ ID NO: 14. The translated encode sequences are provide in SEQ ID NO: 15 (constant light), SEQ ID NO: 16 (FI6 variable heavy), SEQ ID NO: 17 (CH1), and SEQ ID NO: 18 (CH2-3).

The sequences of an intermediate vector which carries the TCN032 heavy and light chain immunoglobulins are provided in SEQ ID NO: 30. The translated amino acid

sequences encoded by this plasmid include the TCN032 heavy chain in SEQ ID NO: 31; the CH1 sequence in SEQ ID NO: 32; the FI6 VH chain in SEQ ID NO: 33; the CH1 sequence in SEQ ID NO: 34 and the CH2-3 sequence in SEQ ID NO: 35.

The sequence of a plasmid carrying the TCN032 and FI6 heavy chains and co-expressing two antibodies having these specificities is provided in SEQ ID NO: 43. The translated amino acids of the TCN032 variable heavy chain are in SEQ ID NO: 44, the CH1 is in SEQ ID NO: 45, the hinge-CH2'-CH3' is in SEQ ID NO: 46, the Fi6 VH is in SEQ ID NO: 47, the CH1 is in SEQ ID NO: 48, the CH2-3 is in SEQ ID NO: 49, and the ampicillin resistance gene is in SEQ ID NO: 50. These sequences and their features are incorporated herein by reference.

(Sequence Listing Free Text)

The following information is provided for sequences containing free text under numeric identifier <223>.

SEQ ID NO: (containing free text)	Free text under <223>
1	<223> Synthetic sequence encoding FI6 heavy chain <220> <221> CDS <222> (1)..(705) <223> FI6 constant
3	<223> plasmid carrying FI6 and 1A6 antibodies <220> <221> polyA_signal <222> (191)..(239) <223> synthetic\polyA <220> <221> misc_feature <222> (246)..(914) <223> complement - CH'2-3

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (915)..(1235) <223> complement - CH'1 <220> <221> misc_feature <222> (1236)..(1598) <223> complement - 1A6\VH <220> <221> misc_feature <222> (1599)..(1655) <223> complement - leader <220> <221> misc_feature <222> (1734)..(2202) <223> Enhancer <220> <221> misc_feature <222> (2388)..(2444) <223> leader <220> <221> CDS <222> (2445)..(2777) <223> FI6\VL <220> <221> misc_feature <222> (3183)..(3242) <223> leader <220> <221> CDS <222> (3243)..(3629) <223> FI6\VH <220> <221> CDS <222> (3630)..(3950) <223> CH1

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> CDS <222> (3951)..(4619) <223> CH2-3 <220> <221> polyA_signal <222> (4626)..(4703) <223> TKpAshort <220> <221> misc_feature <222> (6995)..(7283) <223> COL\E1\Origin
8	<223> Plasmid encoding FI6 and C05 monoclonal antibodies <220> <221> polyA_signal <222> (204)..(252) <223> synthetic\polyA <220> <221> misc_feature <222> (259)..(927) <223> complement - CH'2-3 <220> <221> misc_feature <222> (928)..(1248) <223> complement - CH'1 <220> <221> misc_feature <222> (1251)..(1668) <223> complement - C05\VH <220> <221> misc_feature <222> (1669)..(1719) <223> complement - leader <220> <221> misc_feature <222> (1729)..(1979)

SEQ ID NO: (containing free text)	Free text under <223>
	<223> complement - CMV\mp2 <220> <221> misc_feature <222> (1798)..(2266) <223> Enhancer <220> <221> misc_feature <222> (2267)..(2392) <223> CMV\mp2 <220> <221> CDS <222> (2509)..(2841) <223> FI6\VL <220> <221> CDS <222> (2842)..(3162) <223> CL <220> <221> misc_feature <222> (3247)..(3306) <223> leader <220> <221> CDS <222> (3307)..(3693) <223> FI6\VH <220> <221> CDS <222> (3694)..(4014) <223> CH1 <220> <221> CDS <222> (4015)..(4683) <223> CH2-3 <220> <221> polyA_signal <222> (4690)..(4767) <223> TKpAshort

SEQ ID NO: (containing free text)	Free text under <223>
14	<223> Plasmid encoding synthetic FI6 and 1A6 monoconals <220> <221> polyA_signal <222> (191)..(239) <223> synthetic\polyA <220> <221> misc_feature <222> (246)..(914) <223> complement - CH'2-3 <220> <221> misc_feature <222> (915)..(1235) <223> complement - CH'1 <220> <221> misc_feature <222> (1236)..(1598) <223> complement - 1A6\VH <220> <221> misc_feature <222> (1599)..(1655) <223> complement - leader <220> <221> misc_feature <222> (1665)..(1733) <223> complement - CMV\mp2 <220> <221> misc_feature <222> (1732)..(2202) <223> Enhancer <220> <221> misc_feature <222> (2203)..(2328) <223> CMV\mp1 <220> <221> misc_feature

SEQ ID NO: (containing free text)	Free text under <223>
	<222> (2388)..(2444) <223> leader <220> <221> misc_feature <222> (2445)..(2789) <223> KGL <220> <221> CDS <222> (2784)..(3104) <223> CL <220> <221> misc_feature <222> (3189)..(3248) <223> leader <220> <221> CDS <222> (3249)..(3635) <223> FI6\VH <220> <221> CDS <222> (3636)..(3956) <223> CH1 <220> <221> CDS <222> (3957)..(4625) <223> CH2-3 <220> <221> polyA_signal <222> (4632)..(4709) <223> TKpAshort
19	<223> Plasmid carrying FI6 and CR8033 monoclonals <220> <221> polyA_signal <222> (173)..(221) <223> synthetic\polyA

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (228)..(896) <223> complement - CH'2-3 <220> <221> misc_feature <222> (897)..(1217) <223> complement - CH'1 <220> <221> misc_feature <222> (1218)..(1604) <223> complement - CR8033\VH <220> <221> misc_feature <222> (1605)..(1655) <223> complement - leader <220> <221> misc_feature <222> (1665)..(1733) <223> complement - CMV\mp2 <220> <221> misc_feature <222> (1734)..(2202) <223> Enhancer <220> <221> misc_feature <222> (2203)..(2328) <223> CMV\mp1 <220> <221> misc_feature <222> (2445)..(2789) <223> KGL <220> <221> CDS <222> (2784)..(3104) <223> CL <220>

SEQ ID NO: (containing free text)	Free text under <223>
	<221> misc_feature <222> (3189)..(3248) <223> leader <220> <221> CDS <222> (3249)..(3635) <223> FI6\VH <220> <221> CDS <222> (3636)..(3956) <223> CH1 <220> <221> CDS <222> (3957)..(4625) <223> CH2-3 <220> <221> misc_feature <222> (3968)..(3968) <223> A -> T <220> <221> polyA_signal <222> (4632)..(4709) <223> TKpAshort
24	<220> <223> Plasmid carrying FI6 and CR8033 monoclonal antibodies <220> <221> polyA_signal <222> (191)..(239) <223> synthetic polyA <220> <221> misc_feature <222> (246)..(914) <223> complement - CH'2-3 <220> <221> misc_feature <222> (915)..(1235)

SEQ ID NO: (containing free text)	Free text under <223>
	<223> complement - CH'1 <220> <221> misc_feature <222> (1236)..(1622) <223> complement - CR8033\VH <220> <221> misc_feature <222> (1623)..(1673) <223> complement - leader <220> <221> misc_feature <222> (1683)..(1751) <223> CMV\mp2 <220> <221> misc_feature <222> (1752)..(2220) <223> Enhancer <220> <221> misc_feature <222> (2221)..(2346) <223> CMV\mp1 <220> <221> misc_feature <222> (2406)..(2462) <223> leader <220> <221> CDS <222> (2463)..(2795) <223> FI6\VL <220> <221> CDS <222> (2796)..(3116) <223> CL <220> <221> misc_feature <222> (3201)..(3260) <223> leader

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> CDS <222> (3261)..(3647) <223> FI6\VH <220> <221> CDS <222> (3648)..(3968) <223> CH1 <220> <221> CDS <222> (3969)..(4637) <223> CH2-3 <220> <221> misc_feature <222> (3980)..(3980) <223> A -> T <220> <221> polyA_signal <222> (4644)..(4721) <223> TKpAshort
30	<223> EcoRV <220> <221> polyA_signal <222> (201)..(252) <223> complement - synthetic\polyA <220> <221> misc_feature <222> (268)..(588) <223> complement - CL <220> <221> misc_feature <222> (589)..(909) <223> complement - TCN032\VL <220> <221> polyA_signal

SEQ ID NO: (containing free text)	Free text under <223>
	<222> (910)..(966) <223> complement - leader <220> <221> misc_feature <222> (1026)..(1094) <223> complement - CMV\mp2 <220> <221> misc_feature <222> (1095)..(1563) <223> Enhancer <220> <221> misc_feature <222> (1564)..(1689) <223> CMV\mp1 <220> <221> misc_feature <222> (1749)..(1805) <223> leader <220> <221> CDS <222> (1806)..(2165) <223> TCN032\VH <220> <221> CDS <222> (2166)..(2459) <223> CH1 <220> <221> misc_feature <222> (2460)..(3152) <223> hinge-CH2'-CH3' <220> <221> misc_feature <222> (3239)..(3296) <223> leader <220> <221> CDS <222> (3297)..(3683)

SEQ ID NO: (containing free text)	Free text under <223>
	<223> FI6\VH <220> <221> CDS <222> (3684)..(4004) <223> CH1 <220> <221> CDS <222> (4005)..(4673) <223> CH2-3 <220> <221> polyA_signal <222> (4693)..(4770) <223> TKpAshort
36	<223> FI6 and CO5 immunoadhesins <220> <221> polyA_signal <222> (201)..(432) <223> complement - SV40\polyA <220> <221> misc_feature <222> (453)..(1121) <223> complement - CH'2-3 <220> <221> misc_feature <222> (1125)..(1457) <223> complement - C05\VL <220> <221> misc_feature <222> (1458)..(1502) <223> SL\from\3bn201co <220> <221> misc_feature <222> (1503)..(1916) <223> complement - C05\VH <220>

SEQ ID NO: (containing free text)	Free text under <223>
	<221> misc_feature <222> (1965)..(1973) <223> leader <220> <221> misc_feature <222> (2371)..(2412) <223> complement - CMV\mp2 <220> <221> misc_feature <222> (2413)..(2881) <223> enhancer <220> <221> misc_feature <222> (2882)..(3007) <223> CMV\mp1 <220> <221> misc_feature <222> (3067)..(3055) <223> leader <220> <221> CDS <222> (3124)..(3510) <223> FI6\VH <220> <221> misc_feature <222> (3511)..(3555) <223> SL\from\3bn201co <220> <221> CDS <222> (3556)..(3888) <223> FI6\VL <220> <221> CDS <222> (3892)..(4560) <223> CH2-3 <220> <221> polyA_signal

SEQ ID NO: (containing free text)	Free text under <223>
	<222> (4581)..(4812) <223> SV40\polyA
40	<223> FI6 and CR8033 immunoadhesins <220> <221> polyA_signal <222> (201)..(432) <223> complement - SV40\polyA <220> <221> misc_feature <222> (453)..(1121) <223> complement - CH'2-3 <220> <221> misc_feature <222> (1125)..(1460) <223> complement - 033\VL <220> <221> misc_feature <222> (1461)..(1505) <223> SL\from\3bn201co <220> <221> misc_feature <222> (1506)..(1886) <223> complement - 033\VH <220> <221> misc_feature <222> (1935)..(1946) <223> complement - leader <220> <221> misc_feature <222> (2341)..(2382) <223> complement - CMV\mp2 <220> <221> misc_feature <222> (2383)..(2851) <223> enhancer

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (2852)..(2977) <223> CMV\mp1 <220> <221> misc_feature <222> (3073)..(3045) <223> leader <220> <221> CDS <222> (3094)..(3480) <223> FI6\VH <220> <221> misc_feature <222> (3481)..(3525) <223> SL\from\3bn201co <220> <221> CDS <222> (3526)..(3858) <223> FI6\VL <220> <221> misc_feature <222> (3862)..(4530) <223> CH2-3 <220> <221> polyA_signal <222> (4551)..(4782) <223> SV40\polyA
43	<223> Plasmid carrying TCN032 and Fi6 monoclonal antibodies <220> <221> repeat_region <222> (14)..(143) <220> <221> polyA_signal <222> (204)..(252) <223> synthetic polyA

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (261)..(267) <223> stop cassette (complement) <220> <221> misc_feature <222> (268)..(588) <223> constant light (on complementary strand) <220> <221> misc_feature <222> (967)..(971) <223> Kozak (located on complementary strand) <220> <221> misc_feature <222> (972)..(1019) <223> c-myc 5' UTR (located on complementary strand) <220> <221> misc_feature <222> (1026)..(1094) <223> CMV\mp2 <220> <221> enhancer <222> (1026)..(1094) <220> <221> misc_feature <222> (1564)..(1689) <220> <221> misc_feature <222> (1696)..(1743) <223> c-myc 5' UTR <220> <221> misc_feature <222> (1744)..(1748) <223> Kozak

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (1749)..(1805) <223> leader <220> <221> CDS <222> (1806)..(2165) <223> TCN032 variable heavy <220> <221> repeat_region <222> (1845)..(4974) <223> inverted terminal repeat <220> <221> repeat_region <222> (1845)..(4974) <223> inverted terminal repeat (located on complement) <220> <221> CDS <222> (2166)..(2459) <223> CH1 <220> <221> misc <222> (2166)..(2459) <223> CH1 <220> <221> CDS <222> (2460)..(3152) <223> hinge-CH2'-CH3' <220> <221> misc_feature <222> (3153)..(3164) <223> furin cleavage site <220> <221> misc_feature <222> (3165)..(3236) <223> F2A linker

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (3239)..(3296) <220> <221> misc_feature <222> (3239)..(3296) <220> <221> CDS <222> (3297)..(3683) <223> FI6 VH <220> <221> CDS <222> (3684)..(4004) <223> CH1 <220> <221> CDS <222> (4005)..(4673) <223> CH2-3 <220> <221> misc_feature <222> (4674)..(4680) <223> Stop cassette <220> <221> misc_feature <222> (4674)..(4680) <220> <221> polyA_signal <222> (4693)..(4770) <223> TKpAshort <220> <221> rep_origin <222> (5151)..(5606) <220> <221> CDS <222> (5737)..(6594) <223> Amp-R

SEQ ID NO: (containing free text)	Free text under <223>
	<220> <221> misc_feature <222> (6768)..(.7356) <223> col\E1\origin

This application contains sequences and a sequence listing, which is hereby incorporated by reference. All publications, patents, and patent applications cited in this application, and US Provisional Patent Application No. 61/992,649, filed May 13, 2014, the priority of which is claimed, are hereby incorporated by reference in their entireties as if each individual publication or patent application were specifically and individually indicated to be incorporated by reference. Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be readily apparent to those of ordinary skill in the art in light of the teachings of this invention that certain changes and modifications can be made thereto without departing from the spirit or scope of the appended claims.

MCSLLP

CLAIMS

1. A recombinant adeno-associated virus (AAV) having an AAV capsid and packaged therein a heterologous nucleic acid which expresses at least two functional monospecific antibodies in a cell, wherein the recombinant AAV comprises:

a 5' AAV inverted terminal repeat (ITR);

a first expression cassette which encodes at least a first open reading frame (ORF) for a first immunoglobulin under the control of regulatory control sequences which direct expression thereof;

a second expression cassette which comprises a second ORF, a linker, and a third ORF under the control of regulatory control sequences which direct expression thereof, wherein the second and third ORF are for a second and third immunoglobulin construct; and

a 3' AAV ITR.

2. The recombinant AAV according to claim 1, wherein the recombinant AAV further expresses a bispecific antibody.

3. The recombinant AAV according to claim 1, wherein the recombinant AAV comprises a bidirectional enhancer located between the first expression cassette and the second expression cassette.

4. The recombinant AAV according to claim 1, wherein the first ORF encodes an immunoglobulin light chain, the second ORF encodes a first immunoglobulin heavy chain and third ORF encodes a second heavy chain, whereby the expressed functional antibody constructs have two different heavy chains with different specificities which share a light chain.

5. The recombinant AAV according to claim 1, wherein at least one of the second and third ORF contain modified Fc coding sequences.

6. The recombinant AAV according to claim 1, wherein the linker in the second cassette comprises a linker selected from an IRES or an F2A.

7. The recombinant AAV according to claim 1, wherein the regulatory control sequences for the first expression cassette and/or the second cassette comprise a minimal promoter.

8. The recombinant AAV according to claim 1, wherein the regulatory control sequences for the first expression cassette and/or the second expression cassette comprise a minimal or synthetic polyA.

9. The recombinant AAV according to claim 1, wherein the first expression cassette is bicistronic and comprises a further ORF.

10. The recombinant AAV according to claim 9, wherein each of the ORF comprise an scFv.

11. The recombinant AAV according claim 1, wherein the vector comprises a bidirectional polyA between the first expression cassette and the second expression cassette.

12. The recombinant AAV according to claim 10, wherein the first expression cassette comprises an enhancer and a minimal promoter.

13. The recombinant AAV according to claim 12, wherein the second expression cassette comprises an enhancer and a minimal promoter.

14. The recombinant AAV according to claim 8, wherein the first and second expression cassettes together express two Fabs.

MCSLLP

15. The recombinant AAV according to claim 1, wherein the at least two antibody constructs have different specificities.

16. The recombinant AAV according to claim 1, wherein the at least two antibody constructs are independently selected from a monoclonal antibody, an immunoadhesin, a Fab, a bifunctional antibody, and combinations thereof.

17. A recombinant adeno-associated virus (AAV) having an AAV capsid and packaged therein a heterologous nucleic acid which expresses at least two functional monospecific antibodies in a cell, wherein the recombinant AAV expresses a first monoclonal antibody having a first specificity, a second monoclonal antibody having a specificity different from the first monoclonal antibody, and a bifunctional antibody, and wherein the recombinant AAV comprises:

a 5' AAV inverted terminal repeat (ITR);

a first expression cassette which encodes at least a first open reading frame (ORF) for a first immunoglobulin under the control of regulatory control sequences which direct expression thereof;

a second expression cassette which comprises a second ORF, a linker, and a third ORF under the control of regulatory control sequences which direct expression thereof, wherein the second and third ORF are for a second and third immunoglobulin construct; and

a 3' AAV ITR.

18. A pharmaceutical composition comprising a recombinant AAV according to claim 1 and pharmaceutically acceptable carrier.

19. The recombinant AAV according to claim 17, wherein the recombinant AAV comprises a bidirectional enhancer located between the first expression cassette and the second expression cassette.

20. The recombinant AAV according to claim 17, wherein the first ORF encodes an immunoglobulin light chain, the second ORF encodes a first immunoglobulin heavy chain and third ORF encodes a second heavy chain, whereby the expressed functional antibody constructs have two different heavy chains with different specificities which share a light chain.